Cuadrilla Bowland Ltd

Temporary Shale Gas Exploration

Preston New Road, Lancashire

Environmental Statement

PNR_ES_Vol1_Enviironmental Statement

May 2014

Cuadrilla

ARUP

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Glossary of Terms and Abbreviations

Term or abbreviation	Definition
AADT	Annual average daily traffic.
AD	Anno Domini
ADMS or ADMS5	This is an air quality dispersion model that has been used within the Air Quality model to quantify the potential concentrations of different atmospheric pollutants at locations around the Site.
Aquifer	An underground layer of rock with water storage capability.
Accumulated temperature	Median accumulated temperature above 0°C from January to June which gives a measure of heat energy input and soil drying potential and correlates with crop growth and yield.
Agricultural Land Classification (ALC)	The system devised and introduced by the Ministry of Agriculture, Fisheries and Food to classify agricultural land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use. Land is graded from 1 (excellent quality) to 5 (very poor quality), with grade 3 subdivided into agricultural subgrades 3a and 3b. See 'Grade 1-5' and 'Subgrade 3a and 3b'.
AQMA	Air Quality Management Area
Archaeology	The systematic study of past human life and culture by the recovery and examination of remaining material evidence. These include artefacts from the very earliest stone tools to the man-made objects that are buried or thrown away in the present day.
Baseline	The current environmental conditions as they exist at the time of reporting in 2014.
BHS	Biological Heritage Site
Biological Heritage Site	A schedule of non-statutory sites set up by Lancashire County Council on the basis of the Phase 1 Habitat Survey, Lancashire Wildlife Trust Sites list and other known important sites.
Bq/L	Becquerels per litre.
BSOR	Borehole Sites and Operations Regulations 1995
Buried array	Boreholes containing seismometers and related equipment. At the surface, the boreholes will be capped by an inspection chamber cover mounted flush with the surface and protected by a stock proof fence.
Buttress	A type of thread used to connect lengths of casing together. The properly made-up thread provides a hydraulic seal which is not guaranteed to be a gas-tight seal.
CAMS	Catchment Abstraction Management Strategy
CO_2	Carbon dioxide
Coring	Coring is the process of removing a cylindrical sample, or core, from soil, rock, or paved surfaces.
DCLG	Department for Communities and Local Government
DECC	Department for Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs.
Displacement	Displacement is the difference between the initial position of a reference point and any later position after an earthquake (typically by movement along a fault)
DMRB	Design Manual for Roads and Bridges
Drill bits	A drill bit is the actual device that excavates the rock from the bottom of the well as it is being drilled.

Term or abbreviation	Definition
Drill cuttings	Drill cuttings are the broken bits of solid material removed from a borehole drilled by rotary, percussion, or auger methods.
Drill strings	Structures consisting of coupled lengths of pipe or casing, which occupies the hole made in drilling for oil or gas.
Drilling fluid	Synonymous with "drilling mud" in general usage. Although some prefer to reserve the term "drilling fluid" for more sophisticated and well-defined "muds."
Drilling mud	Any of a number of liquid and gaseous fluids and mixtures of fluids and solids used in operations to drill boreholes into the earth. Synonymous with "drilling fluid" in general usage.
Droughtiness	A physical limitation to the agricultural use of soils. It is a defined calculation in the Agricultural Land Classification guidelines which uses soil and climatic parameters to provide an estimate of likely moisture stress in 'standard' crops due to the crop's requirements for water exceeding the available water capacity of the soil.
EA	Environment Agency
Earthquake	Earthquake is a term used to describe both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth
EC	European Community
EHO	Environmental Health Officer
EIA	Environmental Impact Assessment
Environmental Impact Assessment	EIA is an assessment process by which the potential effects on the environment of a project are considered. It also provides a mechanism by which the interaction of environmental effects resulting from development can be predicted, allowing them to be avoided or reduced through the development of mitigation measures.
Environmental Statement	The document produced to describe the environmental impact assessment process and its findings.
EOS	Environmental Operating Standards
Epicentre	The epicentre is the point directly above the earthquake hypocentre, at the surface of the Earth.
EPUK	Environmental Protection UK.
ES	Environmental Statement
ETS	Emissions Trading Scheme
EU	European Union.
Exploration phase (of shale gas)	The acquisition of geological data to establish whether shale gas is present, involving seismic surveys, exploratory drilling, hydraulic fracturing and initial testing.
Fault	Where two adjacent rock masses are displaced in relation to each other along a plane: Normal faulting – Where the hanging wall (rockmass above the fault plane) is displaced down in relation to the footwall (rockmass below the fault plane). Typically associated with extension; Reverse faulting – Where the hanging wall (as above) is thrust upwards in relation to the footwall (as above). Typically associated with compression; Strike-Slip faulting – Where two adjacent rock masses are displaced horizontally in relation to each other
Fault plane solution	A fault plane solution is a way of showing the orientation of the fault and the direction of slip on it from an earthquake. The fault plane solution is

Term or abbreviation	Definition
	typically illustrated using circles with two intersecting curves that look like beach balls. Also called a focal-mechanism solution
FEH	Flood Estimation Handbook
Felt seismicity	Seismic event that can be detected by humans. Typically an event with a magnitude between 1.0-2.0ML is not felt, except by a very few under especially favourable conditions. Source: Department of Energy & Climate Change. (2013). Guidance: About shale gas and hydraulic fracturing (fracking). <URL: https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking/about-shale-gas-and-hydraulic-fracturing-fracking> [site accessed 13/08/2013].
Flow testing	Flow testing refers to the period of the project when natural gas, flowback waters and hydrocarbons from the hydraulically fractured well will be tested to establish the flow rates of gas and liquid, and confirm the chemical composition of both.
Flowback fluid	For the purposes of this ES the term flowback fluid refers to any liquid that comes to the surface from the exploration wells following hydraulic fracturing.
Focal depth	The focal depth refers to the depth from the surface of an earthquake hypocentre.
Footwall	The rockmass underlying a fault plane
FRA	Flood Risk Assessment
FTE	Full Time Equivalent.
GHG	Greenhouse gas(es).
Graben	A graben is a block of the earth's crust bounded by faults that has dropped down relative to adjacent areas as a result of extension, or pulling apart of the earth's crust
Ground motion	Vibrations associated with seismic waves generated by earthquakes or anthropogenic events such as explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface. Seismic waves can be described in terms of displacement, velocity or acceleration of the ground
Groundwater Source Protection Zone	Areas designated to protect public water supply groundwater abstractions.
Hanging wall	The rock mass overlying a fault plane
HER	Historic Environment Record
HGV	Heavy Goods Vehicle
Horizontal well	The wells that will be drilled as part of the Project will use directional drilling. For the purposes of the EIA a horizontal well is one that deviates from the vertical by 80 degrees or more. The section of the well that is less than 80 degrees from the vertical is referred to the vertical section of the well.
Hydraulic fracturing	The forcing open of fissures in subterranean rocks by introducing liquid at high pressure, especially to extract oil or gas.
Hydraulic fracturing	The process of injecting pressurised, water, sand and specialized chemicals into rock formations with the aim to form and or open fractures in the rock mass.
Hypocentre	The hypocentre is the point within the earth envisaged as the centre of the fault plane or centre of energy release

Term or abbreviation	Definition
IAQM	Institute of Air Quality Management.
ICE	Inventory of Carbon and Energy.
ICRP	International Commission on Radiological Protection.
Induced seismic event	Defined as seismic activity induced by stress or strain perturbations resulting from anthropogenic sources. Induced seismic events [AQ1]release less energy than it takes to initiate them.
IMD	Indices of Multiple Deprivation.
Induced fracture	Fractures which developed in rock as a result of application of pressure above a threshold, such as in hydraulic fracturing.
Lateral	A drilled hole which significantly deviates from the original borehole. usually into the hydrocarbon reservoir rock, and is referred to as a horizontal well if the inclination is in the range of 90°.
LCAS	Lancashire County Archaeology Service.
LCC	Lancashire County Council.
LHER	Lancashire Historic Environment Record.
LNR	Local Nature Reserve
LPA	Local Planning Authority
Local Magnitude (Richter scale)	Magnitude scale developed by Charles Francis Richter for a particular study area in California, based on the amplitude of ground motion displacement as measured by a Wood-Anderson seismograph: • ML = logA – logA0(D) • where A is the maximum excursion of a Wood-Anderson Seismograph and A0 is an empirical function only dependent on the epicentral distance, (D)22
LSOA	Lower Layer Super Output Area are defined by the ONS as areas with a population of 1,500 people or 400 households.
LTOBM	Low Toxicity Oil Based Muds. A drilling mud where the base fluid is a synthetic oil.
LTP	Local Transport Plan
Macro-seismicity	Measured using the European Macroseismic Scale (EMS) ranging from EMS I. Not felt (not felt, even under the most favourable circumstances) to EMS XII. Completely devastating (practically all structures above and below ground are heavily damaged or destroyed.
Magnitude	Magnitude is the value that characterizes the relative size or energy released of an earthquake at the source. Magnitude is calculated on observations of the amplitude of the ground motions recorded by seismographs located locally and around the world. There are a number of different magnitude scales, which can be converted by empirical relationships. In this document seismic events are referred to in 'local magnitude or ML'. The local magnitude scale is commonly used in the field of induced seismicity due the suitability of this scale to shallow, low magnitude and short distance seismic events.
Micro-seismicity	A small seismic event, usually with a magnitude less than 2.0. Source: Bohnhoff, M., Dresen , G., Ellsworth, L., Ito, H. (2010). Passive seismic monitoring of natural and induced earthquakes: Case studies, future directions and socio-economic relevance. In: Cloetingh, S., Negendank, J. (eds.), New Frontiers in Integrated Solid Earth Sciences, Internatinal Year of Planet Earth, DOI 10.1007/978-90-481-2737-5_7, Springer Science+Business B.V.
microSy/yr	
µg	Micrograms. This is a unit of weight equal to one thousandth of a gram.

Term or abbreviation	Definition
µm	Micrometer or micron. This is a unit of length equalling one millionth of metre or one thousandth of a millimetre.
Mini-Frac	Before undertaking the main hydraulic fracturing stage, a pilot hydraulic fracturing stage or "mini-fracture" may be performed. This involves pumping smaller volumes of fracturing fluid (without any proppant) into the well. The purpose of the mini-fracture is to evaluate the injection pressure required to generate fractures in the rock during the subsequent main hydraulic fracturing stage.
Mitigation measures	Measures envisaged to prevent, reduce and where possible offset any significant adverse effect of the project on the environment.
ML	Earthquake magnitude
Modified Mercalli Intensity Scale (MMI)	MMI is a scale designated by Roman numerals, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction. MMI does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects
Moisture deficit (potatoes)	The calculated deficit between the water supplied by average summer rainfall at the Site and the quantity of water required to grow a crop of potatoes, assumed to root to 70cm depth, at that location (without suffering from a lack of water). The larger the moisture deficit, the greater the likelihood of yields being reduced by droughtiness. In practice the deficit has to be met from soil water reserves, irrigation and/or by the crop wilting: the last reduces yields.
Moisture deficit (wheat)	As above but for a wheat crop assumed to root to a depth of 120cm.
Moment Magnitude (MW)	Moment magnitude is a scale that is uniformly applicable to all sizes of earthquakes. It is based on the concept of seismic moment. This measures the size of an earthquake based on the area of fault rupture, the average amount of slip, and the rigidity of the rockmass21. Moment magnitude is also estimated from observation of amplitudes of ground motions measured on seismographs.
MSGs	Most Similar Groups.
MSOA	Middle Layer Super Output areas defined by the ONS as an area that roughly contains a population of 7,200 people or 2,000 households.
NAQS	National Air Quality Strategy
NE	Natural England.
NO2	Nitrogen dioxide.
NOx	Oxides of nitrogen.
NNR	National Nature Reserve
NPPF	National Planning Policy Framework.
NTS	Non-Technical Summary. This document summarises the findings from the EIA process in non-technical language and drawing on the information in the ES.
OD	Ordnance Datum
ONS	Office of National Statistics.
PC	Process contribution.
Peak ground acceleration (PGA)	The maximum instantaneous absolute value of the acceleration of the ground
Peak ground velocity (PGV)	The maximum instantaneous absolute value of the velocity of the ground;

Term or abbreviation	Definition
Peak particle velocity (PPV)	The maximum instantaneous absolute value of the velocity of the ground (mostly used synonymously to PGV);
PEC	Process environmental contribution.
PEDL	Petroleum Exploration and Development Licence
Petroleum Exploration and Development Licence	Licences issued by the Secretary of State under the Petroleum Act 1998 to confer the right to search for, bore for and obtain hydrocarbons.
PM2.5	Particulate matter less than 2.5 microns in size
PM10	Particulate matter less than 10 microns in size
PRoW	Public Rights of Way.
Ramsar Site	An area identified under the internationally agreed Convention on Wetlands of International Importance, including as waterfowl sites and ecologically important wetlands.
Residual effects	Effects which remain after mitigation.
Restoration (of the site)	Refers to the process where the Site would be restored to its original condition on completion of the exploratory drilling, hydraulic fracturing and flow testing work.
RBMP	River Basin Management Plan
Root mean squared (RMS)	Also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity
Scoping	The process of deciding the scope or level of detail of an EIA. During this stage the key environmental issues (likely significant effects) of a project are identified so that the rest of the process can focus on these issues.
Sediment-laden run-off	Soil erosion caused by rainfall.
Seismic array	A seismic array is a set of seismometers distributed at spacing narrow enough so that the signal waveform may be correlated between adjacent seismometers
Seismic Event	The term seismic event is often referred to with regard to microseismicity. Many seismic events can only be recorded by instrumentation.
Seismic Wave	A seismic wave is an elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may travel either along or near the earth's surface or through the earth's interior**Error! Bookmark not defined.**. Seismic waves can be designated as P-waves (Primary waves = particle motion is parallel to the direction of wave propagation), S-waves (Shear waves = particle motion is perpendicular to the direction of wave propagation in the z axis), Love waves (particle motion is perpendicular to the direction of wave propagation in the x axis) and Rayleigh waves (particle motion rolls like a wave on the surface of water)[1].
Seismicity	or seismic activity of an area refers to the frequency, type and size of earthquakes experiences over a period of time
Seismograph	A seismograph, or seismometer, is an instrument used to detect and record earthquakes. The record is proportional to the motion of the seismometer mass relative to the earth, but can be mathematically converted to a record of the absolute motion of the ground
SFRA	Strategic Flood Risk Assessment
Shale gas	Shale gas is natural gas that is found trapped within shale formations.

[1] UPSeis. <URL: http://www.geo.mtu.edu/UPSeis/waves.html> (site accessed 12/12/2013).

Term or abbreviation	Definition
Shear Slip	Slip is the relative displacement of formerly adjacent points on opposite sides of a fault, measured on the fault surface
Site of Special Scientific Interest	A statutory conservation designation denoting a protected area in the United Kingdom of national importance.
SO2	Sulphur dioxide.
SPA	Special Protection Area
Special Protection Area	A designation under the European Union directive on the Conservation of Wild Birds.
SSSI	Site of Special Scientific Interest
Stress	Stress is the force per unit area acting on a plane within a body. Six values are required to characterise completely the stress at a point: in the principle co-ordinate system these are three normal components and three shear components. The stress regime can be tensional, compressional, or shear
Stress drop	The stress drop is the difference between the stress across a fault before and after an earthquak.
Surface array	Shallow buried seismometers with associated above ground control boxes containing data loggers, modems and batteries.
Suspension (of the site)	Refers to the phase of the project where equipment and accommodation from the well pad is removed whilst retaining site security measures and well valves. The Site is only likely to be left in suspension if planning and associated applications are to be made to allow development of the Site for longer term gas production.
tCO2e	Tonnes of carbon dioxide equivalent.
The ‘Project’	The term used to refer to all of the exploration activities at Preston New Road and includes the installation and operation of the seismic monitoring array and the extended flow testing.
The ‘Site’	The term used to refer to surface well pad where all of the hydraulic fracturing, flow testing and decommissioning activities will occur.
TLS	Traffic Light System
Topsoil	Upper layer of a soil profile that is usually darker in colour
TPO	Tree preservation order(s)
Traffic Light System	Refers to the surface seismic monitoring array. In the event of surface vibrations exceeding threshold values hydraulic fracturing injection pressures will be reduced (amber status) or fracturing will be suspended (red status) pending analysis of data.
Triggered seismic event	Seismic event that is caused by only a small change in stress or by migration of fluids into a pre-stressed, pre-existing fault. Triggered events are sometimes referred to as fault reactivation. Triggered seismic events release more energy than is required to initiate them.
TVDSS	True vertical depth relative to sub-sea datum
TVDGL	True vertical depth relative to ground level
UK	United Kingdom
Unconventional gas	Unconventional gas refers to gas resources which cannot be explored, developed and produced by conventional processes just in using the natural pressure of the wells and pumping or compression operations.
Vertical well	This is any section of well that is 80 degrees or less from the vertical.
Viewpoint	A location from which the Project can be seen.
Visual receptor	People who may have view of the Project.
VOC	Volatile organic compounds.

Term or abbreviation	Definition
Water based drilling muds	A drilling mud in which water or saltwater is the major liquid phase as well as the wetting phase.
Water Framework Directive	EC Directive (2000/60/EC) on integrated river basin management. The WFD sets out environmental objectives for water status based on ecological and chemical parameters, common monitoring and assessment strategies, arrangements for river basin administration and planning and a programme of measures in order to meet the objectives.
WC	Soil wetness class.
Well	For the purposes of the EIA for this Project, and to avoid confusion, the term well is used to refer to space within the rock that is created by drilling, is lined with a steel casing, cemented and from within which hydraulic fracturing will occur.
Well integrity	Well integrity is defined as a condition where uncontrolled and unacceptable releases to the environment are prevented. It is similarly defined by Oil & Gas UK as 'the application of people, equipment and processes to ensure that so far as reasonably practicable, there can be no unplanned escape of fluids from the well, and risks to health and safety of persons from or in connection with it are as low as reasonably practicable' Source: Oil and Gas UK. (2012). Well integrity guidelines. Report no. OP069.
Well pad	This term refers to area of compacted stone from which the exploration wells will be drilled and hydraulically fractured. It is also where initial and extended well testing will occur and ancillary equipment and facilities (e.g. equipment stored and welfare facilities) required to undertake the Project will be located.
WFD	Water Framework Directive
Wireline logging	A continuous measurement of formation properties with electrically powered instruments to infer properties and make decisions about drilling and production operations.
WTT	Well to Tank. This is the term used during the calculation of greenhouse gas emission to describe
ZTV	Zone of theoretical visibility

1 Introduction

1.1 Context

1. Ove Arup and Partners Ltd (Arup) has been commissioned by Cuadrilla Bowland Ltd (Cuadrilla) to prepare an Environmental Statement (this document) for the development of temporary exploratory drilling and testing facilities associated with the extraction of natural gas from shale formations underlying the Fylde, Lancashire.

2. In 2012 The British Geological Survey (BGS) began a preliminary evaluation of the natural gas resource within the Bowland Shale on behalf of the Department of Energy and Climate Change (DECC). An interim report was published in December 2012.The completed evaluation was published in 2013[2]. The BGS evaluation provides an indication of the total quantity of natural gas present within the shale. However, in order for Cuadrilla to be able to determine whether or not the Bowland Shale can provide a commercially viable quantity of natural gas, the company needs to undertake exploratory drilling, hydraulic fracturing and flow testing of wells.

3. In 2008 DECC granted Cuadrilla a licence to carry out shale gas exploration within the Fylde area (Petroleum Exploration and Development Licence 165 (PEDL 165)). Cuadrilla (through an affiliate company) also hold licence EXL269 for exploration and production in the Fylde. There are two sites within the Fylde area that are currently proposed for exploration. These are Preston New Road (this site) and another site at Roseacre Wood. Development at both sites also lie partly within licence area EXL269 which also includes the existing gas well operated by Cuadrilla at Elswick and PEDL 165. The licence areas are illustrated in Figure 1 overleaf.

4. Planning applications are being submitted under the Town and Country Planning 1990 An Environmental Impact Assessments (EIA) has been undertaken for the entire project under the provisions of The Town & Country Planning (Environmental Impact Assessment) Regulations 2011 (SI 2011 No. 1824) (referred to as the 'EIA Regulations'). A full description of the project (referred to as the Project hereafter) can be found in Chapter 4 of this Environmental Statement (ES). This ES also provides an assessment of the likely significant effects of the Project and the measures that will be used to mitigate these where reasonably practicable.

[2] Andrews, I.J. 2013. The Carboniferous Bowland Shale gas study: geology and resource estimation. British Geological Survey for Department of Energy and Climate Change, London, UK.

Figure 1.1 PEDL 165 and EXL 269 licence boundaries and extent of the two exploration sites at Roseacre Wood and Preston New Road.

5. Planning permission will be sought at Preston New Road via two separate planning applications defined as:

   - **Exploration Works Application.** Construction and operation of a site for drilling up to four exploratory wells, hydraulic fracturing of the wells, testing for hydrocarbons, abandonment of the wells and restoration, including provision of an access road and access onto the highway, security fencing, lighting and other uses ancillary to the exploration activities, including the construction of a pipeline and a connection to the gas grid network and associated infrastructure to land to the north of Preston New Road, Little Plumpton;
   - **Monitoring Works Application.** The construction, operation and restoration of two seismic monitoring arrays comprising of 80 buried seismic monitoring stations and 10 surface seismic monitoring stations. The seismic monitoring stations will comprise of underground installation of seismicity sensors; enclosed equipment and fenced enclosures. The surface array will also comprise of monitoring cabinets. The application is also for the drilling of three boreholes, each installed with 2 monitoring wells, to monitor groundwater and ground gas, including fencing at the perimeter of the Preston New Road Exploration Site.

6. Figure 2 overleaf provides an overview of the approvals and consents that the Project will need to obtain before exploration works can commence[3].

7. Given that this ES covers more than one planning application the following terminology will be used throughout the ES:

   - As mentioned above, the 'Project' is the term used to refer to all of the exploration activities at Preston New Road site (both above and below ground) and includes the installation and operation of the monitoring works; and
   - The 'Site' is the term used to refer to the surface (well pad) from where all of the drilling, hydraulic fracturing, flow testing and decommissioning activities will be operated.

8. Further standard terms are used to describe different elements of the Project and are defined in the text when they are first used and also in the glossary of terms and abbreviations (found at the front of the ES).

[3] DECC (2013). Regulatory roadmap: Onshore oil and gas exploration in the UK regulation and best practice. https://www.gov.uk/government/publications/regulatory-roadmap-onshore-oil-and-gas-exploration-in-the-uk-regulation-and-best-practice

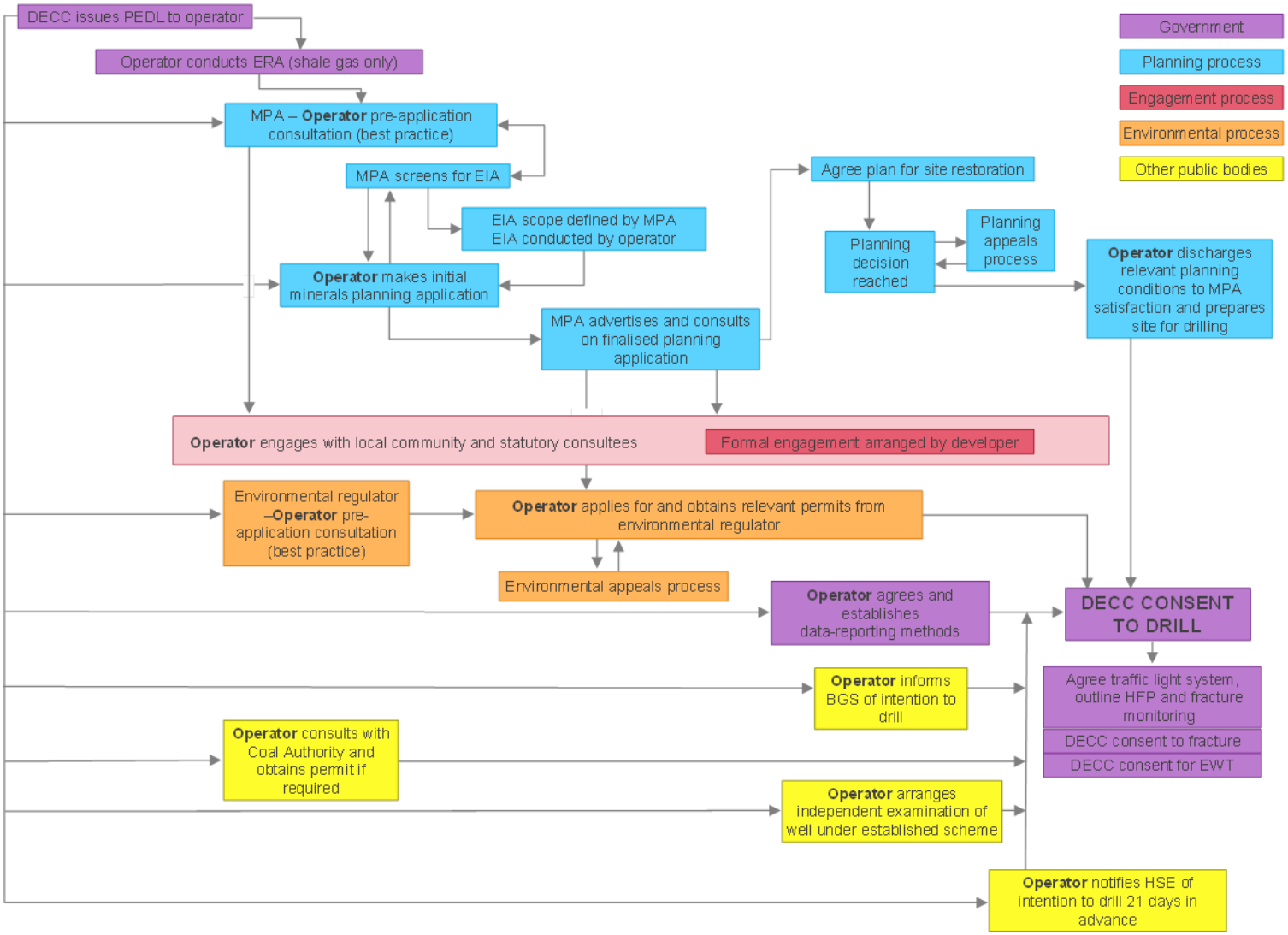

Figure 1.2 Department of Energy and Climate Change onshore oil and gas exploration regulatory and approval roadmap.

1.2 The need for shale gas exploration

9. In 2012 80% of the energy used in the UK to heat homes, provide hot water and to cook with comes from natural gas[4]. The government has indicated that the demand for gas in the UK will continue to exceed the amount that can be provided from existing UK sources over the next 15 years[5]. The UK has been a net importer of gas since 2004 and is becoming more reliant on foreign supply, with the UK growing increasingly dependent on imports from countries such as Norway and Qatar[6]. By 2025 the UK is forecast to be dependent on foreign imports of gas for nearly 70% of the gas needed to meet energy demand[7]. This dependency on foreign supplies of gas presents issues of security of supply for the UK.

10. There is the potential for renewable sources of energy (such as wind power) to meet some of the increased demand for energy and also to reduce reliance on fossil fuels. In 2012 renewables contributed some 4.1% of total UK energy demand[8]. Nevertheless more efficient, reliable and cost effective renewable energy technologies need to be developed, and the infrastructure will need to be delivered, to enable renewables to provide a greater contribution to the energy mix. Renewables are therefore more likely to take the place of fossil fuels as a significant contributor to energy supply over the long term.

11. Natural gas will be required during periods of interruptions of renewable supply (such as wind) and during the period when new technologies are being developed for renewable energy. Natural gas (including gas from unconventional sources) is therefore likely to be a key transition source of energy whilst the technologies and capacity to exploit renewables sources are being developed over the longer term[9].

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[4] DECC (2013) Energy Consumption in the UK, Overall data tables. 2013 update. (Table 1.07: Overall Energy consumption of heat and other end uses by fuel 2012 –provisional estimate). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/238793/overall.xls

[5] DECC (2013) Actual/projected UK oil and Gas Production and Actual/ Projected UK oil and Gas Demand (page 4). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287001/production_projections.pdf

[6] DECC (2014) Gas Statistics. Energy trends section 4: gas (Table 4.4 Supplementary information on the origin of UK gas imports) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287001/production_projections.pdf.

[7] DECC (2012) Energy Security Strategy (Page 4). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65643/7101-energy-security-strategy.pdf.

[8] DECC (2013) UK renewable Energy Roadmap Update 2013. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255182/UK_Renewable_Energy_Roadmap_-_5_November_-_FINAL_DOCUMENT_FOR_PUBLICATIO___.pdf

[9] DECC (2014). Fracking UK shale: climate change (page 3). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287001/production_projections.pdf

1.3 Overview of exploration proposals

1.3.1 Sources of natural gas

12. Natural gas is derived from organic matter contained in sedimentary rocks such as shale. These organic materials (remains of plants, animals and bacteria buried deep beneath the ground) are transformed by heat and pressure, over many millions of years, to form methane and other hydrocarbons. Some of these naturally occurring gases and liquids may gradually escape from the shale (sometimes termed the "source rock") and become trapped in porous rocks such as sandstone lying above the shale to form what is termed a conventional gas reservoir. Gas is often extracted from such reservoirs by drilling a well using vertical borehole techniques, or directional horizontal drilling.

13. However natural gas will also remain trapped within the shale. This is often referred to as an unconventional gas reservoir, because gas will not readily flow through the shale (due to its extremely low permeability). Natural gas can only be extracted from these unconventional reservoirs by hydraulic fracturing. Hydraulic fracturing is a process of creating fractures in rock formations to release the natural gas trapped inside. This is achieved by pumping fluid at high pressure in the rock to create minute cracks. These cracks are held open with grains of sand in the hydraulic fracturing fluid which allows gas from the rock to flow up the well to the surface. As with conventional gas reservoirs wells drilled using vertical borehole techniques or directional drilling can be hydraulically fractured.

1.3.2 Exploration and appraisal of the Bowland Shale

14. As described above, Cuadrilla has a licence to undertake exploration activities within the licence area illustrated in Figure 1. Cuadrilla has previously undertaken drilling activity between 2010 and 2012 at:

    - Becconsall, near Banks
    - Anna's Road, near Peel;
    - Grange Hill, near Singleton; and
    - Preese Hall, near Weeton (including hydraulic fracturing).

15. Data from these wells provided a localised picture of the relative depth of the Bowland Shale and other rocks in the Fylde. To better identify the locations of geological faults and potentially workable sections of the Bowland Shale (see Figure 3), over a wider area of the Fylde, a 3-dimensional (3D) geophysical survey has been undertaken. This covers an area of approximately 100km2, and was completed in June 2012. Using advanced imaging technology, the seismic survey mapped the layers of rock in the area to depths in excess of 4km, significantly improving the knowledge of subsurface geology. The 3D geophysical survey findings, combined with information from earlier drilling and other relevant data, have helped Cuadrilla to identify the most promising areas within the survey area for this phase of exploration activity. The findings from the 3D geophysical survey have been used, in combination with data on surface and environmental constraints, to reduce the impact of exploration activities which are restricted to a small number of sites.

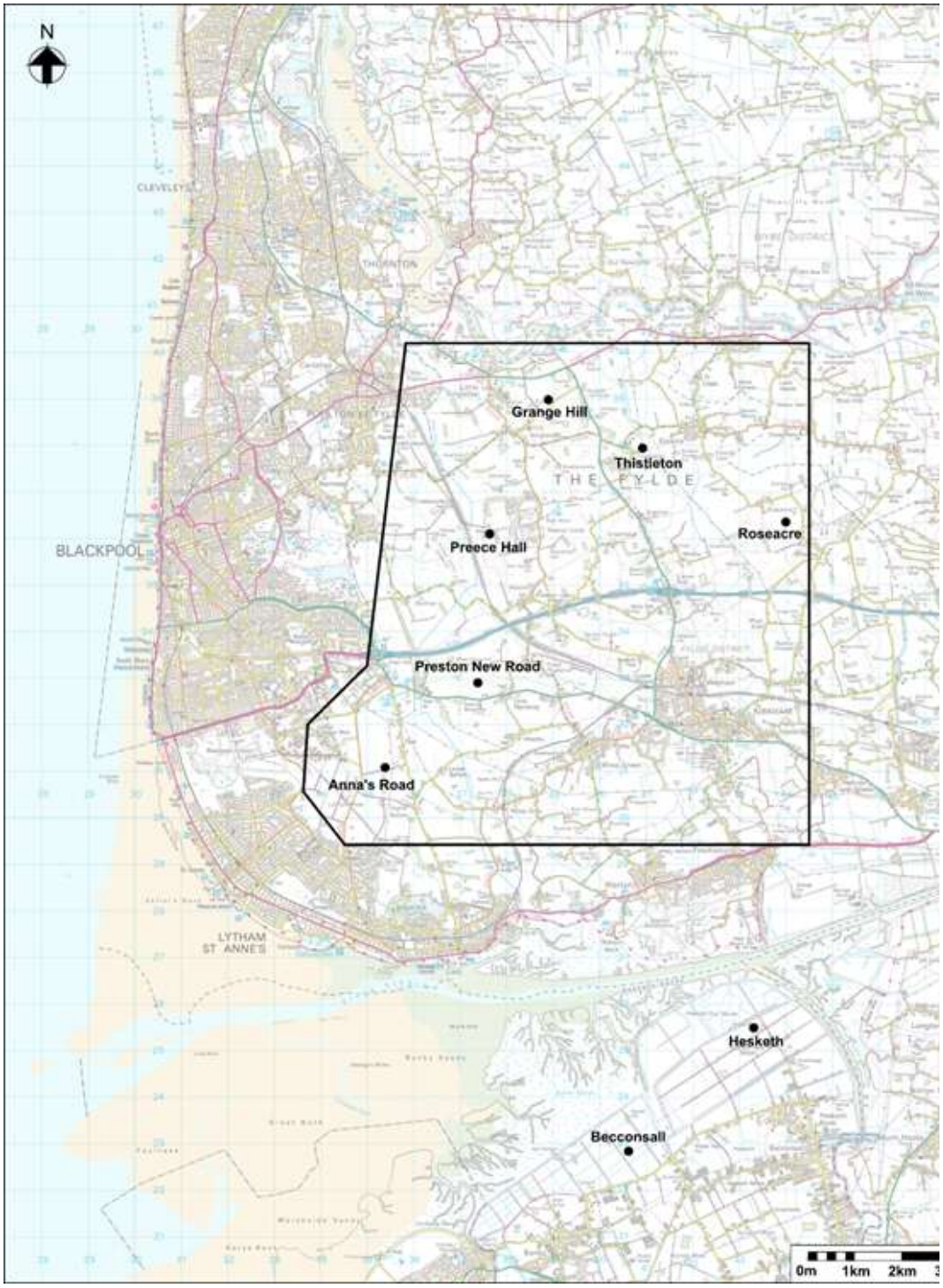


Figure 1.3 Extent of the 3D geophysical survey area.

16. The diagram in Figure 1.4 below illustrates how the activities associated with this Project relate to shale gas exploration, appraisal and production. Only when the testing information from a well on an individual site, combined with information from other sources has been analysed will it be possible to make the decision whether, or not, to proceed to production.

17. For the avoidance of doubt this ES is only concerned with shale gas exploration and appraisal activities. This approach is in line with the current guidance from the

Department of Communities and Local Government (DCLG) which states that individual applications for exploratory phases (in this case shale gas exploration and appraisal) should be considered on their own merits. DCLG also states that "They [EIA and planning applications for shale gas exploration] should not take account of hypothetical future activities for which consent has not yet been sought, since the further appraisal and production phases will be the subject of separate planning applications and assessments"[10]. The project being assessed by the ES is therefore the temporary changes of use and operational development associated with the exploration activities, i.e. the development proposed by the two planning applications. Should planning permission be sought at some future time for further appraisal or for production at the Site or at some other location then such s project would be subject to environmental assessment in its own right.

[10] DCLG, July 2013. Planning practice guidance for onshore oil and gas (paragraph 58).

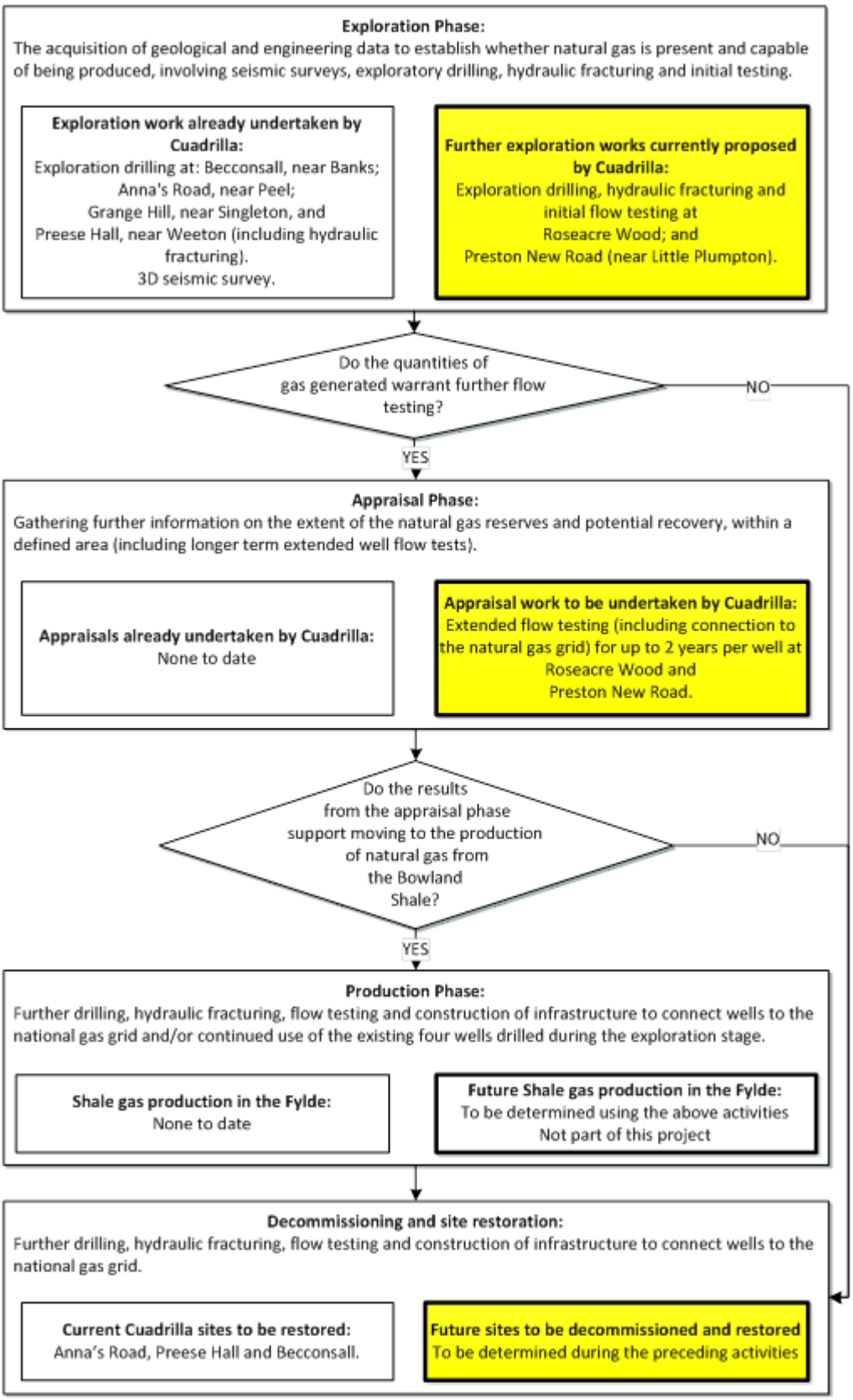


Figure 1.4 Phases of shale gas exploration, appraisal, production and decommissioning. Note: The shaded boxes relate to the Project that is assessed within this ES.

1.4 The need for an EIA

18. The EIA Regulations apply to two distinct and separate types of project:

- Schedule 1 projects, for which EIA is required in every case; and
- Schedule 2 projects, for which EIA is required only if the particular project is likely to give rise to significant environmental effects and meets the threshold criteria set out in planning practice guidance.

19. The proposed development does not fall under the types of project described in Schedule 1, however, the proposed exploratory development includes deep drilling and surface facilities associated with gas extraction, therefore, it may be classified as EIA development under Schedule 2 paragraph 2(d) or Schedule 2 paragraph 2(e)[11] of the EIA Regulations.

20. Preston New Road and Roseacre Wood are likely to be amongst the first onshore deep shale gas exploration sites in England to be subject to an EIA. Consequently the level of detail within the baseline data and the assessment of likely significant effects are greater than that which might typically be produced for a temporary hydrocarbon exploration project. As the exploration (and potential production) of deep shale gas reserves progresses, and the Strategic Environmental Assessment[12] of future onshore oil and gas licensing is completed (and new guidance is published), the scope of future EIAs is likely to be refined and the volume of information contained in the ES may be reduced.

1.5 The Environmental Statement

21. This ES has been prepared in accordance with the EIA Regulations. The ES is divided into three volumes:

- Environmental Statement Volume 1 - Main Text
- Environmental Statement Volume 2 - Appendices and
- Environmental Statement Volume 3 - Non-Technical Summary

22. The data and findings of the EIA contained in this ES provide an assessment of likely significant environmental effects which may be associated with the proposed development. This provides a robust body of information that should be used by decision-makers, stakeholders and others when considering the development proposals.

23. This ES is structured as follows:

- Chapter 1: Introduction
- Chapter 2: The Environmental Impact Assessment (EIA) process;
- Chapter 3: Application sites and the surroundings;
- Chapter 4: The proposed development;
- Chapter 5: Scheme alternatives; and
- Chapter 6 to 19: Technical environmental assessments; and

[11] Schedule 2 paragraph2(d) Deep drillings (where the area of works exceeds 1 hectare) and Schedule 2 paragraph2(e) Surface industrial installations for the extraction of coal, petroleum, natural gas and ores, as well as bituminous shale (where the area of the development exceeds 0.5 hectares).

[12] Department of Energy and Climate Change (2013) Strategic Environmental Assessment for Further Onshore Oil and Gas Licensing Environmental Report. AMEC Environment & Infrastructure UK Limited. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/273997/DECC_SEA_Environmental_Report.pdf

- Chapter 20: A summary of how the ES chapters listed above have assessed potential public health impacts
- Chapter 21: An overview of the cumulative effects

24. Copies of the ES and other documents that accompany the planning submission for this proposed development are available from Lancashire County Council (LCC) in its role as the local mineral planning authority. A charge of £280 for a hard copy of the Environmental Statement will made to cover printing and compilation costs. Copies in PDF format on a CD will also be available at a charge of £5 per copy. Digital copies will also be available to download, free of charge, from: www.cuadrillaresources.com

25. The application will also be available at the following locations:

- Lancashire County Council, Development Management Group, PO Box 100, County Hall, Preston, PR1 0LD. Opening times: 8.30am – 16.30pm Monday to Thursday and 8.30am – 16.00pm Friday. Web address: www.lancashire.gov.uk\planningregister
- Fylde Borough Council, Planning Department, One Stop Shop, 292-294 Clifton Drive South, Lytham St Annes, FY8 1LH. Opening times: 08.30am – 16.30pm Monday, Tuesday and Thursday, 09.30am-16.30pm on Wednesday and 08.00am-16.00pm on Friday.
- Kirkham Library, Station Rd, Kirkham, Preston, Lancashire, PR4 2HD. Opening times: 9.00am-19.00pm on Monday, 9.00am-17.00pm Wednesday and Thursday, 09.00am-19.00pm on Friday, 09.00am-13.00pm on Saturday and closed on Tuesday and Sunday.
- St Anne's Library, 254 Clifton Drive South, St Annes on Sea, Lancashire, FY8 1NR. Opening times: 09.00am-18.00pm Monday and Wednesday to Friday, 09.00am-13.00pm on Tuesday, 09.00am-17.00pm on Saturday and closed on Sunday.
- Lytham Library, 27 Clifton Street, Lytham St Annes, Lancashire, FY8 5EP. Opening times: 09.00am-18.00pm Monday to Wednesday and Friday, 09.00am-16.00pm on Saturday and closed on Thursday and Sunday.
- Ansdell Library, 59 Commonside, Lytham St. Anne's, FY8 4DJ. Opening times: 09.30am-19.00pm Monday and Friday, 09.30am-17.30pm Tuesday and Thursday, 09.30am-13.00pm on Saturday and closed on Wednesday and Sunday.

2 The Environmental Impact Assessment (EIA) process

2.1 General approach to the Environmental Impact Assessment

1. This section describes the following:

- Relevant legislation and guidance for the EIA process;
- Approach to screening;
- Approach to scoping;
- Baseline data gathering;
- Approach to assessment;
- Mitigation;
- Approach to assessment of residual effects; and
- Approach to assessment of cumulative effects.

2.2 Legislation and guidance

2. This ES has been prepared in accordance with the EIA Regulations. The EIA Regulations enact, in UK legislation, the European Community (EC) requirements for the assessment of the effects of certain public and private projects on the environment, as set out in Directive 85/337/EEC (as amended in particular by Directive 97/11/EC) and consolidated in Directive 2011/92/EU (13th December 2011).

3. Reference has also been made to DCLG Planning Practice Guidelines for Environmental Impact Assessment[13], Environmental Impact Assessment: A Guide to Procedures[14] (as far as currently relevant), IEMA (2004) Guidelines for Environmental Impact Assessment, Planning practice guidance for onshore oil and gas[15] and guidance received from LCC and other published sources.

4. The EIA and subsequent ES will be undertaken under the provisions of Part 2; 4(2) of the Regulations. Although no formal screening opinion has been sought by the Applicant, an EIA is being carried out to ensure that the subsequent planning applications are compliant with the EIA Regulations and to ensure that decision makers have sufficient robust environmental information on which to base their decisions.

5. A wide range of other guidance has been published on aspects of the EIA process, in relation to individual environmental topics and this is described in the respective topic sections of this ES.

6. The requirements for information to be included in an Environmental Statement are set out in Schedule 4 of the EIA Regulations. The ES must include, as a minimum, the information specified in Schedule 4; Part 2, and as much of the information in Part 1 as is reasonably required to assess the environmental effects of the development, and which the applicant can reasonably be required to compile. This ES has been prepared to comply with the requirements of Schedule 4; Part 1 of the Regulations; Table 2.1 below sets out where the relevant information is located within this ES.

[13] DCLG (2014). Planning Practice Guidelines for Environmental Impact Assessment. *http://planningguidance.planningportal.gov.uk/blog/guidance/environmental-impact-assessment/*
[14] DCLG (2006) *Environmental Impact Assessment: A guide to good practice and procedures*
[15] DCLG (2013)

Table 2.1 Requirements of Schedule 4; Part 1 of the EIA Regulations.

Summary of requirements of Schedule 4; Part 1, by paragraphs	**Location of information in this ES**
1. Description of the development.	Chapter 4 of this ES contains a detailed description of the proposed development.
2. An outline of the main alternatives studied by the applicant … and an indication of the main reasons for his choice, taking into account the environmental effects.	Chapter 5 of this ES contains an outline of the alternatives considered.
3. A description of the aspects of the environment likely to be significantly affected by the proposed project.	Contained within the technical assessments in Chapters 6-19 of this ES. Sub-section x.6 of the individual technical sections contains the description of the existing baseline environmental conditions and features.
4. A description of the likely significant effects of the proposed development on the environment.	Contained within the technical assessments in Section 6-19 of this ES. Sub-section x.7 of the individual technical sections contains the assessment of likely significant effects on the receiving environment.
5. A description of the measures envisaged to prevent, reduce and, where possible, offset any significant adverse effects on the environment.	Contained within the technical assessments in Sections 6-19 of this ES and Appendix E. Sub-section x.9 of the individual assessment sections contains information on the mitigation methods propose)
6. A non-technical summary.	Volume 3 of the ES is the Non-Technical Summary.
7. An indication of any difficulties (technical deficiencies or lack of know-how) encountered by the developer in compiling the required information.	Contained within the technical assessments in Section 6-19 of this ES. Sub-section x.5 of the individual assessment sections contains information assumptions and limitations for each assessment.

2.3 Approach to Scoping

2.3.1 The Scoping Report

7. Scoping is not a mandatory requirement of the EIA process, however, under Regulation 13 of the EIA Regulations "a person who is minded to make an EIA application may ask the relevant planning authority to state in writing their opinion as to the information to be provided in the environmental statement (a 'scoping opinion')".

8. The purpose of the scoping stage is for the applicant to engage with the local planning authority and other consultees in seeking agreement on the scope of the EIA, and the approach to be adopted for the assessment of those topics which have been included in the EIA. The list of topics in the Scoping Report are listed below:

- Air quality;
- Archaeology & cultural heritage;
- Community and socio-economics;
- Ecology;

- Greenhouse gas emission;
- Hydrogeology and ground gases;
- Induced seismicity
- Landscape and visual amenity;
- Land use (agricultural land quality assessment);
- Lighting;
- Noise;
- Resources and waste;
- Transport; and
- Water resources and flood risk.

9. A Scoping Report for Preston New Road was issued to LCC on 4th February 2014 to assist the Council and its consultees in the formation of a robust scoping opinion. The Scoping Report provided information about the proposed development and gave an overview of existing conditions on the site and locality. On a topic-by-topic basis, the approach to identifying baseline information and assessing likely environmental effects was described. The scope of the assessment, and the methodology for assessing likely significant environmental effects of both operational and decommissioning phases of development, were summarised. A copy of the Scoping Report is included in Appendix C.

10. The Scoping Report was circulated by LCC in their role as the Minerals Planning Authority (MPA) and responses were received from following organisations.

- Natural England
- Environment Agency
- Fylde Borough Council
- Health & Safety Executive
- Campaign for the Protection of Rural England (CPRE)
- National Grid
- Public Health England
- LCC Ecology
- LCC Landscape
- LCC Archaeology
- Highways Agency
- LCC Highways

11. A number of non-statutory, private stakeholders and other bodies also commented on the submitted Scoping Report, via the LCC website.

12. In addition to formal scoping responses, discussions were held with LCC officers to agree the scope of work associated with archaeology, landscape and visual assessment, transport, ecology, and local Environmental Health Officers in respect of air quality and noise assessment.

13. Other statutory consultees and stakeholders have been consulted by Cuadrilla and/or Arup as follows:

- Lancashire, Wildlife Trust
- River Wyre Trust
- River Ribble Trust
- Clinical Commissioning Group
- Blackpool Victoria NHS Trust
- Office of Nuclear Regulation
- National Farmers Union
- Ramblers Association
- British House Society
- SUSTRANS
- Westby-with-Plumptons Parish Council

2.3.2 The Scoping Opinion

14. A Scoping Opinion was received from LCC on 11th March 2014 detailing responses from each of the consultees following their review of the Scoping Report. A summary of all consultee responses on the scoping report is contained in Appendix D. Each of the assessments set out in this ES details the individual topic response to the LCC Scoping Opinion. The Utilities Statement, that forms part of the planning submission, addresses some the issues raised by LCC in their Scoping Opinion regarding potential impacts on utilities. In addition to the utilities covered in the Utilities Statement the following utility related issues have been assessed within the ES:

- Potential effects from induced seismicity on infrastructure (covered by Chapter 12 Induced Seismicity);
- Potential effects on transport infrastructure (covered by Chapter 18 Transport); and
- Potential effects on main water supply (covered by Chapter 19 Water Resources).

15. In addition to the topics listed earlier LCC's Scoping Opinion also requested that the ES include a section that provides signposts to all of the sections of the ES where potential health impacts have been assessed. This section is covered by Chapter 20, Public Health and by supporting information within Appendix T.

16. The topics not considered to be relevant to inclusion in the EIA include:

- Electromagnetic interference. The equipment and activities associated with the Project will not generate electromagnetic interference and hence this topic has been scoped out;
- Microclimate. The rural location of the works and physical massing of the equipment that will be used and the design of the well pad will not have an impact on micro-climate in the same way that the construction of large buildings and areas of hard surfaces can in urban settings; and
- Site monitoring and management. Monitoring proposals are set out, where relevant, within the technical chapters of the ES. A framework for a site specific Environmental Operating Standard for the Project has been produced which will document how the environmental aspects of the Project will be managed (Appendix E).

2.4 Baseline data

17. A wide range of baseline data and information sources on the environmental conditions of the area have been used for the purposes of impact assessment. Data has been gathered via:

- Field survey information, including background noise levels, ecological features, landscape character, and traffic levels on the local road network;
- Maps of historical and contemporary features;
- Data from statutory and non-statutory consultees; and
- Published and unpublished literature.

18. More detailed information is included in each of the topic sections, as required, to describe the aspects of the environment likely to be significantly affected by the proposed development.

2.5 Assessment

19. In accordance with the EIA Regulations each assessment describes *"the direct effects and any indirect, secondary, cumulative, short-, medium- and long-term, permanent and temporary, positive and negative effects of the development, resulting from:*

- *The existence of the development;*
- *The use of natural resources; and*
- *The emission of pollutants, the creation of nuisances and the elimination of waste…"*

20. Where appropriate, the individual topic assessments consider and describe each of the above effects. The methodology used for the EIA varies from topic to topic and is set out in detail in the individual specialist sections.

21. The main components of the Project are described in detail in Chapter 4 of this ES. In summary, they include:

- Installation and operation of seismic arrays and groundwater and ground gas monitoring wells;
- Construction of the well pad and access track;
- Construction of fencing, drainage ditches, earth bunds and utility connections;
- Drilling;
- Hydraulic fracturing;
- Initial flow testing;
- Construction of equipment and pipeline connection to the gas grid; and
- Decommissioning of the wells and restoration of the well pad.

22. The assessment assumes a maximum duration for all of the activities listed in the above bullet points of up to 6 years. An indicative programme of works is included in Chapter 4. Where information is available this has been incorporated into the future baseline and the assessment of cumulative effects, particularly cumulative effects with other developments.

2.6 Mitigation

23. Schedule 4; Part 1 of the EIA Regulations requires an ES to include *"A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment"*. These measures are generally referred to as mitigation measures. Guidance on mitigation measures is provided in the Planning Policy Guidelines for EIA which states that mitigation measures proposed in an ES are to be designed to limit the environmental effects of the development.

24. For the purposes of this ES, mitigation measures have been broadly defined to incorporate the following:

- Measures to prevent or avoid significant adverse effects on the environment;
- Measures to reduce or ameliorate significant adverse effects on the environment; and
- Measures to remedy significant adverse effects on the environment through enhancement[16].

25. In general a 'hierarchy' of mitigation has been adopted during this EIA, such that potentially significant adverse environmental effects have been firstly prevented or avoided (e.g. through environmental design). Where this is not possible, they have been

[16] Enhancement measures increase the positive effects resulting from a project.

reduced or ameliorated as far as practicable. Enhancement measures have been recommended where this is practicable. All types of mitigation measures are described within the individual topic sections.

26. During the development of the Project a range of mitigation measures have been embedded within the proposals so that what might have been potentially significant effects have been avoided from the outset. Some of these measures have been identified by the Arup and Cuadrilla project team, however others have been integrated into the Project as a response to the feedback received from potentially affected residents, statutory consultees and other interested parties. These embedded mitigation measures include (see Appendix E2 for a full list):

- Drilling more than one well from the well pad to reduce the footprint of the well pad required to drill each well;
- The use of directional drilling so that horizontal sections of well can be drilled within the shale. This also reduces the number of well pads required because large sections of the shale can be explored from the one location;
- The design of the wells, with multiple layers of steel casing, and the design of the well pad to prevent breaches of well integrity;
- Incorporation of an impermeable membrane and surface water retention system help to remove potential sources of pollution or contamination from the Project to the surrounding environment;
- Minimising the amount of mains water used by the Project and the potential amount waste water from the hydraulic fracturing activities that has to be removed from Site for treatment and disposal;
- Reusing flowback generated during hydraulic fracturing to reduce the amount of waste generated and mains water consumed by the Project; and
- The use of the surface seismometer array to provide realtime seismic data to Site staff during hydraulic fracturing to minimise the risk of an induced seismic effect.

2.7 Residual effects

27. The remaining residual effects, i.e. those effects which remain after mitigation, are stated in each topic section. In all cases, a matrix is included at the end of each section to present, in a concise way, the key impacts, mitigation measures and residual effects of the Project.

2.8 Cumulative assessment

28. Cumulative impacts arising from the proposed development, which include interactions between environmental parameters, and with other development that has extant planning permission or is under construction (committed development) have been considered. This assessment also assesses the cumulative effects of this site and other known gas exploration sites in the area where site establishment, drilling, hydraulic fracturing, initial flow testing, extended flow testing and site restoration activities may coincide.

2.8.1 Committed developments

29. A list of committed developments has been developed to inform the assessment of cumulative and in combination effects. Applications submitted to Fylde Borough Council that fall within 2km of the Site have been reviewed and applications submitted to Lancashire County Council that are within 10km of the site have also been identified and

reviewed. These are listed in Appendix T. The individual assessment chapters within this ES take into account the technical implications of these other developments on a topic by topic basis. Chapter 21 (Analysis) also includes a review of all of the identified developments and provides a summary of the potential for the Project and to result in a cumulative or in combination impact and whether this results in a significant effect.

2.8.2 Applications for exploration works at other sites

30. In addition to the Project, temporary shale gas exploration works are also proposed by Cuadrilla at a location to the north east of Preston New Road, near Little Plumpton. For the purposes of the EIA it is anticipated that exploration works would occur at both locations simultaneously. Consequently the combined effects of shale exploration gas exploration works at both locations have been assessed. However, the actual timing and sequence of works will not be determined until after consent has been granted for either site.

31. There is the potential the Project could overlap with works being undertaken at Grange Hill and Becconsall (to monitor reservoir pressure and seismicity at Grange Hill and to monitor pressure within the well at Becconsall) for which planning applications have recently been submitted. These sites will not result in combined or cumulative effects with the Project because:

- The separation distance between the two exploration sites is large enough that air quality, heritage, hydrogeological, seismic, water resources noise, visual and general disturbance impacts will not result in a cumulative effect. Likewise, the sites themselves are also separated enough from other development sites that these potential cumulative effects can be avoided;
- There is sufficient separation between the two sites so that their operations will not have a combined effect on the same settlements. For example vehicles will use a different junction from the M55 and different local roads to access the Roseacre Wood site compared to those accessing the Preston New Road site;
- The different activities that will be carried out at the two sites will be synchronised so that, for example, when hydraulic fracturing is occurring at one site a different activity, such as drilling, is occurring at the other site. This will further reduce the risk of any cumulative effects from occurring; and
- The rate and quantity of flowback fluid generated from both this Site and Roseacre Wood can be managed using the mitigation measures set out in Chapter 17 (section 17.9).

2.9 Preparation of the Environmental Statement and Non-Technical Summary (NTS)

32. The detailed results of the EIA process are reported in this ES, which has been prepared in accordance with the requirements of Schedule 4 of the Regulations. A Non-Technical Summary (NTS) document has also been prepared, which is bound separately as Volume 3; this is also an integral part of the ES.

3 Application site and surroundings

3.1 Site location

1. The Site is located approximately equidistant between Blackpool and Kirkham on the south-west of the Fylde coastal plain. The Site is shown in Figure 5. It is situated approximately 500 m west of the village of Little Plumpton and around one kilometre west of the village of Great Plumpton.

2. The Site is located between Moss House Lane and Preston New Road (A583). It is approximately two kilometres east of the M55/Preston New Road junction (Junction 4). The national grid reference for the centre of the Site is E337408, N432740. The wider context of the site is shown in Figure 3.1.

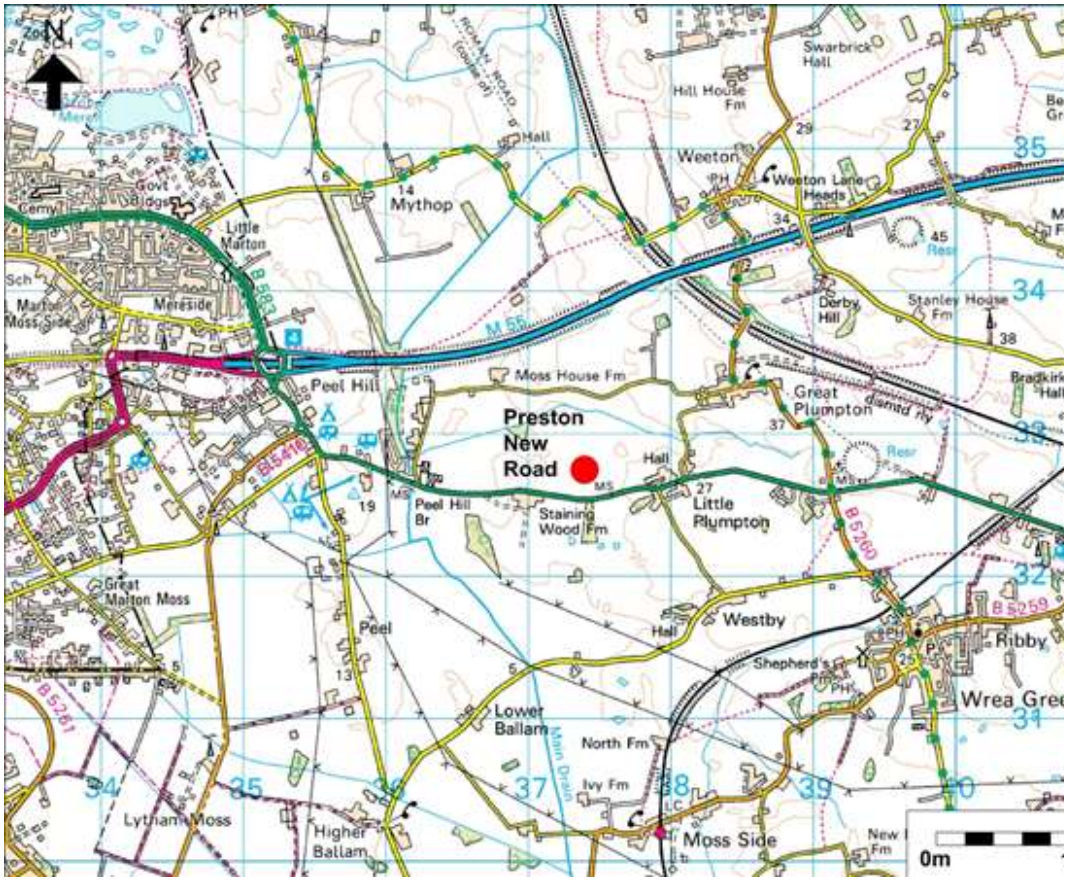


Figure 3.1: Geographic context for the Site (Contains Ordnance Survey data © Crown copyright and database right 2014) (Not to scale).

4. The buried and surface array points are spread over a wider area within 4km of the Site. In the main these are located within areas of farm land and not within areas of previously developed land.

3.2 Site context

5. The area where the well pad, access track and connection to the gas grid will be located is currently an undeveloped greenfield site used for agricultural activities and can only be reached by crossing fields. Carr Bridge Brook runs westward approximately 200m north

of the Site. A number of small wooded areas, hedgerows and ponds are located in the vicinity.

6. Moss House Farm is located approximately 800m to the northwest of the Site, on the northern side of Moss House Lane. About 360m (from the centre of the well pad) to the southwest of the site is Staining Wood Farm. A number of residential properties are located approximately 500m to the southeast of the Site in the village of Little Plumpton and 900m to the east in the village of Great Plumpton. Another residential area is situated approximately 1,200m to the west at Carr Bridge.

7. In EIA terms there are no known nationally important receptors[17] or designated sites within the proposed Site (surface works) boundary or within 3km of the Site. No statutory designations are located within the proposed development site or within a 3km radius surrounding it. The following designations have been identified within a 10km radius surrounding the Site:

- Marton Mere Blackpool Site of Special Scientific Interest (SSSI) and Local Nature Reserve (LNR) - located approximately 3.2km to the north;
- Ribble and Alt Estuaries SPA and Ramsar Site - located approximately 6.7km south;
- Ribble Estuary SSSI and National Nature Reserve (NNR) - located approximately 8.7km south;
- Lytham Coastal Changes SSSI - located approximately 6.4km south-west.
- Lytham St Annes Dunes SSSI - 6.5km south east
- Newton Marsh SSSI - located approximately 8.7km south-east;
- Morecambe Bay SPA and Ramsar - located approximately 6.7km to the north;
- Wyre Estuary SSSI - located approximately 6.7km to the north; and
- Liverpool Bay SPA - located approximately 7.4km to the south-west.

8. There are no statutory designated sites located adjacent to the Site, or in the immediate surroundings.

9. Chapters 6-19 of this ES contain more detailed baseline information about the Site and the array stations.

3.3 Geology, hydrogeology and hydrology

3.3.1 Geology

10. The Fylde Peninsula has been shaped by glacial processes to produce a relatively low-lying area with limited topographic variation. During the Ice Age, successive ice sheets deposited clay with gravel and boulder inclusions (Glacial Till), plus glacial sand and gravel deposits. More recent fluvial and marine processes have further contributed superficial geological deposits including alluvium and tidal flat deposits. Bedrock of Triassic age underlies the shallow superficial deposits and these rocks were eroded considerably during the glaciations.

11. The near surface solid geology across most of the western Fylde Peninsula comprises Triassic Mercia Mudstone, generally over 100m thick, overlying Sherwood Sandstone[18].

[17] A receptor can be any person or feature that can experience an impact or change as a result of the Project.
[18] British Geological Survey, 1990, England and Wales Solid Geology 1:50,000, Sheet 67 Garstang.

12. The assessed geology beneath the Site is summarised in Table 3.1 based on a review of the available nearby borehole records and 3D geophysical survey. The Site is located approximately 6km to the west of the Woodsfold Fault, and 1.5km north-west of the Thistleton Fault[19].

Table 3.1: Summary of predicted geology at the Site (Cuadrilla 2014).

	Geological Unit	Top of Formation (TVDGL) (m)	Thickness (m)
	Superficial deposits	-	30
Triassic	Mercia Mudstone Group	30	260
	Sherwood Sandstone Group	290	840
Permian	Manchester Marls	1130	160
	Collyhurst Sandstone	1290	60
Carboniferous	Millstone Grit	1350	190
	Upper Bowland Shale	1540	390
	Lower Bowland Shale	1930	810
	Hodder Mudstone	2740	-

13. The Manchester Marl locally forms a seal to underlying hydrocarbon bearing geological units. The Collyhurst Sandstone is the gas reservoir at Elswick gas field in central Fylde, where it immediately underlies the Manchester Marl. Beneath the Permian Manchester Marl and Collyhurst Sandstone there are several potentially productive Carboniferous shale gas zones including the Sabden Shales (part of the Millstone Grit Group), Upper and Lower Bowland Shales and the Hodder Mudstone[20]. The target zones for exploration are the Bowland Shales and Hodder Mudstone.

3.3.2 Hydrogeology

14. Although the superficial deposits are generally clay-rich, there are local water-bearing sand and gravel deposits that can support small scale groundwater abstraction and also may locally interact with wetlands and watercourses. The Environment Agency defines these superficial sand and gravel deposits as Secondary A aquifers[21].

15. Underlying the superficial deposits, the Mercia Mudstone comprises a thick unit of generally low permeability. The Mercia Mudstone is defined by the Environment Agency

[19] *Ibid.*
[20] Andrews, I.J. 2013. *The Carboniferous Bowland Shale gas study: geology and resource estimation*. British Geological Survey for Department of Energy and Climate Change, London, UK.
[21] Environment Agency, 2013. Groundwater protection: Principles and practice (GP3). Version 1.1 August 2013.

as a Secondary B Aquifer[22], but in this area it is not used and has no potential as a source of groundwater supply due to its hydraulic properties.

16. The Sherwood Sandstone Group underlying the Mercia Mudstone is defined by the Environment Agency as a Principal Aquifer[23], however in the Fylde Peninsula (west of the Woodsfold Fault) the Sherwood Sandstone is not used as a source of supply and contains saline groundwater of non-potable quality[24]. The nearest Groundwater Source Protection Zone (designated to protect public water supply groundwater abstractions) is in the Sherwood Sandstone (see Appendix B for distances).

17. As indicated by Table 3.1 the Bowland Shale and Hodder Mudstone, where hydraulic fracturing is proposed, are located at depths of over 1.5km and do not contain potable quality groundwater.

3.3.3 Hydrology

18. The two main rivers of the Fylde Peninsula are the River Ribble in the south and the River Wyre in the north, both of which flow westwards to the coast. The area surrounding the Site drains to the north and west towards Carr Bridge Brook and a small tributary drain. Carr Bridge Brook is located approximately 200m north of the Site and flows west discharging into Main Drain approximately 1km to the west, which in turn discharges into the Ribble Estuary 6 km south of the Site.

19. Several small ponds are present in the vicinity of the Plumpton site, likely to have been formed by excavation of marl (from Glacial Till) for agricultural soil conditioning mainly in the nineteenth century.

[22] *Ibid.*
[23] *Ibid.*
[24] Mott MacDonald, 1997, Fylde Aquifer / Wyre Catchment Water Resources Study, Final Report. Environment Agency.

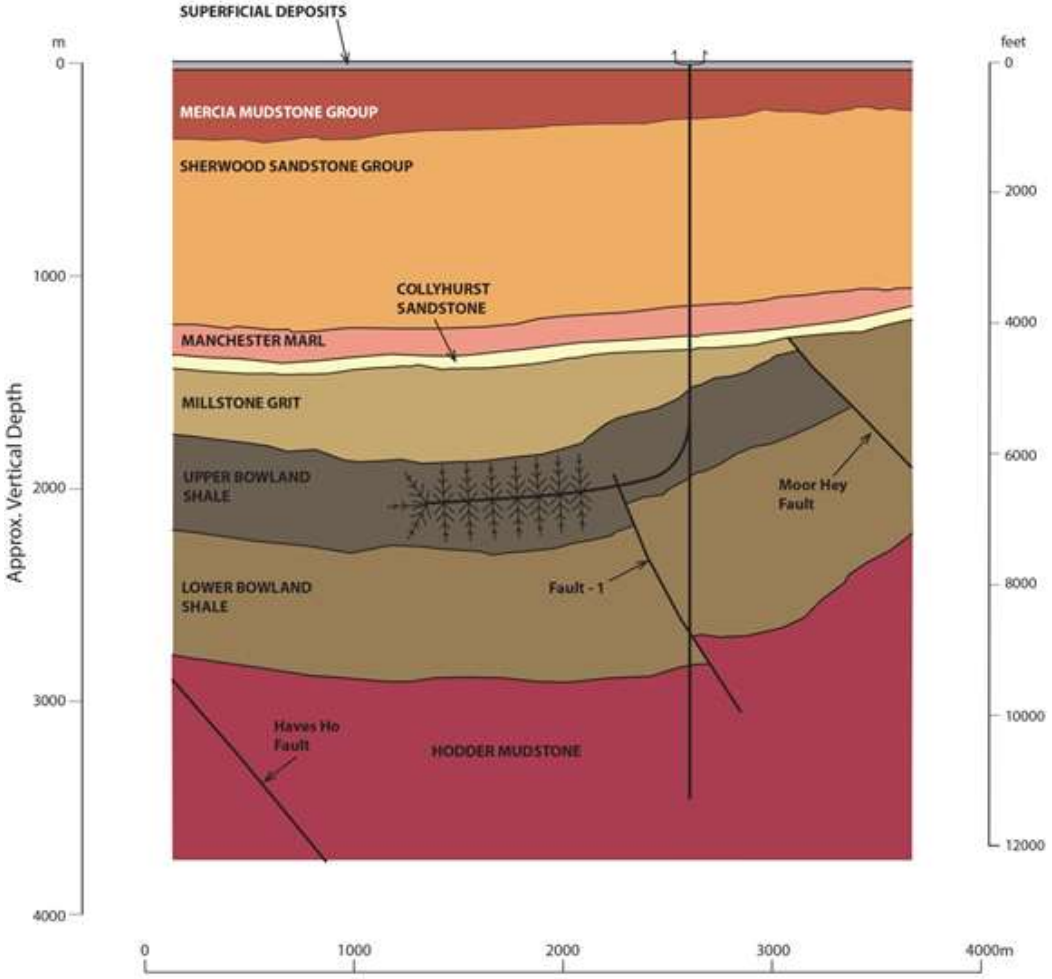


Figure 3.2: Geological strata.

4 The proposed development

4.1 Context

1. The overall purpose of the Project is to establish whether, or not, the Bowland Shale deposits could provide a commercially viable supply of natural gas (primarily methane) . In order to do this it is necessary to drill exploratory wells into the shale to provide detailed geological data about the rock formations and measure the flow and quality of natural gas from the shale. To extract the natural gas reserves in the shale, a process called hydraulic fracturing is used to connect new and existing natural fractures in the rock to allow natural gas to flow out of the shale into the exploration well and up to the surface. Up to four wells will be drilled from the Site. The first vertical well will be drilled into the Hodder Mudstone beneath the Bowland Shale (to a depth of approximately 3500m) to obtain detailed geological data. A horizontal well bore may then be drilled from the vertical well into the shale strata at a depth to be selected following analysis of geological information from the vertical well. Hydraulic fracturing will then occur in the vertical and/or horizontal section of the well bore within the shale formation. Flow testing of gas will follow successful completion of the hydraulic fracturing stages.

2. Depending on the well results, up to three further wells will be drilled (first vertically to the desired depth, and then horizontally), hydraulically fractured and flow tested, from the well pad. These three wells are referred to in this ES as horizontal wells. By drilling more than one well Cuadrilla will be able to hydraulically fracture the shales and test the flow of natural gas from different stratigraphic sections of the shale. This will provide data for Cuadrilla to appraise the commercial potential of the Bowland Shale for gas extraction.

3. Additionally, two seismometer arrays will be constructed (within 4km of the well pad). The first will consist of up to 10 seismometers located just below the ground surface (referred to in this ES as the surface array). These seismometers will detect vibrations at ground level and will allow Cuadrilla to monitor any induced seismic effects from the hydraulic fracturing process and mitigate any potential impacts. These seismometers form a key part in the "Traffic Light System" (TLS) used to control the fracturing operation. A second set of up to 80 seismometers will be located in boreholes (up to 100m below ground level). These will be used to monitor the direction and extent of the small fractures created in the shale which, in turn, will allow Cuadrilla to monitor and optimise the hydraulic fracturing process. This array is referred to in this ES as the buried array.

4.2 Planning and permitting

4. In addition to obtaining planning permissions described earlier, other consents and permits will also be required before different operational stages of the Project can proceed (e.g. drilling and hydraulic fracturing). These are determined by regulatory regimes outside the Town & Country Planning system. However, at the time of writing the key regulators for planning and permitting of shale gas exploration projects are[25]:

   - Department of Energy and Climate Change - issues Petroleum Licences, gives consent to drill under the Licence once other permissions and approvals are in place and has responsibility for assessing risk of, and monitoring, seismic activity, as well as granting consent for flaring of gas;

[25] DCLG, July 2013. Planning practice guidance for onshore oil and gas (paragraph 27).

- LCC (Mineral Planning Authority). - grants permission for the location of any wells and well pads, and imposes conditions to ensure that the impact on the use of land is acceptable;
- Environment Agency - regulates the protection of water resources (including groundwater), treatment and disposal of extractive waste, emissions to air, and accumulation, treatment and management of any naturally occurring radioactive materials (NORM); and

- Health and Safety Executive - regulates the safety aspects of all phases of gas extraction, and has regulatory responsibility for design and construction of the well casings.

4.3 Development summary

4.3.1 Overview

5. The total area of the surface works is 2.65 ha, of which 1.55ha is a compacted crushed stone surfaced well pad from which the drilling, hydraulic fracturing and flow testing activities will be undertaken. A 173 m access track will also be constructed (area approximately 0.26ha). The remainder of the 7.34 ha application site will consist of surface water collection ditches, landscaped bunds (from topsoil and subsoil excavated during construction of the well pad) and fencing and the land required for the extended flow test pipeline and connection as described in Table 4.1.

6. Three pairs of groundwater monitoring wells will be installed around the perimeter of the well pad to a maximum depth of approximately 20-30m (see Appendix B for details).

7. In addition to 80 buried seismometer array points will be installed (up to 100m below ground level) and 10 surface seismometer array points will also be installed in shallow pits (approximately 0.8m below ground level).

8. Up to four exploration wells will be drilled and tested from this well pad during the Project. The overall process is summarised in Table 4.1 and the activities are described in more detail in the subsequent sections of this chapter and illustrated in Figure 4.1.

9. Cuadrilla has developed several documents which describe a management framework to control operations that are safe and to minimise environmental impacts. Cuadrilla's Health, Safety, Security and Environment (HSSE) Risk Management Framework provide the framework to effectively manage operational risks. Site operational health and safety will comply with the provisions of the Borehole Sites and Operations Regulations 1995 (BSOR), and the implementation of the site health and safety procedures, record keeping, monitoring and auditing will be regulated by Health and Safety Executive (HSE). Cuadrilla has also developed Environmental Operating Standards (EOS) to outline the environmental embedded and site specific mitigation measures during site operations. These standards document Cuadrilla's commitment to safeguarding human health and the environment. A document that sets out their rationale and how they will be implemented when consent is granted can be found in Appendix E.

Table 4.1: Summary of the main elements of the Project.

Activity	Description
Install surface seismometer and buried seismometer arrays.	The surface array of up to ten sensitive surface seismometers and the 80 buried array seismometers and related devices will be installed, to monitor ground conditions and manage the seismic Traffic Light System (TLS) (as per section 4.4). These two arrays will be installed so that baseline data can be collected before hydraulic fracturing occurs so that any effects of the subsequent hydraulic fracturing activities can be monitored. A separate planning application has been submitted for the arrays (the Monitoring Works Application as described above in section 1.1).
Installation of the groundwater quality monitoring wells.	Three boreholes will be drilled, each installed with 2 monitoring wells, to monitor groundwater and ground gas. These also form part of the Monitoring Works Application described in section 1.1.
Construct well pad and access track.	It is anticipated that it will take up to two months to construct the exploration well pad, drilling cellars, conductor casing, access track, fencing, and installation of the mains water connection (for site staff welfare, drilling and hydraulic fracturing activities).
Drill vertical section of Well 1.	The first well to be drilled will be a vertical well to a depth of approximately 3,500m below ground level. This well will provide data on the specific geology below the Site. From this data the target zones in the shale for horizontal wells will be identified. It will take approximately 3 months to complete the vertical well (see Figure 20).
Drill horizontal section of Well 1.	A horizontal well may be drilled laterally from the vertical section of Well 1 at between 1500-3500 m depth below the surface (the exact level to be determined). This will take approximately two months to complete, and could extend 2000m horizontally from the drilling cellar.
Hydraulic fracturing.	The vertical or horizontal sections of Well 1 will be hydraulically fractured to create a network of minute cracks within the shale. Hydraulic fracturing will be carried out in a number of stages along the well. Hydraulic fracturing will occur within the horizontal sections of Wells 2, 3and 4. Hydraulic fracturing of each well is estimated to take approximately two months to complete.
Initial Flow Testing.	Natural gas and flowback fluid from the hydraulically fractured well will be tested (for a period of 90 days) to establish the flow rates of gas and liquid, and confirm the chemical composition of both. The initial flow test will involve burning the gas in two flares located within the boundary of the Site. Natural gas produced during the initial flow test will be flared in accordance with the DECC consent to flare gas. Flowback fluid, separated in a closed separation system from the natural gas, will be transported off site to an Environment Agency permitted treatment centre for treatment and disposal. It is likely that flow testing and hydraulic fracturing activities will run in parallel providing sufficient gas flows from the well.
Constructing connection to the gas grid for Extended Flow Testing.	If the quantity and flow rate of natural gas from the initial flow test is sufficient, equipment required to connect the wells to the national gas grid will be constructed and installed. Two gas pipelines will be constructed from the well to existing gas grid pipelines. A separate planning application is being submitted for the pipeline connections to the gas grid.
Extended Flow Testing (EFT).	Extended Flow Test could last between 18-24 months per well. Natural gas produced during this stage will not be flared. Instead, it would be treated and piped into the gas grid. During this period well servicing activities may occur as required to undertake maintenance activities on the wells.
Drill Horizontal	The next well (2) will be drilled vertically from the surface of the well pad

Activity	Description
Wells 2, 3 and 4. Hydraulically fracture and flow test.	to a level within the shale, from where drilling would be continued horizontally. This second well will take approximately three months to complete. This will be repeated for Horizontal Wells 3 and 4 as per the sequence described in section 4.3.2, Figure 4.2, Appendix A and Appendix B. Each of these horizontal wells will then be hydraulically fractured and flow tested (as described above for Horizontal Well 1). Likewise, if the flow of gas is sufficient the well may be subject to further Extended Flow Testing (as describe above for Horizontal Well 1), with natural gas produced being fed into the gas grid.
Decommissioning and Site restoration.	Following completion of the exploratory drilling, hydraulic fracturing and flow testing work, the Site would either be restored to its original condition (restoration) and the wells plugged and abandoned, or an application to undertake shale gas production activities prepared and submitted LCC. If the wells are no longer required they would be plugged, abandoned and monitored in accordance with the legislation applicable at the point in time.

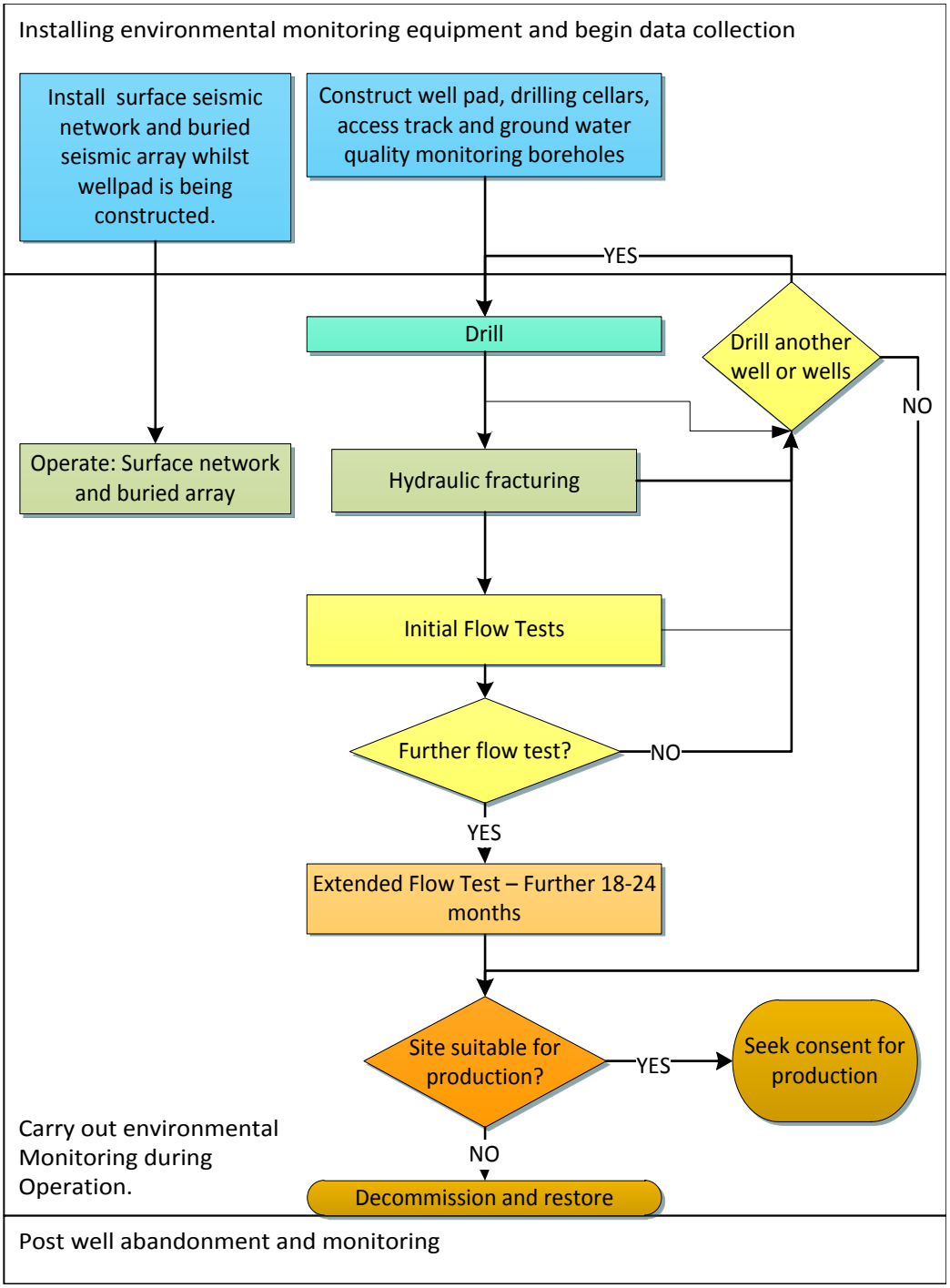


Figure 4.1: Overview of the exploration works related to the Project.

4.3.2 Sequencing

11. The sequence of activities described above, and set out in Table 3, could occur in a variety of different orders once the well pad and access track have been constructed. For the purpose of the EIA it has been assumed that the following operational sequence will be applied:

- The drilling rig and equipment will be mobilised and used to drill the vertical and horizontal elements of Well 1. The drilling rig and equipment would be demobilised from site and replaced by hydraulic fracturing and flow testing equipment;
- Well 1 (either the horizontal or vertical section) would then be hydraulically fractured within the shale formation and initial flow testing would commence;
- Once hydraulic fracturing of Horizontal Well 1 is completed the hydraulic fracturing equipment would be demobilised and the drilling rig remobilised so that Well 2 could then be drilled. However Horizontal Well 1 would continue to be flow tested whilst Horizontal Well 2 is drilled and fractured;
- Following completion of drilling Well 2, the drilling rig and equipment would be demobilised from site and replaced by hydraulic fracturing and flow testing equipment;
- Horizontal Well 2 would then be hydraulically fractured and initial flow testing would commence;
- Horizontal Well 3 would be drilled, fractured and flow tested as described for Well 2 above; and
- Horizontal Well 4 would be drilled, fractured and flow tested as described for Well 2 above.

12. Until initial flow testing has been undertaken on the first well it will not be possible to determine when Extended Flow Testing (18-24 months per well) might begin. This is because Cuadrilla will require data on the quantity, quality and flow rate of gas to determine the details of the connection to the National Grid mains. The timing of connection into the gas grid would be subject to National Grid's processes and procedures.

13. The installation of the surface and buried arrays will be completed before any of the wells at the Site are hydraulically fractured. This is because data from the surface array is required for the Traffic Light System to establish a seismic baseline (part of the procedure to mitigate the risk of hydraulic fracturing inducing a felt seismic event). This baseline data will be collected for at least four weeks before hydraulic fracturing commences.

14. The groundwater monitoring wells will be installed and other environmental monitoring programmes commenced at the beginning of the works to establish baseline data.

15. For the purposes of the EIA the sequence illustrated in Figure 4.2 has been assessed by plotting a sequence of Site activities that would result in the maximum number of vehicle movements (see Appendix A for a more detailed Programme). The maximum duration of the various project activities are also illustrated in Figure 4.2 and Appendix B.

Figure 4.2: Indicative Project activity sequences.

4.3.3 Surface works and below ground works

17. The exploration activities can be split into surface works and below ground works. The surface works include construction and operation and restoration of the well pad, access track and, in due course, any infrastructure required to connect the Site to the gas grid during EFT. The likely maximum extent of the surface works is illustrated in Figure 4.3.

18. The below ground works include the vertical and horizontal wells plus the extent of new fractures in the rock. At this point in time the proposed alignment of the horizontal sections of the wells is not known as this is dependent on results from geological data from vertical Well 1. Figure 4.4 shows the area in which the horizontal wells will be located and encompasses the fractures that will be created.

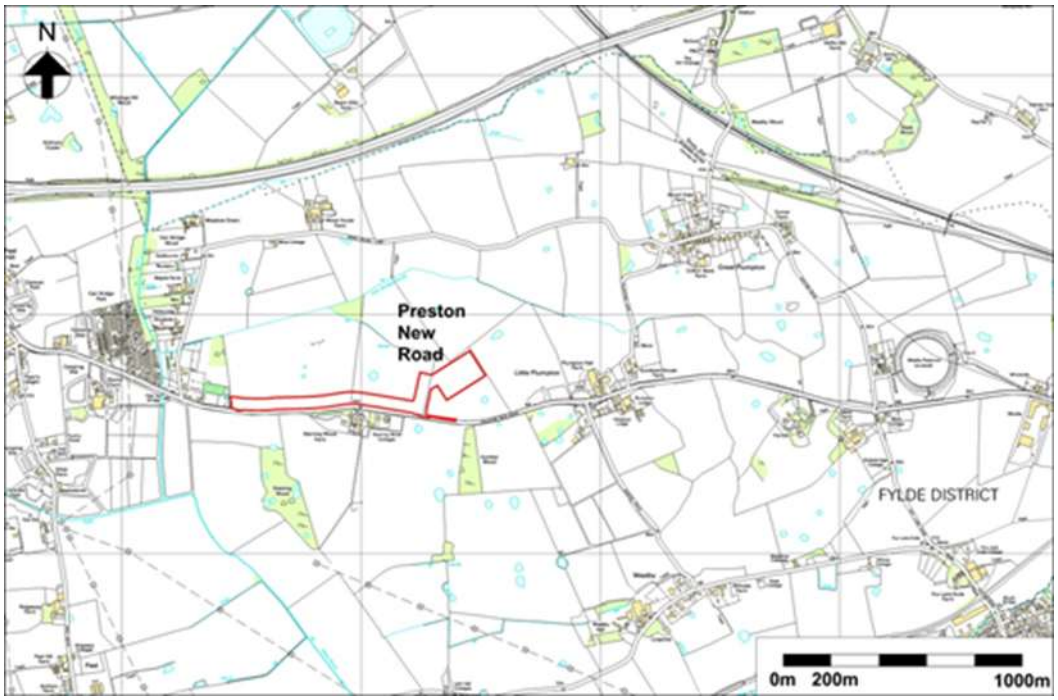


Figure 4.3: Extent of the surface works (the Site) associated with the Project (well pad, access track and areas of works for connection to the National Grid gas grid).

(Contains Ordnance Survey data © Crown copyright and database right 2013) (Not to scale).

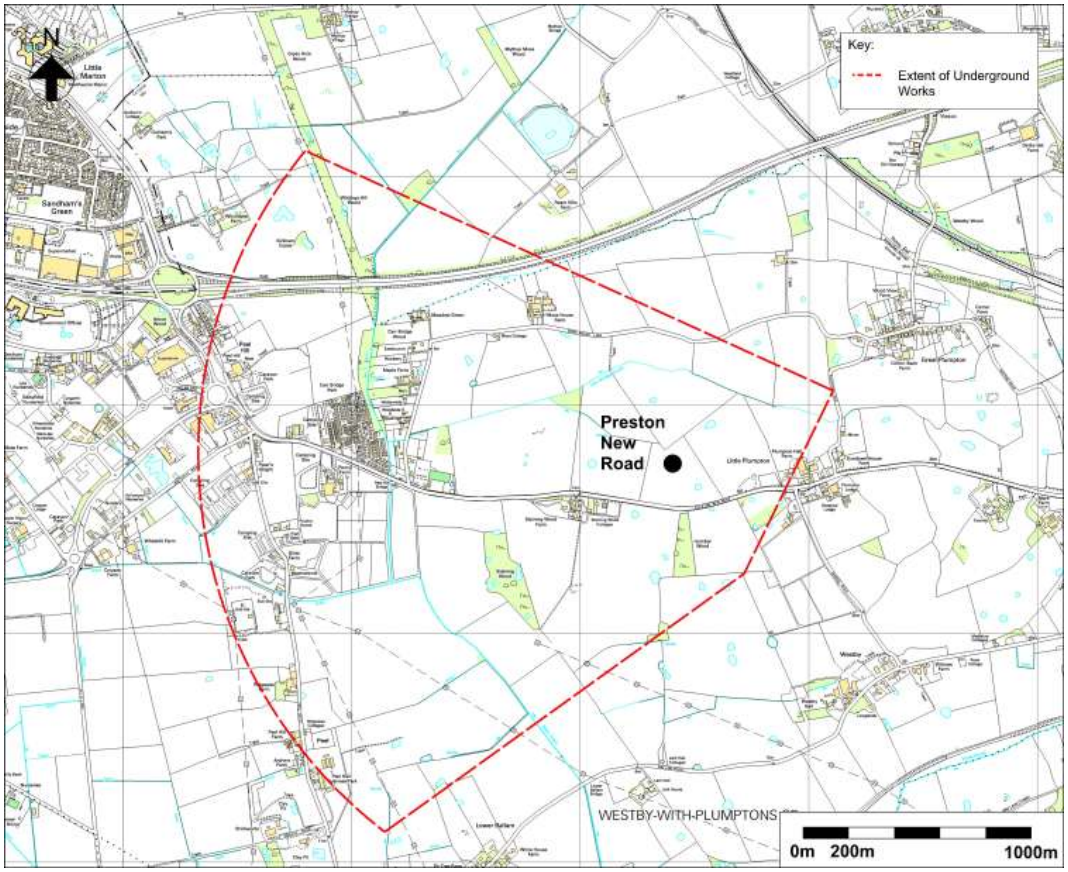


Figure 4.4: Maximum extent of the below ground works.

(Contains Ordnance Survey data © Crown copyright and database right 2014) (Not to scale).

4.4 Installation of the surface and buried seismic monitoring arrays

21. As noted in section 4.1, two seismic monitoring arrays will be implemented as part of the Project. The seismic events induced by hydraulic fracturing do not typically exceed magnitude 0 ML and very rarely exceed 0.5 ML. Data from the surface array will be used to mitigated the level of induced seismicity from hydraulic fracturing operations so that they are below 1.5ML (this a level of magnitude that will not damage buildings or infrastructure and are unlikely to be felt by people)[26]. The buried array will provide data on the location, extent and direction of the fractures that occur within the shale rock during hydraulic fracturing. This will allow the hydraulic fracturing process to be refined throughout the hydraulic fracturing activities.

4.4.1 Surface Array

22. The surface array is a network of shallow buried seismic monitoring stations that will monitor the hydraulic fracturing process in real-time. It will detect vibrations and

[26] The Royal Society and the Royal Academy of Engineering. (2012)
Shale gas extraction in the UK: a review of hydraulic fracturing.
http://royalsociety.org/policy/projects/shale-gasextraction

movement that might occur at the surface due to the creation of fractures at depth, in the shale rock. The surface array will comprise up to 10 shallow pits (to a depth of approximately 0.8m below ground level) within which sensitive seismometers will be located (illustrations of what these look like can be seen in Figure 4.5 and Figure 4.6). The installation of each surface array station will also include small junction boxes to house batteries, data logging equipment, modem and GPS units. This equipment will be located in a small kiosk (approximately 1.1m high and located between 1 to 3m from the seismometer).

23. DECC has developed a Traffic Light System (TLS) that monitors against values measured using the earthquake magnitude scale (ML). In the event of surface vibrations caused by the below ground fracturing operations exceeding threshold values[27] whilst pumping fracturing fluid into the well hydraulic fracturing injection pressures will be monitored and flowback rates adjusted (amber status) or fracturing will be suspended (red status) pending analysis of data.

24. It will take between 1-2 days to install each array point. Once installed the array will record background seismic data to provide baseline seismic data. The TLS system will be operated during hydraulic fracturing operations and will require personnel to visit each site to change the batteries used to power the seismometer, data recording and communications equipment that feed data back to operators at the well pad in real time.

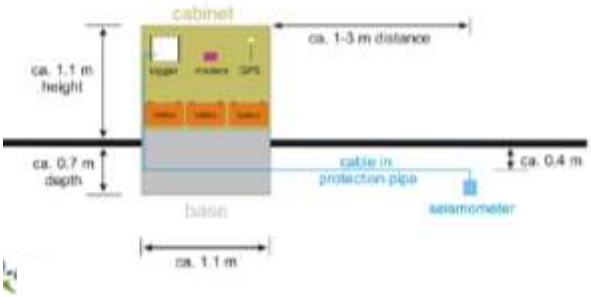


Figure 4.5: Schematic of Traffic light monitoring equipment

Figure 4.6: Indicative illustration of Traffic light monitoring equipment

4.4.2 Buried Array

25. In addition to the surface array described above, the buried array will comprise deep buried seismic monitoring stations (at a depth of approximately 100m below ground level) that will be installed to measure the extent and rate of fracture propagation within the shale rock. The array stations will be drilled by a truck mounted drilling rig, such as that used to drill water wells. These stations will provide data on the direction and extent of the small fractures that are opened up in the underground shale. This array will comprise approximately 80 boreholes containing seismometers. A buried array was installed as part of the exploration works at Anna's Road. It may be feasible to re-use 16 of these buried array stations. If this not the case new boreholes will have to be drilled adjacent to the existing boreholes.

[27] Up to value of $0.0M_L$ operations can proceed as planned; 0.0-$<0.5M_L$ operations can proceed but with caution, possibly with reduced volumes of water, at different locations or with longer monitoring and analysis periods; if vibrations exceed $0.5M_L$ hydraulic fracturing will be suspended and pressures immediately reduced.

26. The surface treatment of the buried array stations will comprise a concrete pad or collar with an inspection cover mounted flush with the ground surface (see Figure 4.7 for reference). They will be located at sites away from buildings, roads and other potential sources of interference. They will also be enclosed by fencing to prevent damage by livestock or farm machinery. The surface and buried arrays will be installed at locations shown in Figure 4.8.

Figure 4.7: Typical surface treatment for the buried array points.

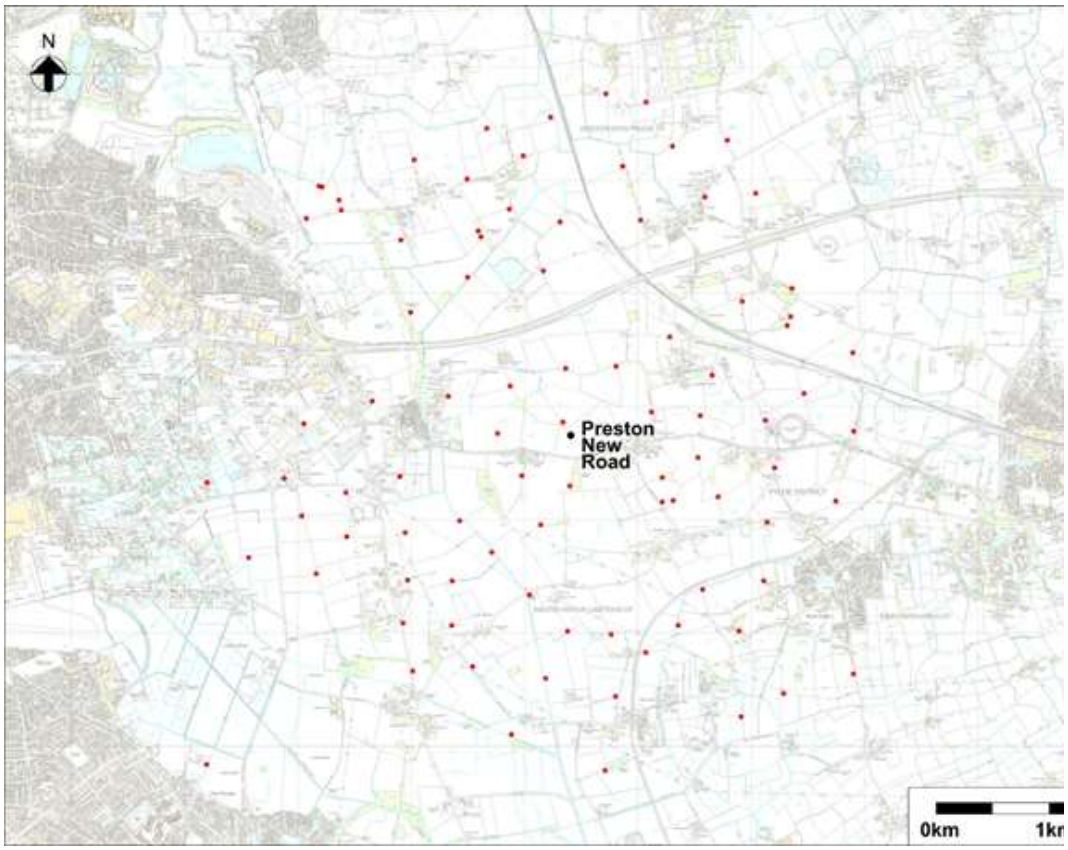


Figure 4.8: Location of the surface and buried seismometer arrays. (Not to scale).

4.4.3 Operation of the surface and buried array

30. During hydraulic fracturing operations, data will have to be downloaded from the buried array points after each time a well undergoes hydraulic fracturing. This will be done remotely via the mobile phone network. As a result operatives will only need to visit the

array sites approximately once a week to change the batteries used to power the seismometers. When hydraulic fracturing operations are not occurring the array points will require less frequent visits.

4.5 Construction of the well pad and access track

4.5.1 Equipment

31. To construct the well pad general earth working equipment will be used. In addition to this the following equipment will be present:

- Truck mounted drilling rig to drill the shallow section of the conductor casing;
- Well drilling rig (for groundwater monitoring wells); and
- Site welfare facilities for construction staff.

4.5.2 Groundwater monitoring wells

32. Groundwater monitoring wells will be constructed within the Site fence line but outside of the impermeable liner and drainage ditches. The boreholes will allow groundwater quality and ground gas data to be collected prior to, during, and post-exploration.

33. The three pairs of monitoring wells would be installed around the well pad to a maximum depth of approximately 30m, using a small drilling rig, typically used for site investigation or water well drilling purposes. The first borehole would be drilled to prove the top of the Mercia Mudstone and to understand the superficial geological sequence. The monitoring installations will comprise, in each borehole, one standpipe in the deeper granular glacial deposits and a second in the shallower superficial deposits.

34. The detailed monitoring scope and reporting procedures would be agreed with the regulators in advance. It would comprise a period of baseline monitoring prior to drilling the shale gas exploratory wells, as well as monitoring throughout drilling, fracturing and flow testing and for an agreed period following abandonment. Continuous monitoring devices that record groundwater quality and gas concentrations in the monitoring wells regularly (e.g. hourly) are likely to be deployed, with periodic sampling and laboratory analysis. Monitoring would be undertaken by a specialist contractor for Cuadrilla.

4.5.3 Site preparation

35. Vegetation and topsoil will be stripped from the entire area of the well pad and access track, and will be stockpiled in contoured bunds surrounding the Site. The soil stockpile will be graded, roughly cultivated and seeded to prevent erosion and sediment-laden run-off. It will be maintained in a tidy and weed-free condition throughout the operational life of the well pad and Defra soil management guidelines will be implemented to ensure maintenance of soil quality.

36. Reprofiling of the sub-soil will be undertaken to create a level platform for the well pad and a sloped embankment for the access to the highway.

4.5.4 Well pad construction

Security

37. The Site and access road will be secured by a 4m high welded mesh security fence. Additional fencing will be installed within the well pad area to help demarcate areas. Security lighting will be installed, and access to the Site will be controlled via a gated entrance onto Preston New Road. A small cabin will be provided on the well pad for security personnel who will actively patrol the Site. CCTV will also be installed at strategic points of the Site.

Well pad construction

38. The well pad will be constructed with a minimum depth of 300mm clean, compacted aggregate laid on an impermeable membrane and geotextile layer with protective felt inter-layers, or similar impervious profile.

39. Four drilling cellars will be constructed at between 5 and 25m spacings (see Drawing PNR_ES_110 in Appendix A). These will comprise voids of about 3 metres in width and depth, with concrete walls and floor. Each exploration well will be drilled from the base of an individual drilling cellar.

40. Surface water run-off drainage and attenuation will be provided by a perimeter ditch system, a pollution interceptor and an isolation valve so that the well pad can be isolated from the adjacent surface water ditches (see Figure 4.9 to Figure 4.11).

41. Figure 4.9 shows the layout of the prepared site before any operation activity commences and Figure 4.10-Figure 4.11 relate to sections showing boundary treatment.

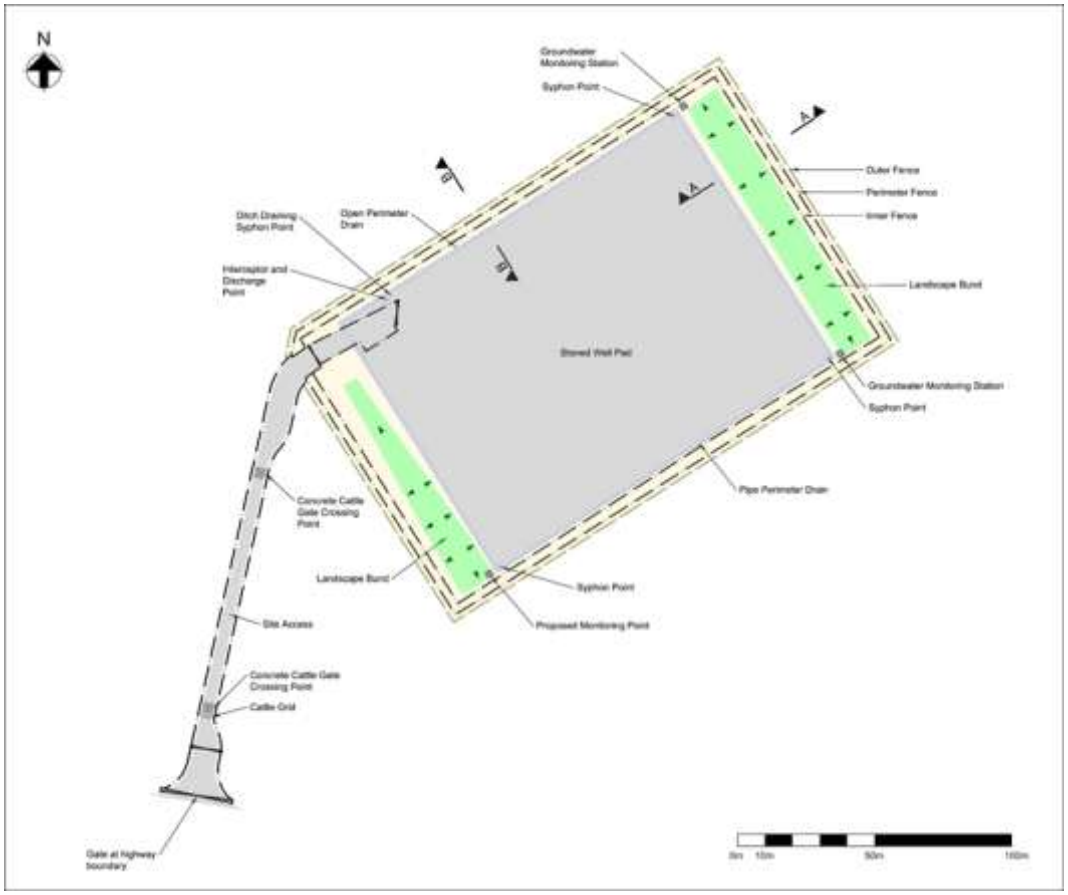


Figure 4.9: Well pad design

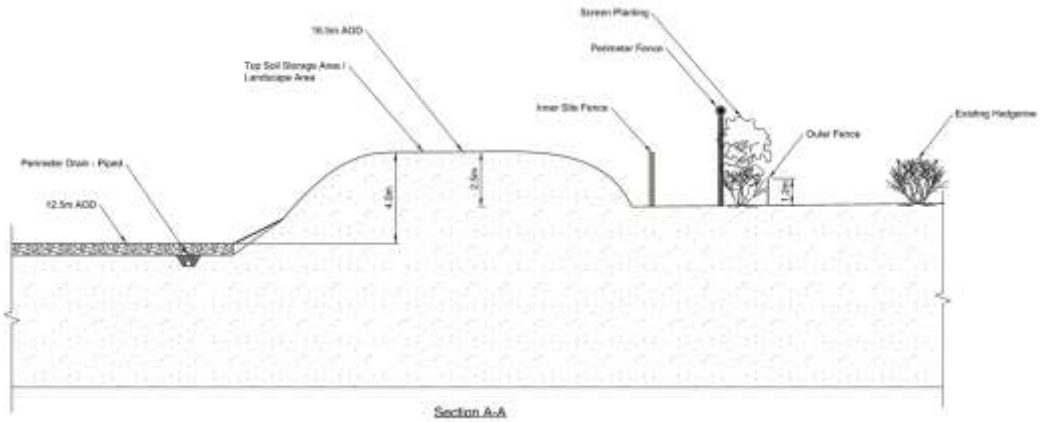


Figure 4.10: Well pad design (cross section A-A)

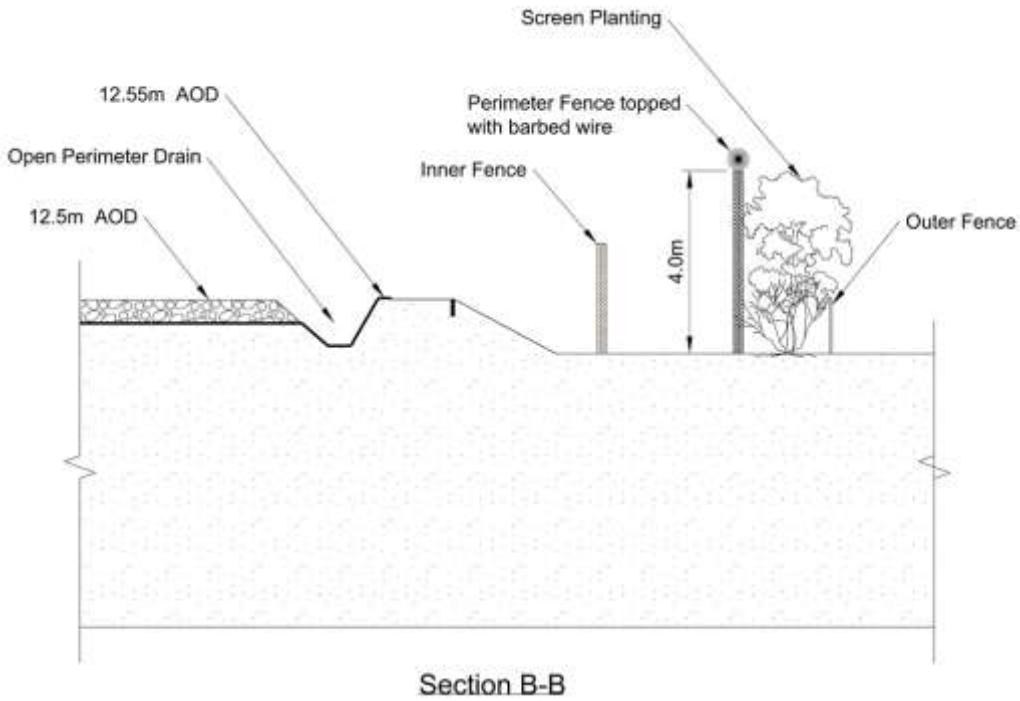


Figure 4.11: Well pad design (cross section B-B) Update with latest design.

4.5.5 Utility connections

45. Mains water required by the Project will be drawn via a 150mm diameter pipe from a United Utilities mains located adjacent to the Site. All foul sewage will be collected and contained on the Site, in pre-fabricated toilet and mess room facilities. Foul sewage will be removed from the Site by tanker by registered waste contractors. Electricity requirements will be provided by on-site diesel-powered generators. Small power (mains electricity) and telecommunication connections may also be provided to the offices and welfare facilities at the Site.

4.6 Access

46. The Site will be accessed via the nearby A583 road and M55 motorway. The entrance to the Site will be located to the east of the existing lay-by approximately 2.2km along the A583 from Junction 4 of the M55. Provision is also made for access to a gas grid compound at the connection point to the gas grid (Figure 4.12). Vehicles will be able to access the Site from either junctions 4 or 3.

47. The Site will be entered through a new opening in the hedgerow on the A583. A wide entrance will be created to allow for the passing of two heavy goods vehicles (HGVs) to avoid waiting and blocking of the main highway. A new track will be constructed to the site which will be surfaced appropriately to withstand HGV traffic Potential mitigation measures, including traffic management proposals, to reduce the impact of additional HGVs traffic along the proposed HGV transport route are set out in Chapter 18.

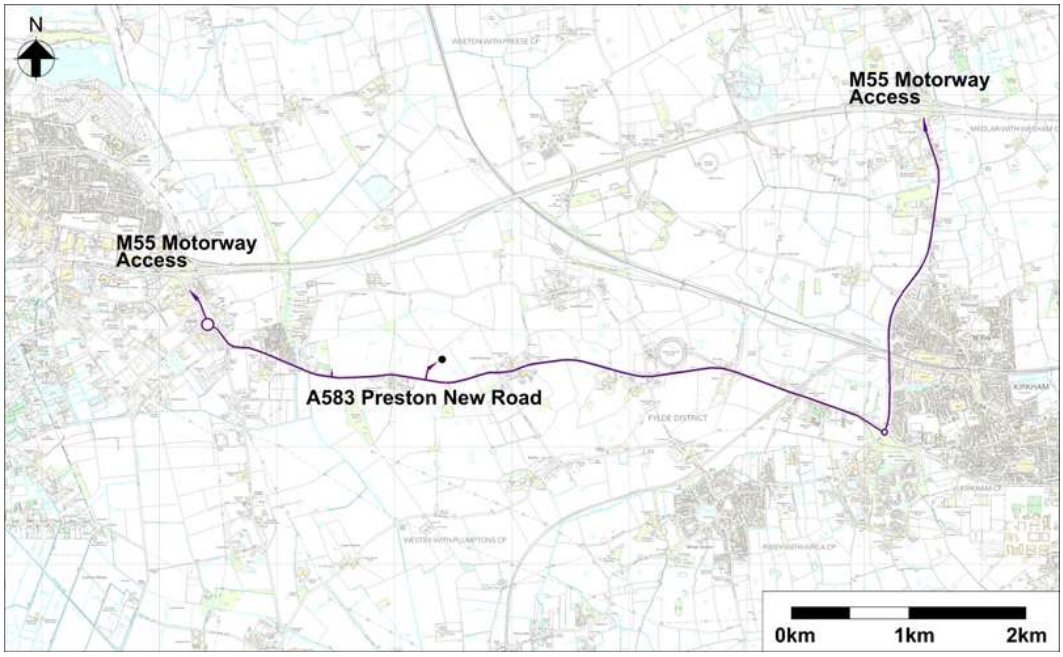


Figure 4.12: Proposed routes from the Site to the M55.

49. Further details about the construction of the well pad and access track can be found in Appendix B.

4.7 Drilling

4.7.1 Equipment

50. The equipment required to undertake drilling will be brought to the Site by HGVs, and will include:

- Plant and equipment specific to the drilling unit used, including a mast with an erected height of between 30m and 53m[28];
- 40ft 'shipping containers' for storage of equipment, workshops, and modules for office, welfare and onsite accommodation (single storey height; shipping containers not stacked double height);
- Cranes to assemble the drilling rig and other equipment;
- Drilling mud logging equipment;
- Well cementing equipment;
- Wireline logging equipment;
- Drilling materials and fluids; and
- Casings and tubulars.

51. The equipment mobilisation period for the drilling stage will typically last for two weeks. The approach to assessing traffic impacts from the equipment mobilisation is discussed in Chapter 18. An illustration of the types of drilling rig that may be used during exploration works is provided in Figure 4.13. The indicative layout for these activities is illustrated in Appendix A - Drilling stage layout (Drawing PNR_EW_102) and Figure 4.14provides an illustration of the equipment likely to be used during drilling.

Figure 4.13: Illustrations of potential drilling rigs to be used during the Project.

4.7.2 Drilling

53. Up to four exploration wells will be drilled at the Site, as summarised in section 4.3. The first well will be drilled vertically through the geological profile to a maximum depth of c. 3,500m. The geological information from this first vertical well will provide data on

[28] For the purposes of the EIA the larger drilling rig has been assessed to ensure that the worst case visual effects have been assessed.

the characteristics of the shale. From this data, the depths and orientation within the shale at which the horizontal wells will be drilled will be selected.

54. The lower section of the vertical well (Vertical Well 1) may be plugged with cement to the selected depth for initiating the drilling of the first horizontal (Horizontal Well 1), which would then be drilled to its anticipated lateral extent (see Figure 4.14).

55. Horizontal Wells 2, 3 and 4 will be drilled from the surface to depths determined by geological information derived from Vertical Well 1.

56. Once commenced, drilling works must take place 24-hours per day, 7 days per week.

57. Low intensity security lighting will be used as well as focussed task lighting around the base of the drilling rig to allow works to be undertaken during hours of darkness).

58. Drilling of the well includes the following elements: drilling mud engineering, casing running and cementing, data acquisition via coring and wireline logging, and directional drilling. Licensed, sealed radiological sources are commonly used for measurement purposes in wireline logging and logging while drilling.

59. The likely waste products from this stage of the Project are outlined in Chapter 17.

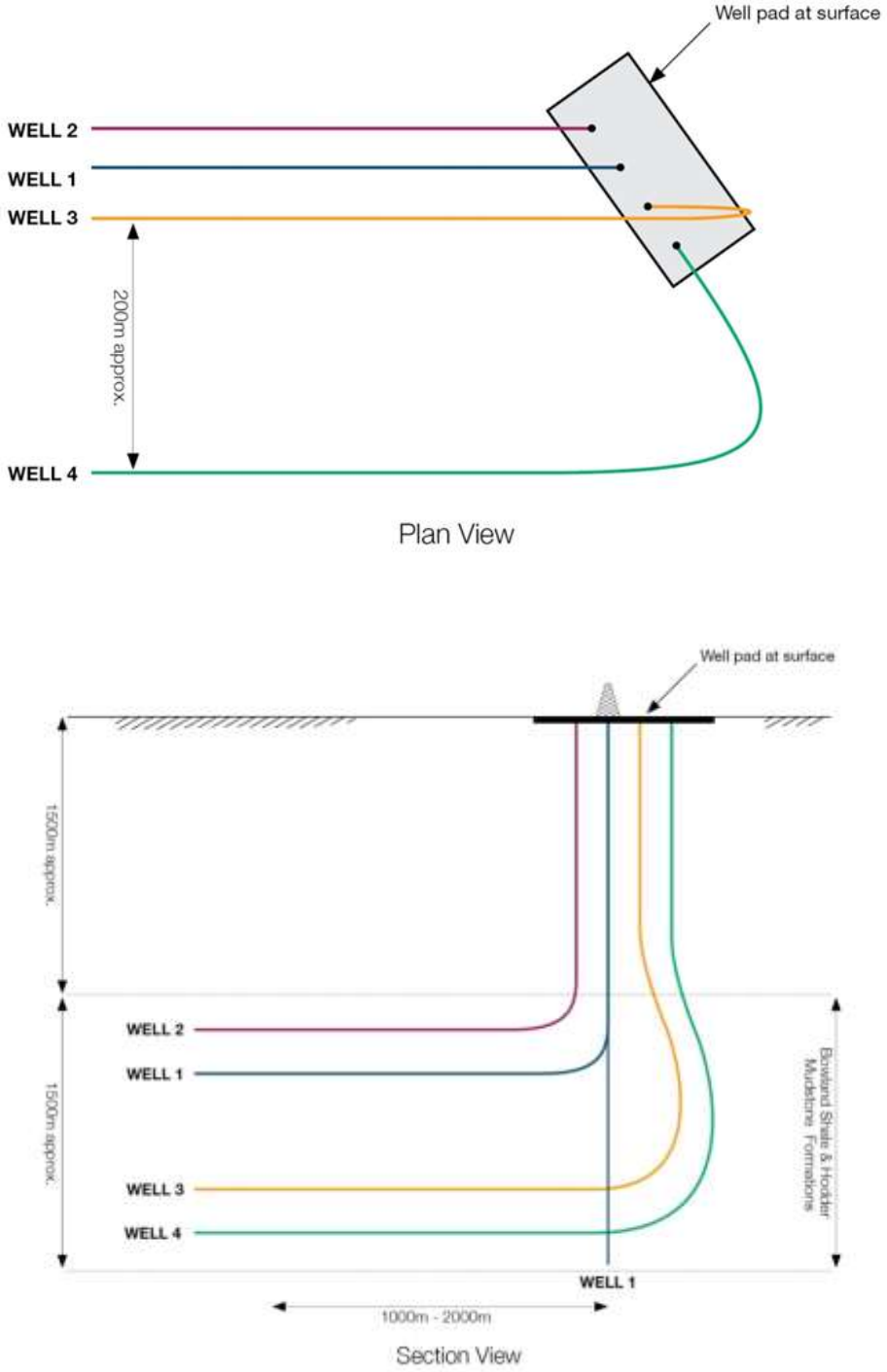


Figure 4.14: Illustrative schematic showing the potential arrangement of vertical and horizontal wells below ground. (Not to scale).

4.7.3 Well design

65. The overall well construction will be designed to provide multiple barriers between the groundwater and deep underlying production zones and will be constructed in accordance with Oil & Gas UK Well Integrity Guidelines, UKOOG UK Onshore Shale Gas Well Guidelines (2013), Borehole Sites and Operations Regulations 1995 (BSOR) and Offshore Installations and Wells (Design and Construction Etc) Regulations 1996 (DCR), The well design and installation will be submitted for review by an independent well-examiner, and notified to the Health and Safety Executive.

66. Three types of well have been designed for the Project (see Chapter 11 and Appendix K for further details). The vertical section of Well 1; the horizontal section of Well 1; and the subsequent three combined vertical and horizontal wells (Horizontal Wells 2, 3 and 4). Although the specific design of these wells may differ, they will all comprise a series of steel casings. The functions of these casings are summarised below; sizes and depths are indicative and are subject to modification according to final geological and operational conditions at and underneath the Site:

- *Shallow conductors* - a series of steel casings ranging from 42 inch (1067mm) to 30 inch (762mm) in diameter. These typically extend down to 60m below ground level depending on shallow soil and geological conditions. These steel casings are driven or fixed in place to provide a stable surface platform from which to drill subsequent sections of the well-bore. The conductor casings are designed to isolate any shallow groundwater, and isolate any shallow unstable sands. Shallow conductors are installed as part of civil site works;
- *Deep conductor*- Nominally 18 5/8 inch (473mm) to 20 inch (508mm) diameter steel casing extending from the surface to a depth of approximately 300m below ground level and terminating within the lower section of the Mercia Mudstone. This conductor may be installed either prior to mobilisation of the main drilling unit, using a smaller specialised conductor setting rig, or by the main drilling unit itself;
- *Surface casing* - Nominally 13 3/8 inch (340mm) diameter steel casing extending from surface to a depth of approximately 1,200m below ground level terminating within the upper section of the Manchester Marl;
- Intermediate casing - Nominally 9 5/8 inch (245mm) diameter steel casing extending from surface to a depth of approximately 2,000m below ground level, targeting the Upper Bowland Shale;
- *Drilling liner and tie back* - Nominally 7 inch (178mm) diameter steel casing extending from inside the 9 5/8 inch (245mm) casing to a depth ranging from 2,300m to 3,200m below ground level and depending on the departure depth from the vertical well. The 7 inch liner will be tied back to surface with 7 inch production casing,; and
- *Production Liner* - Nominally 4 ½ inch (114mm) diameter steel casing extending from inside the 7 inch liner to the final depth of the well, which will be determined once data from Vertical Well 1 has been analysed.

67. Casings and liners will generally be cemented in place to seal off the various subsurface formations through which they extend. However for the 7 inch tie back and intermediate casing, the upper portion of the annulus will be left uncemented to allow for pressure monitoring. It should however be noted that uncemented sections will only be present in sections of the well where there will always be at least one further layer of casing between well and adjacent rock. Each string (section of casing) will be pressure tested and subjected to quality assurance procedures to ensure its integrity. The depths, diameters and specifications of each casing will be dependent on the depth at which the

different geological formations are encountered. For this reason all of the values described above are indicative.

68. A high-pressure wellhead will be installed onto the surface casing. A blow out preventer (BOP) will be installed onto the wellhead to provide secondary well control when drilling the remainder of each well. A BOP is not required for drilling to shallower depths because ground gas has not been encountered whilst drilling in these geological formations in other wells in the Fylde.

4.7.4 Drilling operations

69. When drilling wells, drilling fluids or "muds" are used to:

- Facilitate the removal of drill cuttings (i.e. the fragments of rock created by the drill);
- Manage the hydrostatic pressure within the well as it is deepened for primary control of subsurface pressures to prevent the release of fluids or gas during drilling;
- Stabilise the borehole and the drilled cuttings;
- Lubricate the drill string when drilling the vertical and horizontal wells;
- Cool the drill bit; and
- Allow use of bridging agents in the drilling fluid to minimise any loss of drill cuttings or fluids to permeable formations, where these exist.

70. Two types of drilling mud are proposed, water based muds (primarily polymer drilling) or low toxicity oil-based emulsion mud (LTOBM). In all instances water based muds will be used when drilling through the shallow formations and the permeable Sherwood Sandstone formation. Where borehole stability is problematic and/or maximum lubrication is required during directional drilling and to reach the intended target distance, low toxicity oil-based muds (LTOBMs) offer improved performance over water-based fluids. LTOBM would not be used prior to casing and cementing off all potentially sensitive groundwater receptors in order to provide isolation from the base oil used in deeper sections. This means using LTOBM only after the surface casing has been set and cemented to isolate the Sherwood Sandstone. In addition, LTOBM can be reconditioned for use at other locations, thus minimizing waste generation. Further details are provided in Appendix K

71. The EA will review and assess all drilling fluids and components.

72. Further details about well design and drilling operations can be found in Appendix B and Appendix K.

4.8 Hydraulic Fracturing

4.8.1 Equipment

73. The hydraulic fracturing equipment, accommodation and ancillary equipment will be brought onto the Site in a pre-planned sequence, over a period of approximately two weeks. HGVs and other commercial vehicles will deliver the following (indicative description):

- Storage units (steel containers for additive storage);
- Steel water tanks (for freshwater and flowback storage);
- Sand storage/delivery units;
- Two enclosed gas flare stacks (up to 10m high);

- High volume separator ;
- Work-over rig (up to 36m high);
- Up to 6 hydraulic fracture pumps;
- Blender unit;
- Manifold unit;
- Coiled tubing unit;
- Coiled tubing support tower (up to 36m high); and
- Monitoring cabin

74. The indicative layout for these activities is illustrated in Appendix A (Drawing PNR_EW_103 Hydraulic fracturing layout) and Figure 4.15 which provides an illustration of the equipment likely to be used during hydraulic fracturing.

Figure 4.15: Example of Hydraulic Fracturing equipment.

4.8.2 Overview of process

76. Hydraulic fracturing (commonly referred to as "frac'ing" or "fracking") is a process which is undertaken to enable the flow of liquids and gases through relatively impermeable underground rocks (i.e. to increase permeability). It is used in situations where, under natural permeability conditions, fluids or gases will not flow freely, for example in shale or in rocks such as granite. It has been frequently carried out offshore and onshore in the UK on oil and gas wells in low-permeability reservoirs to increase well productivity. Hydraulic fracturing is also used, in geothermal energy developments to create fractures for water to flow through crystalline rocks such as granite.

77. The Bowland Shale Formation was originally deposited as a mixture of organic-rich siliciclastic and carbonate mudrocks. These deposits accumulated in a deep marine environment, in an ocean basin in which the prevailing conditions were periodically oxygen deprived. This resulted in the accumulation of abundant organic material and therefore the deposits are characterized by relatively high total organic content (TOC). During subsequent shallow burial and compaction of the sediment to form shale, organic matter was converted to kerogen (an insoluble organic compound). During deeper burial (increasing temperature) and greater compaction, the kerogen generated liquid hydrocarbons and natural gas (primarily methane). At the present day this gas is adsorbed onto the remaining organic material and is trapped in the microscopic pore spaces in the Bowland Basin target formations. Because the gas-saturated shales are hard, fine grained, and with very low permeability, they need to be hydraulically fractured to produce the natural gas.

78. Pore spaces within the shales are very small (in the range of 5 to 100 nanometres) and have very limited connectivity. This means gas present in kerogen and pore spaces is trapped in the formation and cannot freely flow. In order to release the gas, and allow it to flow towards a well bore, the process of hydraulic fracturing must be undertaken. Hydraulic fracturing is the process of injecting fluids at high pressure to overcome rock strength and pressures acting on the rock at depth in order to develop a network of small fractures in the rock. As the overall goal is to maximize the surface area of the rock accessible by the well, the fracture sizes are designed to be root-like networks of minute fractures. Proppant (generally sand grains) that is part of the hydraulic fracturing fluid holds open the induced and pre-existing fractures so that pore spaces can be connected to the well.

79. The hydraulic fracturing fluid will consist of the following:

- **Water** is the predominant constituent in the fluid. It is intended that the water will be sourced from the mains water supply and by reusing the hydraulic fracturing fluid that returns to the surface between hydraulic fracturing stages as a closed loop system. This has the combined benefit of reducing both the consumption of mains water and the quantity of flowback fluid that has to be removed for treatment and disposal offsite. Clean rainwater collected in the perimeter ditches could also be used to make up the fracturing fluid. This would further reduce mains water consumption and the quantity of waste water transported from the Site;
- **Proppant** (Silica sand) is mixed in with the fracturing fluid at specific stages during a fracturing event to keep the fractures created in the shale wedged open after the hydraulic pressure has been released; and
- **Friction reducer** is added to the water to minimise the pressure losses incurred due to friction between the water and the well casings as the water travels several kilometres from surface through the well to the shale formation. The proposed friction reducer is polyacrylamide which is non-toxic classified as non-hazardous to groundwater by the Environment Agency.

80. There is the potential that the flowback fluid which is re-used for subsequent hydraulic fracturing stages could contain bacteria. If some circumstances these bacteria can restrict the flow of gas. To kill this bacteria UV treatment will be used. This would also be used to treat rainwater if it were also to be used to make up the hydraulic fracturing fluid.

81. As a contingency, dilute hydrochloric acid may be used to facilitate entry of the fracturing fluid from openings in the production casing to the body of shale. Hydrochloric acid would be used to reduce fracturing pressure requirements and improve treatment

effectiveness. The hydrochloric acid will be stored at a strength of no greater than 10% in solution. However, it has not been necessary to use it at other wells drilled in the licence area to date and it is thus included as a contingency.

82. Cuadrilla proposes to use a fracturing fluid with a composition comprising of at least 99.95% water and sand, and less than 0.05% friction reducer, by volume.

4.8.3 Steps in the hydraulic fracturing process.

Consent for Hydraulic Fracturing

83. A Hydraulic Fracturing Programme (HFP) will be submitted to DECC for review and approval after drilling is completed and before any fracturing starts. The HFP will identify how risks associated with hydraulic fracturing operations will be managed. Like all other activities prior to undertaking hydraulic fracturing activities, all other relevant consents will be obtained. DECC require[29] the HFP to include:

- *A map showing faults near the well and along the well path, with a summary assessment of faulting and formation stresses in the area and the risk that the operations could reactivate existing faults;*
- *Information on the local background seismicity and assessment of the risk of induced seismicity;*
- *Summary of the planned operations, including stages, pumping pressures and volumes;*
- *A comparison of proposed activity to any previous operations and relationship to historical seismicity;*
- *Proposed measures to mitigate the risk of inducing an earthquake and monitoring of local seismicity during the operations; and*
- *For shale gas fracs, a description of proposed real-time traffic light scheme for seismicity, and proposed method for fracture height monitoring.*

Well preparation

84. Prior to hydraulic fracturing, a "Frac Tree" will be installed on the wellhead. The purpose of the Frac Tree is to provide a seal and prevent release of gas and liquids at the surface. The valves within the tree have been specified to withstand the maximum hydraulic fracture pressure. Secondary valves in the tree are used as a contingency in the event that the primary valve (master valve) fails.

85. Following installation, the assembly will be tested to the maximum planned operational pressure. Once the test pressure has been set, operational activities cannot exceed the test pressure. The installation and testing is generally performed prior to mobilisation of hydraulic fracturing equipment to the Site.

Perforation of well-bore casing

86. In order to control where fractures are created, the well casing must be perforated at target locations. These perforations will be pre-set into the well casing by installing sleeves (known as "frac sleeves") during well construction, which can be later mechanically opened.

29 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/79173/Extended_well_tests_and_Frac_Plan.docx

87. In the event that any of the frac-sleeves fail to open satisfactorily, the casing will be perforated using either an abrasive jetting technique or a small shaped explosive charge. If jetting is used, coiled tubing is placed into the well and a jetting fluid is injected through the tubing under pressure. The jetting fluid, similar to the hydraulic fracturing fluid, contains water, sand, and a friction reducer. Following perforation, the jetting fluid can be recovered as very little will have been released into the surrounding formation. During recovery, the sand will settle in the bottom of surface collection tanks and separated from the fluid. The recovered jetting liquid can be reused. However the sand generally cannot be reused as it returns in a damaged form unsuitable for reuse. Explosive charges have the benefit of providing calibration data for the buried array, and as such, may be used on initial perforations.

Mini-fracture testing

88. Before undertaking the main hydraulic fracturing stage, a pilot hydraulic fracturing stage or "mini-fracture" will be performed. This involves pumping small volumes of fracturing fluid (without any proppant) into the well. The purpose of the mini-fracture is both to evaluate the injection pressure required to generate fractures in the rock during the subsequent main hydraulic fracturing stage as well as to calibrate the micro-seismic monitoring network. The fracturing schedule may then be modified subject to the data gathered in the mini fracture. Mini-fracture testing may also be performed at various times during the hydraulic fracturing.

Hydraulic fracturing

89. Hydraulic fracturing will be performed over 30 to 45 stages per well at intervals of 30 to 50m per stage. The exact interval for each stage will depend on a variety of factors including extent of induced fracture networks on preceding stages. The initial stage will be at the end of the horizontal section of the well, furthest from the well pad, with successive stages working backwards along the well length towards the vertical section of the well. In order to induce fractures, pressure will be applied to the target interval. The applied pressure during each stage will be within the maximum operational pressure of the equipment. Within each stage several steps will be performed where the type and quantity of the sand proppant will be adjusted to optimize the fracturing process. Each stage is anticipated to last up to three hours. The entire hydraulic fracturing programme, per well, is anticipated to be less than two months per well.

90. Initial fracturing events will be conservative with respect to fluid and proppant volumes in order to analyse fracture development and potential seismicity.

Flowback fluid

91. Once a hydraulic fracturing stage is complete, the pressure at surface may be reduced, and a portion of the water which was injected into the well, allowed to return to the surface. This water is termed “flowback fluid” and will comprise a mixture of the injected hydraulic fracture fluids, sand, waters naturally occurring within the shale, dissolved minerals and released hydrocarbons. Naturally occurring radioactive materials (NORM) are anticipated to be present in flowback fluid. This is because soluble NORM is naturally present in shale. In addition, if LTOBM is used during drilling, the flowback fluid may also contain small amounts of LTOBM constituents. Sampling and analysis will be performed on flowback fluid in order to ensure appropriate waste classification and adequate handling and disposal. It is anticipated that the flowback fluid will be classified as radioactive waste with non-hazardous composition.

92. On reaching the surface flowback fluid will be passed through a four phase separator that allows solids, water, condensate and gases to be separated for optimal waste recovery and management. This process will separate-out residual sand (by allowing it to settle out at the bottom of the collection tanks), a portion of the NORM (in solid form) and flowback fluid. These materials will be stored temporarily on site in enclosed tanks and then will be subsequently removed to an appropriate waste treatment facility permitted by the Environment Agency (including being licensed to receive NORM). The flowback fluid will then be reused, along with mains water, to create more hydraulic fracturing fluid for the next hydraulic fracturing stage

93. Produced natural gas will be separated, measured and sent to two enclosed flare stacks where it will be combusted to form carbon dioxide and water vapour. More detailed information on flare stack emissions are contained in Chapter 6 of this ES.

Management of Hydraulic fracturing operations

94. After hydraulic fracturing operations have been authorised by the relevant regulatory authorities, hydraulic fracturing will commence. It will generally comprise the stages illustrated in Figure 4.16.

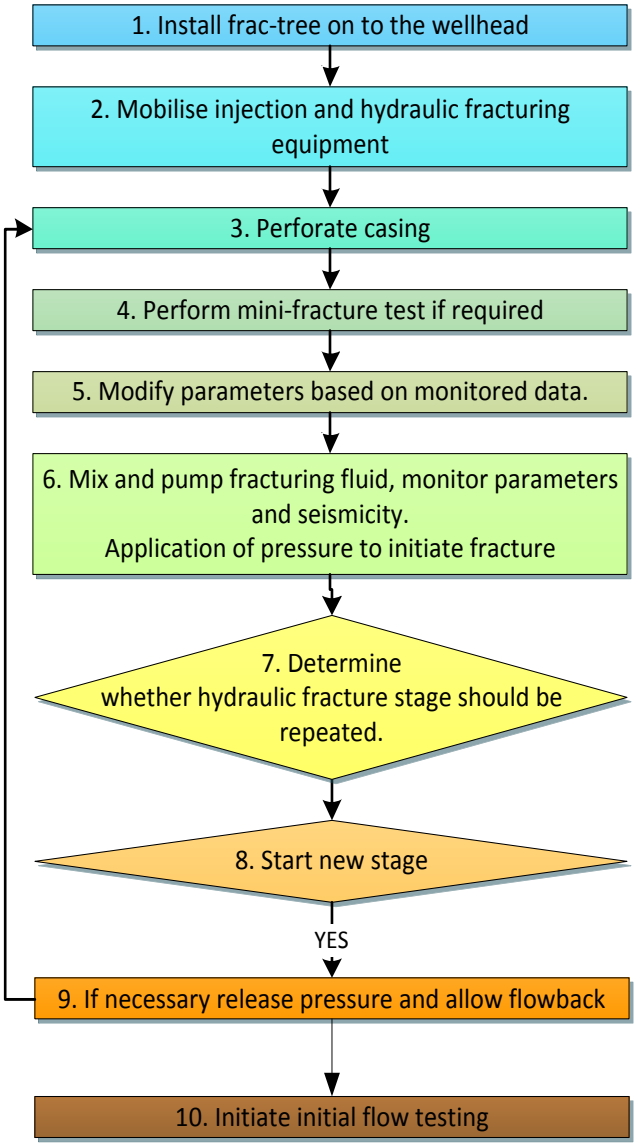


Figure 4.16: Hydraulic fracturing process.

96. Once all hydraulic fracturing activities are completed on a single or multiple wells, fracturing equipment will be removed from the Site and initial flow testing of the well will commence (see below). The duration of hydraulic fracturing activities for each well will vary according to the total number of hydraulic fracture stages undertaken in each well. However, it is not expected to last more than 2 months per well. Staff will be present on Site 24 hours a day, 7 days a week. However the pumps used to pressurise the well to create the fractures will not be operated at night[30].

97. Further details about hydraulic fracturing operations can be found in Appendix B.

[30] Night time is taken to be the time between the hours of 2300 and 0700 (as defined by BS5228).

4.9 Initial flow testing

98. Although initial flow testing is described below as a standalone stage there is potential for some initial flow testing to be undertaken while hydraulic fracturing is also being implemented (i.e. in between fracturing stages).

4.9.1 Equipment

99. Following completion of hydraulic fracturing activities on a well, the equipment listed below will remain on Site for initial flow testing (see Appendix A Drawing PNR_EW_103):

- Site staff offices, welfare facilities and storage containers;
- Coiled tubing rig (up to 36m high);
- Service rig to install/remove tubing (up to 36m high);
- 2 enclosed gas flares (10m high) (an indicative illustration of the flare is included in Figure 4.17);
- Flowback separator with line heater and associated equipment;
- Enclosed flow-back tanks; and
- Water storage tasks.

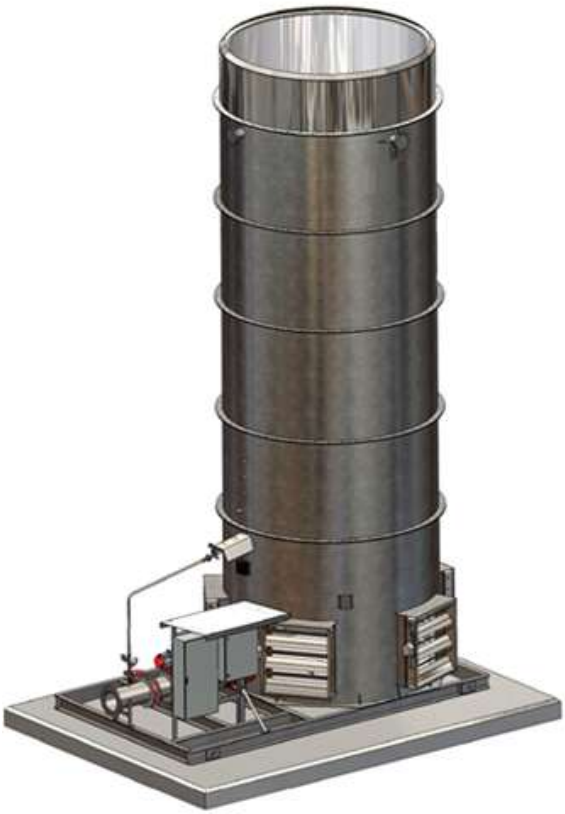


Figure 4.17: Indicative enclosed flare stack to be used during initial flow testing (not to scale).

4.9.2 Initial flow testing operation

101. Following the hydraulic fracturing injection period, the well will be opened at the surface to reverse the flow of the fracturing fluid. The purpose of this operation is to remove a portion of the injected hydraulic fracturing fluid from the reservoir to enable natural gas flow into the well.

102. To maintain full pressure control during the flowback process, and to prevent excessively high flowback velocities through the surface production equipment, the flow coming out of the well is passed through a device called a "choke manifold", which reduces the pressure downstream of the frac head to a safe operating level as fluid is removed from the well. After the pressure reduction the flow stream enters a high-volume test separator, the purpose of which is to separate the water from the natural gas, and also to remove small amounts of sand, solids and condensate that may be produced during the flowback. The water and natural gas flow rates are measured and recorded. Samples of each are periodically taken so that a full compositional analysis of the water and hydrocarbons can be obtained.

103. At some point the well will start to produce mainly natural gas, and diminishing volumes of flowback fluid. It is at this point when the initial flow test begins. This test will run for up to 90 days by burning the gas in the flare system to establish an initial production rate or "IP". If the findings are favourable, it may be followed by an extended flow test (as described below).

104. Natural gas produced during the initial flow test (but not extended flow test) will be burned via the two on-site enclosed flare stacks. Flaring of natural gas would only occur during this relatively short initial flow test period. Any further flowback fluid produced during this stage would be stored in tanks and periodically removed from Site for disposal at an Environment Agency approved permitted waste treatment facility.

4.10 Extended Flow Testing (EFT)

105. If flow rates indicate potentially viable flows and quantities of natural gas, a subsequent EFT period of between 18-24 months could be implemented.

106. The purpose of the extended flow test is to produce gas from the well for a longer period to gather data on the relationship between flow rates and well pressures, measure decline rates, and determine how much flowback fluid will be produced over time. This extended flow test data will contribute to an understanding of the reservoir and the predictability of the production performance. This data will also allow future well performance to be predicted, and this may be scaled up to estimate performance of a group of shale gas wells during any subsequent development phase.

107. In the event of EFT being undertaken, the resultant gas would be piped into the gas grid via a connection to the nearest main of appropriate size and pressure. This would eliminate the need for gas flaring. Additional equipment would be required to treat and regulate the pressure of the gas prior to connection to the gas grid, subject to the quality of gas produced.

4.10.1 Equipment for the EFT

108. At the Site the separation, dehydration and filtration plant and associated storage vessels will be located in the open areas of the well pad. The area required for this equipment will be approximately 25m x 17m. There will be a kiosk of size 6m x 3.5m which will house

gas quality monitoring, pressure control and energy measurement equipment. The process required to treat the gas before it enters the high pressure gas grid is described in Table 4.2.

Table 4.2. Treatment and monitoring processes required to connect to the gas grid

Process	Description
Separation	Volumes of sand and liquids will normally be produced from the well along with natural gas. Separation equipment will be used to separate out the gas, with sand, water and condensate being retained in separate vessels. These tanks will be emptied on a regular basis and the materials disposed of at an appropriately permitted facility via tanker transport.
Drying	After separation the gas will still be too wet for gas grid injection and, a dehydration process will be used to remove the remaining water from the gas.
Filtration	Subject to gas quality (determined in the initial flow test), the separated natural gas may need to be passed through an active carbon filter to remove impurities. The activated carbon material would be periodically replaced, typically twice a year dependent on the level of components being removed and size of activated carbon beds.
Gas Quality Monitoring	Measurements will be made to determine water and hydrocarbon dew points and other components (such as nitrogen) in order to comply with National Grid entry quality standards.
Energy Measurement and Adjustment	The natural gas will be continuously measured for flow rate and calorific value, together with gas quality monitoring, and pressure control. If necessary propane wil be added to meet National Grid's calorific requirements. A meter will be installed at the boundary of the well pad to measure the flow and quantity of gas produced at the Site.
Pressure Regulation	The pressure of the gas at the well head is estimated to be in excess of 75bar. Therefore a regulator will be installed to limit the pressure of the gas to 75bar prior to injection into the transmission network. After the pressure control there will be a Remotely Operable Valve (ROV) that will mark the boundary between the Cuadrilla system and the National Grid infrastructure.
Ancillary Equipment	A small flare will be fitted as part of the installation in order to enable safe operation of the facility in accordance with standard procedures. This flare would only be used in emergency conditions in order to avoid pressure build up above design conditions. It is noted that the gas well can be shut off at surface to control gas flow should this be required, therefore the flare is unlikely to be used.

4.10.2 Layout and connection to the gas grid

109. To allow connection to the gas grid two buried pipeline (depth of 1.2m and 6 inch diameter), will be laid. One will run parallel to the access track and connect to the gas grid pipeline running parallel to Preston New Road (approximately 200m long). The second pipeline will run west, parallel to Preston New Road to connect to a gas main to the west of the Site (approximately 800m long). At the connection points to the gas grid National Grid would require separate fenced area off areas of approximately 8m x 9m. These will contain a small kiosk (approximately 4m x 2m) containing telemetry and gas quality monitoring equipment. (See Appendix A Drawing PNR_EW_104).

4.11 Well servicing

110. During the initial flow testing and extended flow testing stages there may be need for occasional servicing of the well [well servicing]. A service rig, coil tubing unit and other equipment would be brought to Site to undertake this procedure. The well servicing visits

are unlikely to last more than a week and will only occur occasionally (see Appendix B for details).

4.12 Decommissioning and restoration

111. Once the exploration activities, described above (sections 4.3 to 4.11), have been completed, the well pad and associated surface works will either be taken on into production, subject to further consents and EIA, or decommissioned and restored to its current agricultural use.

112. Decommissioning and restoration would include the following activities:

- The well will be suspended, plugged and abandoned, the wellhead removed and the casing cut of at least 2.0 m below ground in accordance with regulatory requirements[31].
- Monitoring of the groundwater monitoring wells will continue following exploration well abandonment for a period agreed with the regulators, and subsequent decommissioning of the groundwater monitoring wells;
- Removal of remaining plant, equipment and temporary buildings;
- Removal of the surface array;
- Removal of the buried array surface features;
- The ditches would be emptied;
- All utilities would be disconnected and the layers of aggregate, high density poly ethylene membrane, geotextile and felt would be removed;
- If a connection to the gas grid has been constructed this would be removed up to the connection point to the gas grid and capped in accordance with any requirements from National Grid;
- Sub-soil stored on Site would be treated with selective herbicides, as appropriate, prior to placement on the site sub-grade;
- Topsoil stored on Site would be treated with selective herbicides, as appropriate, prior to placement on the replaced subsoils;
- Removal of Site boundary fencing; and
- Reinstatement of fences, gates and field drains.

4.13 Environmental management

4.13.1 Environmental Operating Standard (EOS)

113. Cuadrilla has produced an Environmental Operating Standard (EOS) document which will establish a framework to enable environmental impacts, risks and compliance arrangements for operational activities to be effectively managed (see Appendix E)..

114. A ‘Structure and Rationale’ version of the EOS has been prepared to accompany this ES which sets out the purpose and structure of the EOS. The EOS will be updated with specific measures required to meet the conditions of the various permits and the planning conditions.

[31] Offshore Installations and Wells (Design and Construction Etc) Regulations 1996 (DCR). Regulation 15.

4.13.2 Environmental monitoring

115. During the Project Cuadrilla will monitor a range of environmental parameters to allow them the effectively manage their operations. The following provides an overview of the aspects of the Project that that may be monitored:

- Seismicity (using the surface and buried arrays);
- Ambient air quality around the Site;
- Noise levels;
- Flowback fluid composition;
- Surface water and groundwater composition and concentrations;
- Ground gas composition and concentrations; and
- Fugitive gas emissions.

116. The monitoring parameters, frequency of sampling and dissemination of the data during operations will be confirmed once the planning and environmental consents are in place and agreed with the appropriate authorities.

5 Scheme alternatives

5.1 General

1. Schedule 4, Part 1 (2) of the EIA Regulations requires the ES to provide "*an outline of the main alternatives studied by the applicant or appellant and an indication of the main reasons for the choice made, taking into account the environmental effects*".

2. Unlike other types of mineral development where there are very narrowly defined locations for development, exploration sites could potentially be located at a variety of sites within Cuadrilla's exploration licence area. A systematic process has therefore been adopted to select the preferred sites for this stage of exploration.

5.2 Do nothing

3. A 'do nothing' option has been considered as an alternative to the Project. In this scenario it has been assumed that Cuadrilla would not undertake any exploration activities such as those proposed as part of the Project.

4. The 'do nothing' option would not provide Cuadrilla with data that would allow the potential commercial viability of shale gas reserves in the Lancashire area to be confirmed. In addition, a practical opportunity to understand the nature and extent of potential fracture propagation within the Bowland Shale would not be available, which would hinder the technical understanding of the viability of shale gas production in this area of the UK.

5. At the national level, uncertainty surrounds the difference between estimates of Gas-in-Place (i.e. the total amount of gas estimated to be present in the shale deposits) and the volume of commercially recoverable gas. The Site (in combination with the Site at Roseacre Wood) would be the first opportunity in the UK to reduce this uncertainty and provide specific UK shale gas flow data, and thus represents a proposal of national importance.

6. Furthermore the exploration of shale gas is supported by the Government through measures such as tax allowances to support early investment for shale gas[32]. The Project (and the proposed exploration works at Roseacre Wood) will also contribute towards addressing one of the concluding points in the UK Gas Generation Strategy published by DECC[33]. The Strategy concludes (paragraph 5.24) in respect of shale gas:

   "If it can be shown to be economic and safe, domestic shale gas production could offer a significant economic opportunity for the UK, with the prospect of new sources of indigenous supply, new industrial activity and skilled jobs."

7. In the context of the above, the 'do nothing' option is not considered to be appropriate.

5.3 Exploration requirement

8. Cuadrilla require gas flow and quality data from up to eight wells in order to provide sufficient data to confirm the commercial viability of shale gas extraction in this area of the Fylde. A strategy based on two well pads with up to four wells from each was

[32] Chancellor George Osborne budget speech (20th March 2013).
[33] DECC, Gas Generation Strategy, 5th December 2012.

selected. By drilling a number of wells from one site, different strata within the shale can be explored for natural gas.

9. By testing from two well pads, valuable data will also be gained on the productivity of different parts of the licence area. Understanding the variability in production across a licence area is an important consideration in determining the commercial viability of production.

5.4 Site Selection

10. The selection of the proposed Sites has considered geological, environmental, community, land ownership and other technical factors in a staged manner. This process has considered the use of the existing "part-developed" sites at Anna's Road, Becconsall, Preese Hall and Grange Hill, as well as the development of new exploration sites.

11. The first stage involved a detailed understanding of the geological conditions to identify areas of suitable geology. The second stage involved identifying features and receptors which were avoided for this stage of the exploration programme. The final stage has involved identifying a site within the area that remain based on a wide range of environmental, technical and land/ property related issues.

5.4.1 Stage 1: Identifying areas of suitable geology

12. The principal objective of this project is to determine the commercial viability of shale gas extraction in the Fylde. Geological factors including the properties of the shale, (depth, thickness, orientation, continuity) and location of faults within the rock all influence the effectiveness of the drilling and hydraulic fracturing operations. Geological considerations are therefore fundamental in selecting a suitable site for exploration.

13. The Bowland Basin, below the Flyde, is one of the thickest deposits of shale in the UK and therefore represents a suitable location for exploration. Available geological mapping information, 2-D seismic data and information from existing borehole records (including Hesketh-1 (near Southport), the Elswick production well and an existing exploratory borehole at Thistleton) helped inform the locations for Cuadrilla's initial exploration sites within their licence area (Anna's Road, Becconsall, Preese Hall and Grange Hill).

14. Following the two tremors which occurred after hydraulic fracturing at Preese Hall, more detailed geological information has been obtained from the 3D geophysical survey (see Figure 1.3 for the extent of this area). This data has been processed to identify suitable areas for this next phase of exploration. By locating the wells to avoid hydraulically fracturing near regional faults, together with using real time monitoring (the "Traffic Light System") to control operations, the risk of inducing a felt seismic event can be reduced considerably.

15. Cuadrilla's aim for this stage of exploration is to undertake drilling and hydraulic fracturing operations in areas of relatively consistent geology – areas of relatively flat lying (horizontally bedded), continuous and thick sections of Bowland Shale. By targeting these areas horizontal drilling can be performed through a consistent shale "zone", and, by using the buried array to monitor fracture growth, the performance of the hydraulic fracturing process can be accurately assessed and optimised.

16. With data from areas of relatively consistent geology, Cuadrilla will be able to refine the hydraulic fracturing process to enable future exploration or production to be undertaken

in areas of more complex geology – for example, areas with dipping (inclined) strata- which will be helpful to facilitate exploration and production activities over a wider area.

17. Using the process outlined above, two areas were identified within the 3D geophysical survey coverage with relatively shallow, flat-lying shale – one to the south of Roseacre, the other to the west of Little Plumpton.

5.4.2 Stage 2: Identification of Tier 1 environmental constraints

18. Within the two areas of search defined by the geology, two sets of environmental constraints were analysed to guide the selection of appropriate sites. The first (tier 1) consisted of features or receptors, set out in Table 5.1, that would be avoided for this stage of the exploration programme.

Table 5.1 Tier 1 criteria.

Sensitive feature or receptor
Existing and proposed European and national designations (for example Special Protection Areas, Sites of Special Scientific Interest).
Nationally designated heritage assets including: listed buildings, Scheduled Monuments, Registered Parks and Gardens, Registered Battlefields and World Heritage Sites.
Groundwater Source Protection Zone 1.
Flood Risk – avoiding flood risk zone 3b.

5.4.3 Stage 3: Identification of Tier 2 environmental constraints

19. Following the assessment described above for Tier 1 technical specialists undertook desk based studies and site visits to collect further information to assess the factors in Table 5.2 which have influenced the decision on the final site locations in order to select locations less likely to result in significant environmental effects.

Table 5.2 Tier 2 criteria.

Site Selection Criteria	Approach
Connections	
Highway routes and access	A review of the existing road network and access arrangements was undertaken to identify locations where it would be suitable to use an existing access or create a new access to an exploration site.
Utilities	Areas were identified where there is potential to connect to existing utilities networks (principally potable water supply and gas).
Environmental Constraints	
Cultural heritage	All heritage assets identified via the historic environmental record were mapped and reviewed.
Landscape character	Landscape character areas were mapped and considered in regard to the location of exploration well sites and the County's Landscape Strategy.
Visual impact	A broad zone was used to establish the area in which the exploration well sites may be visible.
Protected species	Data was collected from site walkovers, surveys and existing ecological records were reviewed.
Non-designated sites/valuable habitat	Non-designated sites and valuable habitats were defined and reviewed for each site.

Site Selection Criteria	Approach
Agricultural land quality	Information on agricultural land classifications (i.e. 1, 2, 3a and 3b) was reviewed.
Proximity to housing and other sensitive uses	Residential properties and other sensitive uses were considered and the distance from these uses was taken into account.
Light pollution	The potential for light pollution was considered for each zone taking into account the topography of the site, existing barriers and sensitive receptors.
Noise	A more detailed consideration of noise was undertaken for each zone, taking into account existing noise levels, potential noise barriers and distance from residential properties and sensitive receptors.
Air quality	The potential for air quality impacts was considered taking into account air quality management designations and sensitive receptors.
Water resources, flood risk and drainage	Proximity to watercourses, wetlands and ponds, and the potential for future development of groundwater resources was considered. Flood risk issues and drainage requirements were also considered
Planning Constraints	
Local planning policy	The Development Plan allocations and planning designations were identified
Land Ownership Issues	
Potential to secure a lease from the landowner	The likelihood of using the land for the purpose of an exploratory well was determined based on discussions between Cuadrilla and the land owners.

20. The two exploration sites selected for this phase of the exploration are at Roseacre Wood and Preston New Road. These sites were preferred in light of the criteria described above.

5.5 Alternative sites not selected

21. Cuadrilla currently has four sites related to exploration of shale gas in the Fylde study area, developed and drilled prior to suspension of activities in early 2011. These sites – Grange Hill (near Singleton) Preese Hall (Weeton), Becconsall (near Banks) and Anna's Road all comprise a fenced area containing a consolidated aggregate surface, earth bund, drainage channels, and drilling cellar(s). These have been considered for further development alongside the proposed Sites.

5.5.1 Grange Hill

22. Following analysis of the 3D geophysical survey information, the Grange Hill site near Singleton does not have the geological characteristics (as described in section 5.4.1) for this phase of the exploration. Local faulting and folding structures limit the volume of continuous, horizontally bedded shale. Furthermore, the existing well pad would require extending to allow up to four wells to be drilled and hydraulically fractured.

23. Cuadrilla are currently seeking temporary planning permission, for three years, to retain the existing site compound and access track, to monitor reservoir pressure and seismicity, prior to plugging and abandoning the existing exploratory well and fully restoring the site.

5.5.2 Preese Hall

24. The Preese Hall site was drilled and hydraulically fractured in 2010, following which two tremors occurred. This triggered the suspension of operations. and the site was cleared of all superstructures, operational equipment and ancillary accommodation.

25. Due to the geological characteristics at the site it has been decided that further exploration works will not be undertaken at this location. Instead the well will be plugged and cut off below ground level and the well pad removed so that the land can be restored and returned to agricultural uses.

5.5.3 Anna's Road

26. Anna's Road is located in a Biological Heritage Site, and is close to internationally designated conservation areas of Morecambe Bay. The presence of winter resting areas for important species of birds, would restrict drilling and hydraulic fracturing activities to a relatively narrow period. For these reasons, this site is not proposed for this phase of exploration and will be restored during the summer of 2014.

5.5.4 Becconsall

27. The Becconsall site is located outside of the 3D geophysical survey area. For this reason there is insufficient geological data to progress exploration on this site at this time.

28. A planning application was submitted to LCC on the 25th March 2014 to allow perforations to be made in the well casing and pressure monitoring equipment to be installed for 12 months in the existing well. At the end of this period the equipment will be removed. The well will then be plugged and abandoned and the site restored.

5.6 Layout and Site arrangement

29. The wells will be located towards the middle of the Site so that plant and equipment can be easily accessed. Site accommodation (offices, welfare facilities, data room and equipment stores) will be located around the periphery of the Site to allow a safe working area around the wells.

30. Parking for staff and visitors will be located close to the Site entrance to minimise the risk of damage by moving vehicles to static equipment, accommodation and people. Similarly, there would be a designated delivery area, located away from sensitive equipment to minimise the risks from heavy good vehicles moving around the Site.

31. The location for the flares have been selected to be distant from hedgerows. This will help to minimise the impact on species of wildlife.

32. In the context of the above factors, and the fact that the activities at the Site are temporary, no further internal site layout options have been developed.

5.7 Highway access routes

5.7.1 Overview and preferred route

33. The Site is located immediately adjacent to the A583 Preston New Road. It has been demonstrated through traffic surveys that this road currently carries high traffic volumes

in the order of 13,000 vehicles per day (see Appendix R for details). The additional traffic generated by this development would not represent a material increase in traffic. In percentage terms, this represents an increase of less than 1%.

34. Similarly, Preston New Road is a primary route designed to accommodate HGV movements. The road currently carries over 300 HGV movements per day. The additional HGV movements generated by the Site will not have an observable impact upon the composition of traffic on Preston New Road.

35. Preston New Road is therefore considered to represent a suitable route for HGV and other site traffic to use to access the strategic road network (SRN). The SRN can be accessed at either Junction 3 or Junction 4.

5.7.2 Access from junction 4 of the M55

36. Junction 4 would be accessed using only Preston New Road. It would require vehicles to turn left into the site and right out of the site. The additional traffic on this section of Preston New Road is not considered to impact upon any residential communities as it would be using a road that already carries high traffic volumes.

5.7.3 Access from junction 3 of the M55

37. Junction 3 would be accessed using Preston New Road and the A585 Fleetwood Road. It would require vehicles to turn right into the site and left out of the site. The additional traffic on this section of Preston New Road is not considered to impact upon any residential communities as it would be using a road that already carries high traffic volumes. Similarly, the A585 is a busy primary road and there would be no observable impact upon any residential communities. The junction between Preston New Road and the A585 is a large roundabout that is designed to accommodate HGV turning movements.

38. It is therefore considered that a route to Junction 4 (via Preston New Road) and a route to Junction 3 (via Preston New Road and the A585 Fleetwood Road) could both be used.

5.8 Exploration methodology

39. Hydraulic fracturing is the only known and tested commercially viable method that can be used to determine gas flow rates from low permeability rock such as shale. As a result no alternative methodologies or technologies are available for consideration.

6 Air Quality

Chapter Summary- Air Quality

This chapter assesses the potential for the Project to emit pollutants into the air. It does this by predicting the likely changes in pollutant concentrations as a consequence of the Project. These are then compared to air quality objectives and limit values for these pollutants to determine whether the predicted changes are significant.

The area in which the Site is situated is rural and not densely populated. There are no existing significant sources of emissions to the atmosphere. Likewise, there are no areas within the vicinity of the Site where there is an existing problem with air quality or pollution.

The main source of atmospheric pollutants from the Project are the gases that are emitted when gas is burnt in the flare. The assessment quantifies the amount of nitrogen dioxide, benzene and radon that could be emitted from the flare and how it would be dispersed using weather data for the prevailing wind directions. This assessment concludes that for all of the above gases the concentrations that could be emitted from the flare are well below the level where a significant effect would be identified. An additional assessment of the potential for the Project to generate dust has also been assessed. This concluded that there is a low risk of the Project creating dust and as a result is not a significant effect.

The only mitigation measures required are standard dust control measures that are used during construction of the access track, well pad and the installation of the connection to the l national transmission system. These will be sufficient to manage the risk of the Project generating dust that could adversely affect vegetation or nearby properties.

The Preston New Road and Roseacre Wood Sites are sufficiently distant from one another that their combined impacts on air quality will not result in a greater combined effect than individually.

6.1 Introduction

1. This Chapter assesses the likely significant effects of the Project on air quality. Air quality impacts can arise when there are emissions of pollutants into the atmosphere. This section therefore examines the Project, and identifies those processes that could result in atmospheric emissions. The impacts of these emissions are then assessed using various tools such as dispersion modelling to assess the likely changes in pollutant concentrations. The significance of these changes is then determined by reference to UK air quality objectives and limit values and appropriate guidance documents.

6.2 Key Development Issues

2. The exploration works have five main activities that will result in emissions to the atmosphere, these are:

- Emissions from construction activities;
- Emissions from the vehicles associated with the use of the Site;
- Emissions from the flaring of gas during flow testing;
- Emissions from equipment associated with the operation of the Site (e.g. generators, pumps and blenders); and

- Emissions from fugitive emissions.

3. Emissions from construction activities can also include fugitive dust. Operational activities such as on-site diesel generators produce nitrogen oxides and particulate matter as the main pollutants of concern. Vehicle emissions are a source of nitrogen oxides and particulate matter. The key pollutant emitted from the flares are nitrogen oxides. Benzene has also been considered in the assessment of the flare emissions as this was requested. There is also potential for radium to be present in the returned waters to de-gas and this would result in radon emissions from the flare. Uncontrolled fugitive emissions may give rise to volatile organic compounds (VOCs) and odours.

6.3 Scoping and Consultation

4. During the scoping phase, consultations were made with the following local authorities as listed in Table 6.1.

Table 6.1. Preston New Road scoping and consultation overview.

Consultee	Nature of request	Response
Lancashire County Council	Assessment of air emissions should include an assessment of the impacts on air quality management areas.	Air quality management areas (AQMAs) have been identified in the assessment. There are no AQMAs within Fylde Borough however one AQMA has been formed within Wyre Borough and Blackpool,. Due to the distance from the Site and predicted level of emission emitted no further assessment was required.
	The measures to control emissions should be described and demonstrate that guideline levels or health based values will not be exceeded.	The emission of NO_2, particulates and radon gas have been assessed against guideline levels or health based values.

5. In addition to this the Environmental Health department at Fylde Borough Council was contacted on 04/03/2014 by telephone and the proposed methodology of assessment was discussed. The proposed methodology was agreed with the environmental health officer (EHO) and an email was sent confirming the conversation (see Appendix F). No replies to this email were received with regards to any further comments.

6. During the public consultation events concerns have been raised by residents about pollutants such as volatile organic compounds (VOCs) and benzene in particular. Following these events additional air quality modelling has been undertaken to forecast the potential emission of benzene from the Project (see section 6.4.5.3).

6.4 Methodology

6.4.1 Legislation and Policy

7. In 1996, the European Commission published the Air Quality Framework Directive on ambient air quality assessment and management (96/62/EC). This Directive defined the policy framework for 12 air pollutants known to have harmful effects on human health and the environment. Limit values (pollutant concentrations not to be exceeded by a

certain date) for each specified pollutant are set through a series of Daughter Directives, including Directive 1999/30/EC (the 1st Daughter Directive) which sets limit values for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and oxides of nitrogen (NO_x), particulate matter less than 10 microns in size (PM_{10}) and lead in ambient air.

8. In May 2008, the Directive 2008/50/EC on ambient air quality and cleaner air for Europe came into force. This Directive consolidates the above (apart from the 4th Daughter Directive, which will be brought within the new Directive at a later date), provides a new regulatory framework for particulate matter less than 2.5 microns size ($PM_{2.5}$) and makes provision for extended compliance deadlines for NO_2 and PM_{10}.

9. In a parallel national process, the Environment Act was published in 1995. The Act sets out objectives for specified pollutants and outlines measures to be taken by local authorities through the system of Local Air Quality Management (LAQM) and by others "to work in pursuit of achievement" of these objectives. A National Air Quality Strategy (NAQS) was published in 1997 and subsequently reviewed and revised in 2000, as the Air Quality Strategy for England, Scotland, Wales and Northern Ireland and an addendum to the Strategy was published in 2003. The current Air Quality Strategy for England, Scotland, Wales and Northern Ireland was published in July 2007.

10. The above European Directives, 2008/50/EC and the 4th Daughter Directive, were transposed into legislation in England by the Air Quality Standards Regulations 2010. The Secretary of State for the Environment has the duty of ensuring the air quality limit values are complied with.

6.4.1.1 European Habitats Directive

11. European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora requires member states to introduce a range of measures for the protection of habitats and species. The Conservation of Habitats and Species Regulations 2010 No. 490 transposes the Directive into law in England and Wales.

12. The Habitats Directive requires the competent authority, which in this case would be the planning authority, to firstly evaluate whether the Site is likely to give rise to a significant effect on the European site. Where this is the case, it has to carry out an 'appropriate assessment' in order to determine whether the Site would adversely affect the integrity of the European site.

6.4.1.2 Air quality limit values and objectives

13. Air quality limit values and objectives are quality standards for clean air, which can be used as assessment criteria to determine potential changes in local air quality resulting from a development.

14. Some pollutants have standards expressed as annual average concentrations owing to the chronic way in which they affect health or the natural environment (i.e. effects occur after a prolonged period of exposure to elevated concentrations) and others have standards expressed as 24-hour, one-hour or 15-minute average concentrations owing to the acute way in which they affect health or the natural environment (i.e. after a relatively short period of exposure). Some pollutants have standards expressed in terms of both long-term and short-term concentrations. Table 6.2 sets out these EU and UK air quality limit values for the pollutants of greatest concern to human health for this assessment.

Table 6.2 Air quality objectives and limit values.

Pollutant	Averaging Period	Limit Value/Objective	Date for Compliance	Basis
Nitrogen dioxide (NO_2)	1 hour mean	200 µg/m^3, not to be exceeded more than 18 times a year (99.8th percentile)	31 Dec 2005	UK
			01 Jan 2010	EU
	Annual mean	40 µg/m^3	31 Dec 2005	UK
			01 Jan 2010	EU
Particulate Matter (PM_{10})	Annual mean	40µg/m^3	11 June 2010	UK
			01 Jan 2005	EU
	24-hour mean	50µg/m^3	11 June 2010	UK
		not to be exceeded more than 35 times a year (90.4th percentile)	01 Jan 2005	EU
Benzene	Running annual mean	16.25µg/m^3	31 Dec 2003	UK
	Annual mean	5µg/m^3	31 Dec 2010	EU

15. In the majority of cases the air quality limit values for the EU and UK have the same pollutant concentration threshold and date for compliance. The UK limit values also have the same pollutant concentrations as set out in the NAQS. The key difference is that the Secretary of State for the Environment is required under European law to ensure the air quality limit values are complied with, whereas LPAs are only obliged under national legislation to undertake best efforts to comply with the air quality objectives set out in the NAQS. To assist LPAs in demonstrating best efforts, the Environment Act 1995 requires that when carrying out their local air quality management functions, LPAs shall have regard to guidance issued by the Secretary of State.

16. There are specific objective pollutant concentrations for vegetation called 'critical levels'. These are concentrations below which harmful effects are unlikely to occur and are summarised in Table 6.3.

Table 6.3 Vegetation and ecosystem critical loads.

Pollutant	Time period	Objective
Nitrogen oxides (expressed as NO_2)	Annual Mean (objective)	30µg/m^3
	Daily Mean (guideline)	75µg/m^3

6.4.1.3 Radon Gas Criteria

17. The International Commission on Radiological Protection (ICRP)[34] has set a dose constraint of 300 microSv/yr for a single source. This has been used as the level above which a significant effect would be assessed.

6.4.1.4 Dust Nuisance Criteria

18. Dust is the generic term used in the British Standard document BS 6069 (Part Two) to describe particulate matter in the size range 1–75µm in diameter. Dust nuisance is the

[34] ICRP (1993) Board Statement on the 1990 Recommendations of the ICRP. Doc NRPB 4 (1)

result of the perception of the soiling of surfaces by excessive rates of dust deposition. Under provisions in the Environmental Protection Act 1990[35], dust nuisance is defined as a statutory nuisance.

19. There are currently no standards or guidelines for dust nuisance in the UK, nor are formal dust deposition standards specified. This reflects the uncertainties in dust monitoring technology and the highly subjective relationship between deposition events, surface soiling and the perception of such events as a nuisance. In law, complaints about excessive dust deposition would have to be investigated by the local authority and any complaint upheld for a statutory nuisance to occur. However, dust deposition is generally managed by suitable on-site practices and mitigation rather than by the determination of statutory nuisance and/or prosecution or enforcement notice(s).

6.4.1.5 Institute of Air Quality Management Guidance on the Assessment of Dust from Demolition and Construction (2014)

20. The Institute of Air Quality Management (IAQM) guidance[36] was produced in consultation with industry specialists and the Greater London Authority (GLA) and gives guidance to development consultants and EHO on how to assess air quality impacts from construction. The IAQM guidance provides a method for classifying the significance of effect from construction activities based on the magnitude of dust impact (high, medium or low), proximity of the site to the closest receptors and the background PM_{10} concentration. It also suggests criteria for the classification of dust classes to be used along with professional judgement. The guidance recommends that once the significance of effect from construction is identified, the appropriate mitigation measures are implemented. From experience it is noted that once mitigation measures are applied the effects are reduced to negligible levels.

6.4.1.6 Environmental Protection UK Guidance (2010)

21. The 2010 Environmental Protection UK (EPUK) guidance note Development Control: Planning for Air Quality[37] responds to the need for closer integration between air quality and development control. It provides a framework for air quality considerations within local development control processes, promoting a consistent approach to the treatment of air quality issues within development control decisions.

22. This document updates the guidance originally published by EPUK (formerly known as the National Society for Clean Air and Environmental Protection) in November 2004 (and subsequently revised in September 2006). The guidance has been widely used by local authorities, air quality consultants and developers.

23. The guidance includes a method for assessing the significance of the impacts of development proposals in terms of air quality and how to make recommendations relevant to the development control process in light of this assessment. The need for early and effective dialogue between the developer and local authority is identified to allow air quality concerns to be addressed as early in the development control process as possible. The guidance also provides some clarification as to when air quality constitutes a material

[35] Environmental Protection Act 1990, Chapter 43, Part III Statutory Nuisances and Clean Air
[36] IAQM (2014) Guidance on the Assessment of dust from construction and demolition
[37] Environmental Protection UK (2010) Development Control: Planning for Air Quality

consideration in the planning decision process. The tables outlining the assessment process are provided in the appendix to this chapter.

24. The EPUK guidance provides a set of factors that determine the significance of a proposal in terms of air quality (Appendix F, Table A.3), stating that these factors (allowing professional judgement to be made) should be given weighting equal to the flowchart determination method described below. These factors should be considered, before a suitably qualified professional can determine with sufficient justification whether the overall significance of a potential development should be termed insignificant, minor, moderate or major.

25. A second approach is also detailed in the EPUK document that provides guidance on the priority that air quality issues should be given in the planning process. This approach is based around a flowchart (Appendix F), which assumes air quality impacts have been assessed and quantified. The priority which air quality should be afforded in the planning process is then determined through a series of questions with closed (yes/no) answers. Each question is addressed in descending order until the arrow points to one of the outcomes in the right hand column.

6.4.1.7 National Planning Policy Guidance

26. As part of the NPPF, planning practice guidance on various topics was recently published[38]. In relation to air quality, the guidance refers to the significance of air quality assessments to determine the impacts of proposed developments in the area and describes the role of local plans with regard to air quality. It also provides a flowchart method to assist local authorities in determining how considerations of air quality fit into the development management process, this flow chart is provided in Appendix F.

6.4.1.8 Environment Agency H1 Guidance

27. The Environment Agency (EA) H1 Annex F – Air Emissions[39] provides guidance on the assessment of industrial emissions in the UK. The guidance is part of the EA horizontal guidance for all sectors regulated under the environmental permitting regulations (EPR).

28. The guidance takes a risk based approach for actions which may have an effect on the environment. For air quality this involves screening the emissions from the activity against the criteria set out in the guidance.

29. The Environment Agency, in its H1 Guidance[40] states that air quality impacts can be considered to be insignificant if:

- The annual mean process contribution is less than 1% of the long term environmental standard; and
- The short term (1 hour mean) process contribution is less than 10% of the short term environmental standard.

30. Where emissions exceed these criteria detailed modelling is recommended.

[38] http://planningguidance.planningportal.gov.uk/blog/guidance/air-quality/ [accessed April 2014]
[39] Environment Agency H1 Guidance – Annex F Air emissions - 2011
[40] Environment Agency (2011) Horizontal Guidance Note H1

6.4.2 Baseline methodology

31. The study area for the assessment is a 10km radius from the centre of the Site. This is based on the screening distance for nature conservation sites required in the Environment Agency's H1 guidance[41]. The assessment has shown that area is more than sufficient to identify all potentially significant impacts.

32. Baseline air quality has been determined by collating information produced by Defra and by the local authorities in the area. Defra provide estimates of background air quality for the UK for every 1km grid square on the LAQM website[42] for both NO_2, fine particulate matter (PM_{10}) and benzene. The information is also available for future years based on predicted changes in air quality in the UK.

33. Local authorities are required to regularly review air quality in their administrative areas to determine whether air quality objectives are likely to be exceeded. As part of their duties they will carry out air quality monitoring to measure actual levels in their areas and determine whether concentrations comply with the air quality objectives. Where there is a risk that air quality objectives may be exceeded, they will carry out a more detailed assessment often using air quality modelling tools to predict concentrations of pollutants. These assessments have been used to provide further information on baseline air quality for this study.

6.4.3 Assessment methodology for the effects of dust from construction

34. The construction effects have been assessed using the qualitative approach described in the IAQM guidance[36] and mitigation measures proposed where necessary.

35. The IAQM guidance considers the potential for dust emissions from the following activities:

    - Demolition;
    - Earthworks i.e. soil stripping, ground levelling, excavation and land;
    - Construction; and
    - Trackout incidental movement of dust and dirt from the construction or demolition site onto the public road network, by vehicles.

36. For each of the above activities, the guidance considers three separate dust effects:

    - Annoyance due to dust soiling;
    - Harm to ecological receptors; and
    - The risk of health effects due to a significant increase in PM_{10} exposure.

37. The methodology takes into account the scale to which the above effects are likely to be generated (classed as small, medium or large). Also the distance of the closest receptors and background PM_{10} concentrations are taken into account in order to determine the sensitivity of the surrounding area. This is then taken into consideration to derive an overall site risk and identify suitable mitigation measures. The receptors can be both

[41] Environment Agency (2011) Horizontal Guidance Note H1 Overview Document, Environment Agency
[42] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

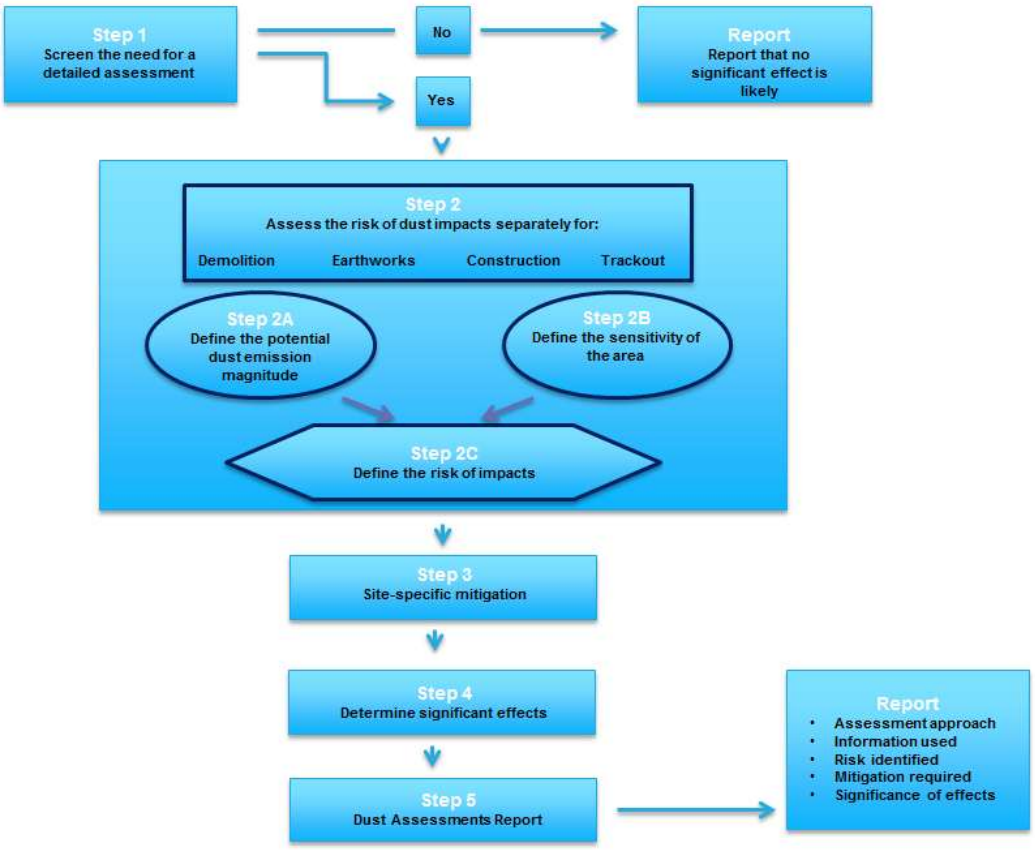
human or ecological and are chosen based on their sensitivity to dust soiling and PM_{10} exposure.

38. The four assessment steps are summarised in Figure 6.1 with further description of each step in the following sections.

Step 1: Screen Need for Assessment

The first step is the initial screening for the need for an assessment. According to the IAQM guidance, an assessment is required where there are sensitive receptors within 350m of the site boundary and/or within 50m of the route(s) used by the construction vehicles on the public highway and up to 500m from site entrance. The guidance notes that these distances are indicative and the use of professional judgement is encouraged; it is likely that some developments may need the use of greater separation distances.

Figure 6.1 IAQM construction dust assessment methodology.



Step 2: Assess the Risk of Dust Arising from the Works

39. This step is divided into three sections, 2A, 2B and 2C, details of which are provided below.

40. **Step 2A** - Identifies the scale and nature of the works, which determines the potential dust emission magnitude as small, medium or large.

41. For this step, a description of the site and its surroundings has been collated to inform the overall significance and professional judgement. Each of the construction activities has been given a dust emission magnitude, based on the criteria shown in (Appendix F).

42. **Step 2B** – defines the sensitivity of the area to dust impacts which is defined as low, medium or high sensitivity.

- This step takes into account a number of factors:
- The specific sensitivities of receptors in the area;
- The proximity and number of those receptors;
- In the case of PM_{10} the local background concentrations; and
- Site-specific factors, such as whether there are natural shelters, such as trees, to reduce the risk of wind-blown dust.

43. The sensitivity of an area is based on the guidance and professional judgement. The general principles to assess sensitivity are provided in (Appendix F).

44. Once the specific receptors have been identified the sensitivity of these receptors is determined based on the sensitivity of the area to dust soiling effects on people and property and on the sensitivity of the area to human health impacts. The tables used in assessing these sensitivities are shown in Table 6.4 and Table 6.5.

Table 6.4 Sensitivity of the area to dust soiling effects on people and property.

Receptor Sensitivity	Number of receptors	Distance from the Source (m)			
		<20	**<50**	**<100**	**<350**
High	>100	High	High	Medium	Low
	10-100	High	Medium	Low	Low
	1-10	Medium	Low	Low	Low
Medium	>1	Medium	Low	Low	Low
Low	>1	Low	Low	Low	Low

Table 6.5 Sensitivity of the Area to Human Health Impacts.

Receptor Sensitivity	Annual Mean PM_{10} concentration	Number of receptors	Distance from the Source (m)				
			<20	**<50**	**<100**	**<200**	**<300**
High	>32 µg/m^3	>100	High	High	High	Medium	Low
		10-100	High	High	Medium	Low	Low
		1-10	High	Medium	Low	Low	Low
	28-32 µg/m^3	>100	High	High	Medium	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	High	Medium	Low	Low	Low
	24-28 µg/m^3	>100	High	Medium	Low	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	Medium	Low	Low	Low	Low
	<24 µg/m^3	>100	Medium	Low	Low	Low	Low
		10-100	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low

Receptor Sensitivity	Annual Mean PM_{10} concentration	Number of receptors	Distance from the Source (m)				
			<20	<50	<100	<200	<300
Medium	-	>10	High	Medium	Low	Low	Low
	-	1-10	Medium	Low	Low	Low	Low
Low	-	>1	Low	Low	Low	Low	Low

45. **Step 2C** – takes the results from step 2A and 2B and combines these to define the risk of impacts.

The guidance provides the matrices with which the risk of dust impacts can be defined from the results of both the dust magnitude and sensitivity of the area. The matrices for assessment are provided in Table 6.6.

Table 6.6 Risk of Dust Impacts.

Sensitivity of Area	Dust Emission Magnitude		
	Large	Medium	Small
Demolition			
High	High Risk Site	Medium Risk Site	Medium Risk Site
Medium	High Risk Site	Medium Risk Site	Low Risk Site
Low	Medium Risk Site	Low Risk Site	Negligible
Earthworks			
High	High Risk Site	Medium Risk Site	Low Risk Site
Medium	Medium Risk Site	Medium Risk Site	Low Risk Site
Low	Low Risk Site	Low Risk Site	Negligible
Construction			
High	High Risk Site	Medium Risk Site	Low Risk Site
Medium	Medium Risk Site	Medium Risk Site	Low Risk Site
Low	Low Risk Site	Low Risk Site	Negligible
Trackout			
High	High Risk Site	Medium Risk Site	Low Risk Site
Medium	Medium Risk Site	Low Risk Site	Negligible
Low	Low Risk Site	Low Risk Site	Negligible

46. In terms of the EIA Regulations a significant effect from dust emissions is assessed as a site with a medium or greater risk of generating dust. However, in line with the IAQM guidelines dust mitigation measures will be implemented relative to the risk level that has been assessed regardless of whether or not it is a significant effect from the perspective of the EIA Regulations.

Step 3: Determine Site Specific Mitigation (if Required)

47. Following assignment of a risk impact rating to each of the activities, appropriate mitigation measures have been identified. Where the risk has been assessed as negligible, no mitigation measures beyond those required by legislation, such as UK environmental legislation and work place legislation, are necessary.

Step 4: Define Risks of Effects and their Significance

48. Once the appropriate mitigation measures have been identified in Step 3 remaining significant effects may still exist. For all construction activity the aim should be to prevent significant impacts on receptors through the use of effective mitigation. Experience shows this is normally possible. Hence the residual effect will normally be 'not significant'.

6.4.4 Assessment methodology for the effects from installation of surface network and buried array

49. A desk based study will review vehicle movements and earth working activity with regards to any potential impacts based upon the criteria set out in the road traffic impacts section below and the dust impacts section set out above.

6.4.5 Assessment methodology for operational effects

50. As mentioned air quality impacts from operational effects will come from four main sources; the emissions from the vehicles associated with the use of the site, emissions from equipment, emissions from the flaring of gas and fugitive emissions.

51. The first two of these effects will take place throughout all well operations and are not attributed to a particular stage of well development. The flaring of gas is associated with the flow testing stage of development. Fugitive emissions would result in any uncontrolled gas releases, however such emission are not planned. Measures will be adopted to avoid fugitive emissions. The approach to the assessment of each of these sources is detailed below.

52. A significant effect, as defined by the EIA Regulations, will be where the relevant guideline or limit value is exceeded.

6.4.5.1 Drilling

53. During drilling, the main activities that could give rise to atmospheric emissions are vehicle movements and on-site equipment. This section therefore describes the methodology to assess emissions from vehicles emissions and from site equipment although as mentioned these are applicable to these activities in all phases of the development.

Road traffic impacts

54. To assess the impacts from road traffic an initial screening exercise has been undertaken that examines the likely changes in vehicle numbers on the road and compares these with criteria from the Design Manual for Roads and Bridges (DMRB) to determine whether a quantitative assessment is required. If these criteria are not exceeded then no significant air quality impacts are likely. The two criteria used are:

- A change in daily traffic flows by 1,000 Annual Average Daily Traffic (AADT) or more; or
- A change in heavy duty vehicle flows by 200 AADT or more.

55. If one of these criteria is met, then a further assessment is undertaken for the two key traffic-related pollutants namely nitrogen dioxide (NO_2) and fine particulate matter (PM_{10}). This further assessment would use the air quality screening tool (described in the Design Manual for Roads and Bridges, Volume 11, Section 3) to predict pollutant concentrations at sensitive receptors for the opening year with and without the development in place.

Generator and site equipment impacts

56. Cuadrilla has provided details of equipment that will be used at the Site, i.e. pumps, fracturing water transfer pumps, generators, blender units and service rigs. The equipment will be used during the drill phases for the duration of the drilling. During the hydraulic fracturing the engines will be run for only a few hours at a time. Given the size of the generators and engines and the relatively short period of operation, these sources have been scoped out of the assessment. A table summarising the generators used on site is provided in Appendix F.

6.4.5.2 Hydraulic Fracturing

57. During this phase of the development the activities likely to give rise to atmospheric emissions are vehicle movements and on-site equipment. The methods used to assess vehicle emissions and emissions from site equipment have already been described above. The generators used during hydraulic fracturing operate for only a few hours per day during operation.

6.4.5.3 Initial Flow Testing

58. During initial flow testing, emissions to the atmosphere will arise from vehicle movements, on-site equipment and flaring. The methods for assessing impacts from vehicles and on-site emissions have already been described. The impact from the emissions from flares is described below.

Flare impacts

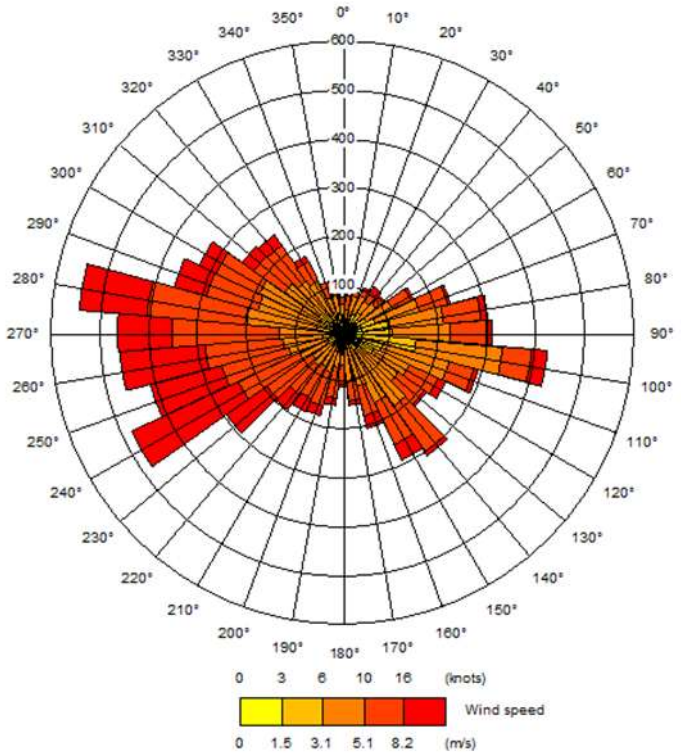
59. The assessment of the likely impact from emissions from the flares has been assessed using an air dispersion model known as ADMS 5. This is a well-established model widely used in the UK and is a type of model known as a “new generation” dispersion model favoured by the EA.

60. The model requires information on pollutant emissions which for NO_x have been obtained using information from the European Emissions Inventory Guidebook[43]. Emission rates for nitrogen oxides have been calculated as this is the pollutant of most significance to human and ecological health. Emissions of benzene have also been included in the model due to concerns about this pollutant being raised in the consultation stage. Emissions of benzene have been calculated based on the gas composition identified at Preese Hall well site (gas composition is provided in the Appendix F) and a flare combustion efficiency of 98%. The data from Preese Hall only details composition as C_6 (and greater). As a worst case, all C_6 and greater compounds have been assumed to be benzene.

[43] EMEP-EEA air pollutant emission inventory guidebook - 2013

61. Meteorological data for the dispersion model has been obtained from the Blackpool[44] monitoring site. Five consecutive meteorological years (2008-2012) have been used to determine a worst case year. The worst case year was 2012. Data from this year has been used to produce a conservative set of results. A wind rose derived from this 2012 data is shown in Figure 6.2. The DEFRA technical guidance LAQM.TG(09)[45] recommends that meteorological data should only be used if the percentage of usable hours is greater than 75%, and preferably 90%. The 2012 meteorological data from Blackpool include 8,179 lines of usable hourly data out of the total 8,760 for the year, i.e. 93% of usable data. This is above the 75% threshold, and it therefore meets the DEFRA guidance recommendations.

Figure 6.2 Wind rose of meteorological data at Blackpool meteorological station, 2012.



62. The ADMS-Model has been used firstly to predict concentrations of nitrogen dioxide and benzene up to 2km around the Site as a contour plot, secondly to predict concentrations at specific residential receptors near to the Site and finally to predict nitrogen deposition rates at designated ecological receptors within 10km.

63. The selected specific receptors are shown in Table 6.7. The most representative receptor with regards to potential exposure in each direction from the Site has been selected. Residential properties to include in the model were identified from aerial maps. The

[44] Cloud cover is not complete from Blackpool, therefore this was supplemented by data from Liverpool

[45] Department for Environment, Food and Rural Affairs, 2003. Part IV of the Environment Act 1995: Local Air Quality Management: Technical Guidance LAQM.TG (09), London: Crown.

closest ecological receptor to the Site is Marton Mere SSSI located 3.4km north west of the flare location. A specific receptor has been added at this location. As Marton Mere SSSI is the closest ecological receptor the results at other ecological sites which are further away will be lower. A map showing the location of the flare and the specific receptors is shown below.

Table 6.7 Specific receptor locations.

Receptor ID	Location ID	X	Y
1	Staining Wood Farm 1	337084	432570
2	Staining Wood Farm 2	336980	432580
3	Plumpton Hall Farm 1	337894	432694
4	Plumpton Hall Farm 2	337888	432608
5	Great Plumpton	338208	433274
6	Moss House Farm	336860	433315
7	Peel Hill	336219	432870
8	Derby Hill	338461	434049
9	Marton Mere SSSI	334753	435121

Figure 6.3 Map of specific receptor locations.

64. Ecological receptors within 10km of the flare are detailed in Table 6.8. The critical loads for each respective designation area are provided. The most sensitive sites for nitrogen deposition within 10km are Morecambe Bay SPA and Lytham St Anne Dunes SSSI with

a lower critical load of 8kgN/ha/yr. The closest sensitive ecological site to Preston New Road is Marton Mere SSSI which has a lower critical load of 20kgN/ha/yr.

Table 6.8 Ecological site critical loads.

Designated Site	Background Deposition (kgN/ha/yr)	Critical Load - nitrogen deposition (kgN/ha/yr)	Distance to Flare (km)
Marton Mere SSSI	15.96	20-30	3.4
Lytham Coastal Changes SSSI	Not Sensitive to nitrogen		4.9
Lytham St Annes Dunes SSSI	16.38	8-10	6.5
Wyre Estuary SSSI/SPA	Not Sensitive to nitrogen		6.8
Morcombe Bay Ramsar	34.44	8-10	6.8
Newton Marsh SSSI	29.07	20-30	7.9

65. The air quality model used predicted concentrations of nitrogen oxides which is a mixture of mainly nitrogen dioxide and nitric oxide. Both gases react in the atmosphere particularly with ozone and, in general, the nitrogen oxides are mainly emitted as nitric oxide and this converts to nitrogen dioxide in the atmosphere. The air quality standard has been set for nitrogen dioxide and therefore it is important that an appropriate conversion rate is used. The EA has advice[46] on conversion rates to be applied that suggests a worst case assumption of 35% for short-term (i.e. hourly average) and 70% for long-term (i.e. annual mean) average concentration should be considered. In practice, these ratios represent conditions some distance away from a release source. Close to a source, the proportion of nitrogen dioxide in nitrogen oxides is typically much lower than this. Applying these ratios thus provides a worst case assessment.

66. Information for deriving the source parameters were provided by Cuadrilla, the ADMS manual and from calculations based around combustion of the gases. Full details of these calculations are provided in Appendix F.

Radon Gas exposure

67. As described in Appendix F, predicted radon gas exposure levels were calculated using the EA's initial radiological assessment methodology[47]. The potential radon exposure to a 'local resident family' has been calculated. This is a hypothetical exposure group, described in the Initial Radiological Assessment Methodology. Exposure pathways are:

- inhalation of radionuclides in the effluent plume; and
- external irradiation from radionuclides in the effluent plume and deposited to the ground.

68. The family is assumed to live at 100m from the discharge point, and consume food produced 500m from the discharge point.

[46] http://www.environmentagency.gov.uk/static/documents/Conversion_ratios_for__NOx_and_NO2_.pdf
[47] Initial Radiological assessment methodology – part 1 user report and part 2 methods and input data.

Criteria to assess significance for gas flaring

Human receptors

69. The detailed modelling results have been used to screen the process contribution (PC) against the criteria set out in the H1 guidance.

70. In the case of nitrogen dioxide, where the long and short term standards are 40 and 200µg/m^3 respectively, this means that changes in the annual mean concentrations below 0.4µg/m^3 and hourly average concentrations below 20µg/m^3 are considered insignificant. These guidelines do not imply that any increase in concentration above this level would be significant, further consideration of significance is required that examines the total pollutant concentration (i.e. the process contribution plus the background levels) and compare these with relevant air quality standards.

71. For benzene which only has a long term standard of 5µg/m^3 the H1 criteria would relate to annual mean concentrations below 0.05µg/m^3 being considered to be insignificant.

72. Where process contributions (PC) are above the 1% and 10% criteria the H1 guidance provides some criteria for further assessment taking into account the ambient background concentrations examining the process environmental contribution (PEC). The PEC is the process contribution plus the background concentration.

73. The criteria set out for assessing long term process contributions is to check if the process environmental contribution (PEC) is greater than 70% of the long term standard.

    PEC > 70% standard

74. For assessing short term contributions the process contribution is assessed to determine if it is above 20% of the short term standard minus twice the background.

    $PC_{\text{short term}} > 20\%\ (\text{standard}_{\text{short term}} - 2\text{x background}_{\text{long term}})$

75. Where the long term PEC is below the 70% criteria and the short term PC is below the 20% criteria it is not anticipated the emissions will be significant.

76. The guidance from Environmental Protection UK[48] provides a further useful framework for assessment of significance.

77. The EPUK guidance[37] provides an approach to determining the significance of impacts resulting from a proposed development on local air quality for individual receptors. Firstly, descriptors of change are defined as follows:

    - Predict the absolute change in annual mean NO_2 concentrations (in µg/m^3);
    - Determine the magnitude of change resulting from the development; and
    - Use the magnitude of change to determine the impact descriptor.

78. The impact descriptor depends on the magnitude of the change in predicted concentrations in relation to the air quality standard. The impact descriptor is then used in the assessment of significance.

Ecological Receptors

79. NO_2 is the main pollutant of concern of ecological receptors, benzene is not considered in this section as this pollutant is unlikely to impact ecological health.

[48] EPUK, (2010) Development Control, Planning for Air Quality (2010 Update)

80. In the context of habitat regulations the critical level is 30µg/m^3 and therefore concentrations below 0.3µg/m^3 would be considered insignificant. For assessment of European designated sites EA guidance recommends that if the predicted contribution of the installation under investigation (Process Contribution, PC) exceeds 1% of the Critical Level, then the contribution of the installation in conjunction with the prevailing background airborne concentration (Predicted Environmental Concentration, PEC) must be assessed against the Critical Level. If the total PEC is less than 70% of the Critical Level, the installation is not likely to have a significant effect on the sensitive ecosystem.[49]

81. Nitrogen (N) deposition poses a significant threat to sensitive semi-natural habitats in the UK, e.g. heathland. Changes in both species occurrence and ecosystem function indices often occur at low levels of nitrogen deposition (less than 10 kgN/ha/yr), which is sometimes lower than the established critical loads, suggesting that the critical loads are not set at a level which prevents an impact to all species or ecosystem functions. Changes in species occurrence and indices of ecosystem function also progressively continue as nitrogen deposition levels continue rising above the current critical loads values. This suggests that there are some benefits from reduction in deposition even if it remains above the critical load.

82. Despite reductions in emissions of reactive nitrogen gases as required under international policy obligations[50], a relatively small reduction in deposition is forecast for 2020 by recent national studies; therefore risk levels will remain high, and impacts observed on the ground across the UK may well increase in frequency and occur over a wider area than at present due to the cumulative effects of nitrogen deposition over time[51].

Radon

83. The assessment of potential radon gas exposure, as described in the appendix uses the ICRP assessment criterion of 300 microSv/yr. Accordingly a predicted exposure level below this criterion would not be considered significant.

6.4.5.4 Extended Flow Testing

84. The emissions from fugitive gas emissions are covered in this section as the potential for an uncontrolled fugitive emission increases with the longevity of the Site. However there is a potential impact for this to occur at any stage of the operational phase.

Fugitive Gas release impacts

85. Potential odour or VOC impacts from an uncontrolled release of gas have been assessed qualitatively. The assessment of uncontrolled releases takes account of the planned activities on the Site, the duration of those activities, the distance between the Site and any potentially sensitive locations and the direction of any sensitive locations in relation to the prevailing wind direction.

86. The assessment takes into account potential exposure everywhere beyond the Site boundary and does not focus only on the receptors shown in Figure 6.3.

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[49] Environment Agency Stage 1 and 2 Assessment of New PIR Permissions under the Habitats Regulations, Doc No251_06, 2010
[50] 2012 Review of transboundary air pollution (RoTAP)
[51] JNCC, 2011

6.4.6 Assessment methodology for decommissioning and restoration effects

87. The impacts from the decommissioning and restoration that could give rise to atmospheric emissions are vehicle movements and on-site equipment and construction dust. The method to assess these activities has been described above.

6.5 Assumptions and limitations

88. There are a number of limitations and uncertainties associated with modelling predictions. The model is required to simplify real world conditions based upon a series of algorithms and is dependent on input data. Emissions for the flares have been taken from appropriate literature sources[52] but are generic values so the exact emissions may be slightly higher or lower than those modelled. To minimise uncertainty around the operation times a worst case approach is taken assuming the daily maximum volume of gas is flared each day of the year and the worst case 90 day period identified and reported.

89. Regarding the aspects of the assessment which do not rely on the dispersion modelling, the conclusions are reliant upon information provided by the applicant, the validity of national guidance and screening tools, and on the professional judgement of the consultants.

90. As acknowledged some small sources of atmospheric emissions have not been included in the dispersion modelling as they are not considered to be significant. However as the dispersion modelling results are likely to be over predictions, the assessment can be considered robust and remains worst case.

91. Whilst the average Radium-226 activity in the flowback fluid was 28 Bq/L from Preese Hall-1 analysis the peak reading of 90 Bq/L was used and the assessment is subsequently based on a worst case assumption that all radon present in the waters returned to the Site (i.e. all radon produced via decay of the Ra-266 contained within the flowback fluid) would de-gas and would be discharged as radon from the flare.

6.6 Baseline

92. The Site is located in a relatively undeveloped area with no large urban areas nearby (the nearest residential receptors being Blackpool and Wesham, which are approximately 2km and 2.5km from the Site respectively). Existing air quality at the Site would therefore be expected to be good, with concentrations of pollutants within air quality limits and objectives. Air quality in the nearby towns would be influenced by local traffic emissions and would experience comparatively higher concentrations of pollutants.

93. The Site is located within the Fylde Borough Council area, however is close to the border of Blackpool Borough Council. As required by the Environment Act 1995, each council has undertaken a regular review of air quality in their area to identify where air quality objectives may be exceeded. Both councils also carry out air quality monitoring to measure nitrogen dioxide concentrations using diffusion tubes. In the most recent report available on its website (Fylde Borough Council, Air Quality Progress Report, April 2013) it lists five monitoring locations for diffusion tubes throughout the borough. Monitoring is generally carried out in more urban locations and some distance from the

[52] http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook

site of the proposed development and therefore the results are not applicable for determining existing air quality from the proposed development. Fylde Borough Council has not declared any Air Quality Management Areas (AQMA) within their administrative area.

94. Blackpool Borough Council does undertake some monitoring that is closer to the proposed development. The closest monitoring site to the development is near Marton Mere to the north west of the Site where concentrations were well below the air quality objective for nitrogen dioxide during 2012 (the period reported in the 2013 Blackpool Borough Council Progress Report). There are also several diffusion tubes located in Blackpool town centre, two of which recorded concentrations above the annual mean nitrogen dioxide objective in 2012. This area has been designated an AQMA, there are no other AQMAs in the Borough.

95. The Defra website[53] includes estimated background air pollution data based from 2010 with projections for future years for NO_x, NO_2 and PM_{10} for each 1km by 1km OS grid square. The average background concentrations have been calculated from the nine, 1km grid squares surrounding the Site. Estimated concentrations of NO_2 (10.1µg/m^3) and PM_{10} (12.9µg/m^3) at the proposed development are well below the annual mean NO_2 and PM_{10} objectives in 2013.

96. Background maps are also available for benzene. The maps created in 2001 have a projected year of 2010 for each 1km by 1km OS grid square. Defra have provided a methodology[54] and factors for predicting future year benzene concentrations up till 2025. The factors have been used in this case to predict benzene concentrations in 2013 at the grid square where the Site is located (see Appendix B for grid reference). The concentrations of benzene at the Site are well below the objective level in 2013.

Table 6.9 Estimated annual mean background concentrations in 2013.

Year	NO_2 µg/m^3	PM_{10} µg/m^3	Benzene µg/m^3
2013	10.1	12.9	0.21

6.7 Assessment

6.7.1 Installation of Surface and Buried Arrays

Surface array

97. No significant air quality impacts are expected as a result of the installation of the surface array. This is because there are limited earthworks and vehicle movements associated with this activity.

Buried array

98. No air quality impacts are expected as a result of the installation of the buried array. This is because there are limited earthworks and vehicle movement are associated with this activity.

[53] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html
[54] http://laqm.defra.gov.uk/documents/guidance_note_background_projections_1.pdf

6.7.2 Construction of Well Pad and Access

99. An assessment is required due to the presence of residential receptors within 350m of the development site (Figure 6.4).

Figure 6.4 Construction dust buffer zone.

Risk of Dust Arising from Works

100. The proposed development site as a whole covers an area of approximately 2.5 ha. The risk of dust arising from the works is classified in four main categories that are potential to occur at any construction site, i.e. demolition, earthworks, construction and trackout.

Worst case assumptions have been made as part of the assessment of dust impacts. Dust emission classes have been assigned to the four activities in Table 6.10 against the criteria in Appendix F.

Table 6.10 Dust emission magnitude for construction activities

Activity	Dust Emission Magnitude	Reasoning
Demolition	Not applicable	• No demolition is taking place
Earthworks	Medium	• Estimated total area where earthworks might occur greater than 10,000m^2 • Estimated total material to be removed less than 20,000 tonnes
Construction	Small	• Estimated total volume of buildings to be constructed less than <25000m^3 • Potentially dusty construction material

Activity	Dust Emission Magnitude	Reasoning
Trackout	Medium	• Estimated number of daily HGV trips less than 100. • Compacted road surface • Moderately dusty.

101. The sensitivity of the area has been assessed using the criteria in Table 6.4 and Table 6.5. The results were then then used to assess the overall sensitivity of the area to dust impacts. The overall sensitivity has been defined as shown in Table 6.11. There is an overall low sensitivity of the area. The area has been determined as having *low sensitivity* because:

- The area is rural in nature;
- There are no receptors within 100m of the Site and there are only <10 within 350m; and
- Local PM_{10} concentrations are low.

Table 6.11 Sensitivity of the surrounding area

Potential Impact	Sensitivity of the surrounding area			
	Demolition	**Earthworks**	**Construction**	**Trackout**
Dust soiling	Negligible	Low	Low	Low
Human Health	Negligible	Low	Low	Low

102. Using the criteria set out in Table 6.6 the risk of dust impacts at the proposed site without mitigation is negligible to low and is **not significant**.

Table 6.12 Summary of dust risk.

Source	Dust soiling	Human Health
Demolition	Negligible	Negligible
Earthworks	Low	Low
Construction	Negligible	Negligible
Trackout	Low	Low

103. Vehicle traffic movements during the construction phase reach a worst case maximum of 34 average annual daily traffic (AADT) movements (12 cars or vans and 22 HGVs). Following the EPUK guidance[37] which states the number of vehicles required in order to trigger the need for a detailed assessment (an increase in HGVs by 200 or an increase in total AADT by 1000) it is clear the number of vehicles is well below the thresholds which would require a detailed assessment. It is therefore concluded that the air quality impacts of exhaust emission from vehicles in this phase is **not significant**.

6.7.3 Drilling

Mobilisation

104. Vehicle traffic movements during the drilling phases reach a worst case maximum of 45 AADT (32 cars or vans and 13 HGVs). Following the EPUK guidance[37] which states the

number of vehicles required in order to trigger the need for a detailed assessment (an increase in HGVs by 200 or an increase in total AADT by 1000) it is clear the number of vehicles is below the thresholds which would require a detailed assessment. It is therefore concluded that the air quality impacts of exhaust emission from vehicles in this phase is **not significant**.

Drilling

105. As described earlier, impacts from site equipment have been scoped out of this assessment.

6.7.4 Hydraulic Fracturing

Mobilisation

106. No air quality impacts are expected as a result of the mobilisation phase for hydraulic fracturing. Less than 100 vehicle movements in total per day, will occur during this phase of activity. These movements will not have a significant impact. It is therefore concluded that the air quality impacts of exhaust emission from vehicles is **not significant**.

Hydraulic fracturing

107. No air quality impacts are expected as a result of the hydraulic fracturing. On site engines will be in use and the impact of these has been scoped out as they are small sources of pollutants.

6.7.5 Initial Flow Testing

Mobilisation

108. The maximum impacts on air quality will take place during the initial flow testing stage. This period coincides with the maximum period of vehicle movement associated with the Site. The day with maximum vehicle movements is expected to result in 4 HGV and 11 car movements.

109. These traffic flows are well below the level which would require a detailed assessment. The impact from vehicle movements during this phase is therefore considered **not significant**. This also applies to vehicle movements during the initial flow testing activities assessed below where the maximum number of daily vehicle movements are less than the 100 vehicle movements per day threshold[55].

110. Other activities during mobilisation do not involve equipment that will emit air pollutants at a level that would cause a significant impact and therefore have not been assessed.

Initial Flow testing

111. The principal source of air pollutants during this phase of operations would be the operation of the flares during testing. Other sources of atmospheric emissions are not considered to be significant. An initial test for a period of 90 days would be undertaken when the flares would be operational.

112. Two enclosed flares will be used this design is intended to reduce the air quality impacts from this part of the Project. This approach is referred to as the best available technique

[55] This would also apply if greater than anticipated flowback rates were encountered.

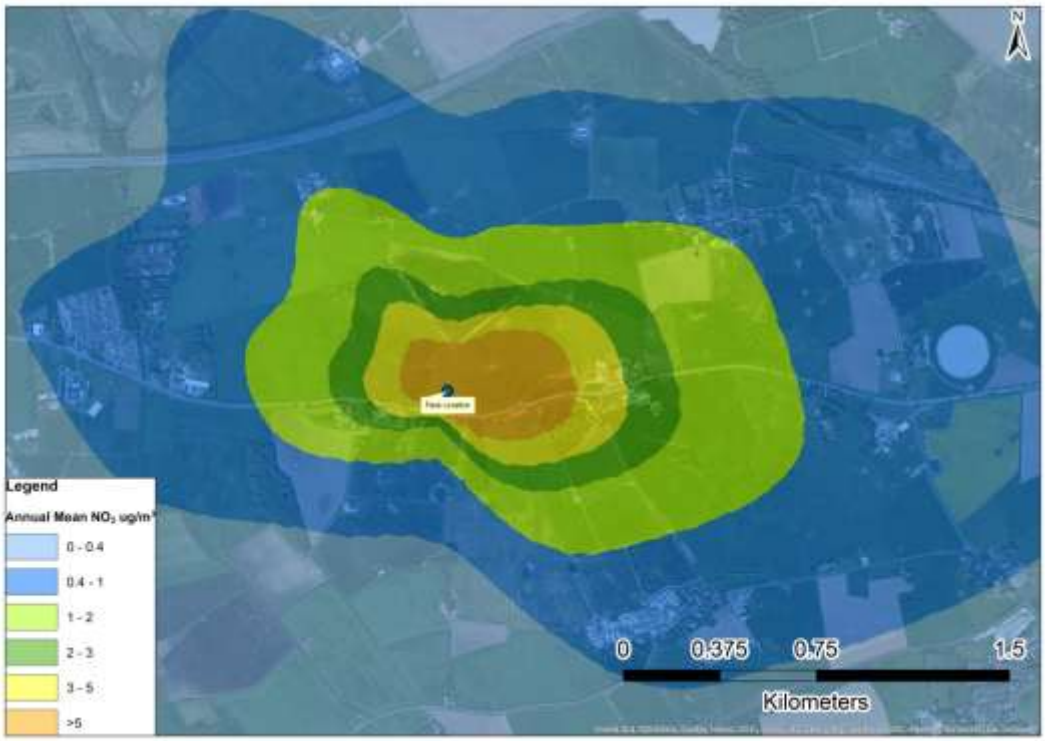
(BAT) by the EA[56]. Flaring takes place within a burn chimney which increases the height of the emissions and reduces the heat given off by the flares hence increasing the thermal buoyancy of the exhaust gases and improving dispersion from this source. The burn chimneys have a 3m diameter and are 10m high from ground level. Model input parameters are included in Appendix F.

As discussed in the methodology detailed dispersion modelling has been undertaken to ensure a robust assessment is carried out. The results of the modelling have been used to assess significance of effects.

NO_2 modelled results

113. The results of the modelling of nitrogen dioxide concentrations (assuming a 70% conversion of NO_x to NO_2 for annual mean NO_2) are shown as a contour plot in Figure 6.5.

Figure 6.5 Predicted Process Contribution Annual Average NO_2 concentrations (µg/m^3).



114. The initial screening test for significance set by the EA of 1% of the relevant standard for long term emissions and 10% for short term emissions has been undertaken. Results at specific receptors chosen as representing the most sensitive locations around the Site have been produced using detailed dispersion modelling.

115. Table 6.13 and Table 6.14 show the results at the specific receptors. The screening test of 1% against the long term standard (40µg/m^3) is exceeded at seven sites. The screening test of 10% against the short term standard (200µg/m^3) is exceeded at two of the modelled receptor sites.

[56] Environment Agency, Guidance Note: Regulation of exploratory shale gas operations (November 2012)

Table 6.13 Predicted annual average NO_2 concentrations at specific receptors (flare contributions only).

Location	X	Y	Annual mean NO_2 (µg/m^3) (PC)	% of long term annual mean (40µg/m^3)
Staining Wood Farm 1	337084	432570	2.9	**7.3**
Staining Wood Farm 2	336980	432580	2.3	**5.6**
Plumpton Hall Farm 1	337894	432694	4.4	**10.9**
Plumpton Hall Farm 2	337888	432608	4.6	**11.5**
Great Plumpton	338208	433274	1.1	**2.6**
Moss House Farm	336860	433315	1.2	**2.9**
Peel Hill	336219	432870	0.6	**1.5**
Derby Hill	338461	434049	0.3	0.7
Marton Mere SSSI	334753	435121	0.1	0.3

*1% of the long term standard for NO_2 is 0.4µg/m^3 (exceedences in bold).

Table 6.14 Predicted short term average NO_2 concentrations at specific receptors (flare contributions only).

Location	X	Y	99.79th%ile of 1hr means (µg/m^3) (PC)	% of short term standard (200µg/m^3)
Staining Wood Farm 1	337084	432570	44.4	**22.2**
Staining Wood Farm 2	336980	432580	30.0	**15.0**
Plumpton Hall Farm 1	337894	432694	18.8	9.4
Plumpton Hall Farm 2	337888	432608	19.6	9.8
Great Plumpton	338208	433274	7.6	3.8
Moss House Farm	336860	433315	10.6	5.3
Peel Hill	336219	432870	7.0	3.5
Derby Hill	338461	434049	3.7	1.9
Marton Mere SSSI	334753	435121	2.4	1.2

*10% of the short term standard for NO_2 is 20µg/m^3 (exceedences in bold).

116. As the screening has shown the results are above the criteria for the long term concentrations, further analysis of the results is required to determine significance. The results of this further analysis are provided below.

The EA H1 guidance indicates that where the process contribution (PC) exceeds the screening criteria, as above, the process environmental contribution (PEC) should be also considered. For long term concentrations it is recommended to assess the significance of the installation where the PEC is greater than 70% of the long term standard. For NO_2 this would be 28µg/m^3.

117. Table 6.15 shows none of the sites exceed PEC greater than 70% of the long term standard.

118. For short term concentrations it is recommended to assess significance of the installation where the PC is greater than 20% of the standard minus twice the background concentrations. For NO_2 in the locality of the flare this would be 36µg/m^3. Table 6.16 shows none of the sites exceed this criterion.

Table 6.15 Predicted long term average PEC NO_2 concentrations at specific receptors (flares plus background).

Location	X	Y	Annual mean plus background (PEC)	PEC as a % of long term standard (40µg/m^3)
Staining Wood Farm 1	337084	432570	13.0	46.5
Staining Wood Farm 2	336980	432580	12.4	44.1
Plumpton Hall Farm 1	337894	432694	14.5	51.7
Plumpton Hall Farm 2	337888	432608	14.7	52.5
Great Plumpton	338208	433274	11.2	39.9
Moss House Farm	336860	433315	11.3	40.2
Peel Hill	336219	432870	10.7	38.3
Derby Hill	338461	434049	10.4	37.1
Marton Mere SSSI	334753	435121	10.2	36.5

*70% of the long term standard for NO_2 is 28µg/m^3

Table 6.16 Predicted short term average PC NO_2 concentrations at specific receptors (flare plus background)

Location	X	Y	99.79th%ile of 1hr means (PC)	% of short term standard minus 2x background (200µg/m^3)
Staining Wood Farm 1	337084	432570	44.4	24.7
Staining Wood Farm 2	336980	432580	30.0	16.7
Plumpton Hall Farm 1	337894	432694	18.8	10.5
Plumpton Hall Farm 2	337888	432608	19.6	10.9
Great Plumpton	338208	433274	7.6	4.2
Moss House Farm	336860	433315	10.6	5.9
Peel Hill	336219	432870	7.0	3.9
Derby Hill	338461	434049	3.7	2.1
Marton Mere SSSI	334753	435121	2.4	1.3

*20% of the short term standard for NO_2 plus twice the background for this site is 36µg/m^3

119. Based on the results and the assessment against the EA criteria, it is considered that the predicted changes in concentrations of NO_2 will not be be significant.

120. The EPUK guidance has also been used as an alternative method to assess significance. The results of the assessment of magnitude are shown in Table 6.17.

Table 6.17 Change in annual mean NO_2 concentration and associated impact descriptors.

Location	Annual mean NO_2		
	Change (µg/m^3)	Relative change	Impact descriptor
Staining Wood Farm 1	2.9	Medium	Negligible
Staining Wood Farm 2	2.3	Medium	Negligible
Plumpton Hall Farm 1	4.4	Large	Slight Adverse
Plumpton Hall Farm 2	4.6	Large	Slight Adverse
Great Plumpton	1.1	Small	Negligible
Moss House Farm	1.2	Small	Negligible
Peel Hill	0.6	Small	Negligible
Derby Hill	0.3	Imperceptible	Negligible
Marton Mere SSSI	0.1	Imperceptible	Negligible

EPUK factors to judge significance

121. Considering the significance of the air quality impacts according to the criteria set out in the guidance, the following points are noted:

- The overall magnitude of impact is slight adverse to negligible for NO_2 concentrations;
- No new public exposure is being introduced in the area by the proposed development;
- Pollutant concentrations remain well below the air quality standards for NO_2 with the proposed development at all receptors;
- The development site does not lie within any AQMAs;
- Pessimistic assumptions have been made throughout the assessment.

122. Based on the above, the air quality is judged to be a *minor* consideration in the case of this development proposal for NO_2 and **not significant**.

EPUK flowchart to determine the priority of air quality in the planning process

123. Using the EPUK flowchart method, the following points are noted:

- No breach of an EU limit value is observed for NO_2 concentrations;
- No breach of an air quality objective is observed for NO_2 concentrations;
- The proposed development is not judged to interfere with the implementation of any local plans and strategies;
- The proposed development leads to a *large* increase in pollutant concentrations at the worst case location, however concentrations at this location are well below objective levels and concentrations fall rapidly away from the site.

Based on the above, air quality is considered to be a *low priority* in the planning process. This result indicates the NO_2 impact, and therefore the impacts upon human health are **not significant**.

Ecological receptors

124. Annual mean NO_x concentrations at the worst case ecological receptor (receptor 9, Marton Mere SSSI) are predicted to be 0.2µg/m^3. The process contribution (PC) at this location is 0.2µg/m^3 which is below the 1% significance criteria for the critical level (30µg/m^3) as shown in Table 6.18. Therefore the installation is not likely to have a significant effect upon the ecosystem. As this is the worst case location for the impact from the flare all other ecological areas will have a lower process contribution.

Table 6.18 Predicted annual average NO_2 concentrations at Morecambe Bay SPA (flare contribution only).

Location	X	Y	Annual mean NO_x	% of long term annual mean (30ug/m3)
Marton Mere SSSI	334753	435121	0.2	0.6

*1% of the long term standard for NO_2 is 0.3µg/m^3

125. When comparing the flare contribution to the most stringent, lower critical load it is clear the background nitrogen deposition rate at the qualifying feature is below the lower limit (Table 6.8). The modelling results show that there is a nitrogen deposition rate of 0.01kgN/ha/yr which is equivalent to 0.26% of the lower critical load. Therefore based on the EA significance test[49] an increase of more than 1% of the lower critical load would not be exceeded.

Table 6.19 Predicted annual average nitrogen deposition Nkg/ha/yr.

Location	Annual deposition kgN/ha/yr	% of lower critical load
Marton Mere SSSI	0.03	0.25

*1% of the lower critical load of 8kgN/ha/yr is 0.08kgN/ha/yr.

126. In terms of the 24-hour mean critical load, the EA states that the short term concentrations can be estimated by adding the process contribution to twice the annual mean background concentration. The maximum predicted process contribution anywhere within the Marton Mere SSSI is 0.2µg/m^3. Combined with the predicted background concentration of around 10µg/m^3 this gives a total short term concentration of 20µg/m^3. This is well below the critical load of 75µg/m^3 such that the predicted effect is **not significant**. This result indicates the health impacts on local ecology will be **not significant**.

Benzene modelled results

127. Results of benzene concentrations at the nearest receptors have been presented in Table 6.20. The maximum concentration of 0.025µg/m^3 is well below 1% of the annual mean benzene concentration. As a result effect of benzene on human health is **not significant**.

Table 6.20 Modelled annual mean benzene concentrations.

Location	X	Y	Annual mean benzene (µg/m^3)
Staining Wood Farm 1	337084	432570	0.014
Staining Wood Farm 2	336980	432580	0.011
Plumpton Hall Farm 1	337894	432694	0.021
Plumpton Hall Farm 2	337888	432608	0.022
Great Plumpton	338208	433274	0.005
Moss House Farm	336860	433315	0.006
Peel Hill	336219	432870	0.003
Derby Hill	338461	434049	0.001
Marton Mere SSSI	334753	435121	0.001

Radon Gas

128. The assessment of impacts relating to radon gas is provided in Appendix F. It explains that the potential effective dose of radiation to the 'local resident family' resulting from the assumed activity would be 0.3microSv/yr. This can be compared with the average dose routinely received in the home or workspace in the UK of 1,300microSv/yr, and is well below the ICRP assessment criterion of 300microSv/yr. As such it can be concluded that the effect is **not significant**.

Fugitive Gas release

129. There is no planned intention to vent gas at any point during well testing or operation. As part of the embedded mitigation measures there are a number of steps that will be implemented to minimise the risk of fugitive emissions and monitor for any potential emissions.

130. If gas is released there is the potential it may give rise to odours (e.g. from H_2S) or VOC emissions, if the gas contains these elements. The gas is not expected to include any H_2S as none has been found in nearby test wells. Emissions could only occur as a result of a range of possible uncontrolled releases, such as equipment failure or leaks. Due to stringent safety measures and equipment checks this probability of uncontrolled releases is very low. All contained releases would be flared and not vented off.

131. In order for members of the public to experience significant odour or VOC impacts, they would need to be present very close to the source and for the wind to be blowing towards them.

132. The closest properties are over 3000m (from the centre of the well pad) from any potential source and the predominant wind direction for the area is west to east. This, coupled with the short term nature of any unexpected release and the limited chance of winds blowing towards sensitive receptors , means that the risk of a significant effect is negligible and **not significant**.

6.7.6 Extended Flow Testing

Construction

133. No significant air quality impacts are expected as a result of the construction phase for extended flow testing. Limited vehicle movements will occur during this phase of activity, these movements will have a negligible effect on air quality and therefore are **not significant**.

Operation

134. During extended flow testing the gas will be captured for use and not flared off. The capture of the gas reduces air quality impacts from the Site. A small safety flare will be used on limited occasions to remove gas from the surface pipe work and would not be used routinely. Therefore this will not impact on air quality and is **not significant**.

6.7.7 Decommissioning and Restoration

Extended Flow Testing Infrastructure

135. No air quality impacts are expected as a result of the decommissioning of extended flow testing infrastructure, limited vehicle movements will occur during this phase of activity. There are therefore no significant effects on air quality.

Exploration well, pad and access track

136. Decommissioning the well pad and access track will require the same number of vehicle movements as during construction (see section 6.7.2). It is therefore concluded that the air quality impacts of exhaust emission from vehicles is **not significant**.

137. Additionally removal of the concrete well pad and access track has the same potential for dust impacts as the construction phase. See section 6.7.1 for the assessment of dust impacts. The result of decommissioning will be the same as for the construction phase with a negligible impact on air quality and is **not significant**.

6.8 Cumulative and Interactive Effects

6.8.1 Combined effects of simultaneous hydraulic fracturing and initial flow testing

138. Combined effects on air quality from hydraulic fracturing and initial flow testing occurring at the same time on the Site are **not significant**. The impact of the generators and vehicles combined with the flare would not be significantly greater to the impact from the flare alone. As shown in the modelling of the flare the concentrations at human and ecological receptors are well below the objective levels. Adding in emissions due to cumulative impacts from hydraulic fracturing would not cause a breach of any objectives as the additional concentrations would be minimal.

6.8.2 Combined effects of simultaneous drilling and initial flow testing

139. Combined effects on air quality from drilling and initial flow testing occurring at the same time on the Site are **not significant**. The impact of the generators and vehicles

combined with the flare would not be significantly greater to the impact from the flare alone. As shown in the modelling of the flare the concentrations at human and ecological receptors are well below the objective levels. Adding in emissions due to cumulative impacts from drilling would not cause a breach of any objectives as the additional concentrations would be minimal.

6.8.3 Combined effects of Preston New Road and Roseacre Wood

140. For air quality the main effects from each site occur during the initial flow testing stage. ADMS dispersion modelling has been used to assess the effect of both Sites operating simultaneously. The same worst case approach was taken as used for the modelling of just Preston New Road.

141. In order to assess the combined impacts of the two Sites additional receptors have been added to the list of receptors considered for Preston New Road. These receptors are worst case locations closest to both the flares at Roseacre Wood and Preston New Road. Also receptors between these two locations have been added to assess areas where the combined impact will be greatest.

Figure 6.6 Combined RW and PNR receptor locations.

142. The results of the cumulative effects are compared with the results with only the flares at Preston New Road. The change in concentration when both sites are assessed beyond 3km of the flares is shown to be minimal, less than 0.5µg/m^3 (Table 6.21). Only cumulative effects were observed at receptors 18 to 28. The changes in concentrations at the additional receptors between the two sites and the additional effect of all flaring on the Preston New Road receptors is minimal and would not create a significant impact. As such the cumulative effects of the flares are **not significant**.

Table 6.21 Predicted annual average NO_2 concentrations combined flare receptors.

Location	X	Y	Annual Mean combined PNR and RW µg/m^3	Annual mean PNR µg/m^3	Change µg/m^3
18	339424	434689	0.2	0.2	0.1
19	338326	434477	0.3	0.2	0.1
20	337084	432570	3.0	2.9	0.0
21	336980	432580	2.3	2.3	0.0
22	337894	432694	4.4	4.4	0.0
23	337888	432608	4.6	4.6	0.0
24	338208	433274	1.1	1.1	0.0
25	336860	433315	1.2	1.2	0.0
26	336219	432870	0.6	0.6	0.0
27	338461	434049	0.3	0.3	0.0
28	334753	435121	0.2	0.1	0.0

143. Other effects such as cumulative vehicle emissions are avoided by ensuring that the HGVs and cars for each site do not both follow the same proposed routes. This would be unlikely to occur given the distance between the Sites.

6.8.4 Cumulative effects with other local developments

144. The cumulative effects with other developments (see Appendix T2) will not cause a significant effect on air quality. This is because of the scale and nature of these developments coupled with their proximity to the Site cause no cumulative impact on air quality.

6.9 Mitigation Measures

6.9.1 Construction of Well Pad and Access, Decommissioning and Restoration

145. Whilst the Site has been assessed as being a *low risk* Site, the dust emitting activities assessed in the assessment section can be further reduced or eliminated by applying the site specific mitigation measures outlined in the IAQM guidance[36]. The full list of recommended measures is provided in Appendix F.

6.9.2 All other Project Stages

146. No mitigation is required as there are no anticipated air quality impacts.

147. Cuadrilla will carry air quality monitoring. The specific details of this will be set out within the EOS, Air Quality Control Plan following the planning determination (provided in Appendix E).

6.10 Residual Effects

148. With the mitigation measures described above the residual effects are **not significant.**

6.11 Assessment Summary Matrix

Table 6.22. Air quality assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad and Access			
Dust soiling at local sensitive receptors	**Not Significant**	Best practice measures recommended to ensure no impacts.	**Not Significant**
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**
Installation of the Surface and Buried arrays			
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**
Drilling and hydraulic fracturing			
Emissions from plant equipment	**Not Significant**	None required	**Not Significant**
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**
Initial Flow testing			
Emissions from plant equipment	**Not Significant**	None required	**Not Significant**
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**
Flare Emissions	**Not Significant**	Ensure best available technology is used.	**Not Significant**
Extended Flow Testing			
Emissions from plant equipment	**Not Significant**	None required	**Not Significant**
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**
Decommissioning and Restoration			
Dust soiling at local sensitive receptors	**Not Significant**	Best practice measures recommended to ensure no impacts.	**Not Significant**
Emissions from plant equipment	**Not Significant**	None required	**Not Significant**
Vehicle emissions to the atmosphere.	**Not significant**	Not required.	**Not Significant**

7 Archaeology and Cultural Heritage

Chapter Summary - Archaeology and Cultural Heritage

This chapter assesses the effects of the Project on heritage features that are given protection because of their historical and/or architectural value, such as listed buildings and scheduled monuments. It is also concerned with the effects of the Project on archaeology, in other words the above or below ground remains left by previous generations.

Historical data from a variety of sources has been reviewed including sources of information held by Lancashire County Council and nationally by English Heritage. There are no World Heritage Sites, Scheduled Monuments, Registered Parks and Gardens, Registered Battlefields, Listed Buildings or Conservation Areas within the 1km the Site. Likewise, there are no records of (or recorded) archaeological finds within the planning application boundary for any of the surface works.

The only activities associated with the Project that have the potential to result in a significant effect on archaeology are the construction of the well pad, access track and connection to the gas grid. All of these activities will require excavation of the top soil and sub-soil and might encounter archaeology which without any specific mitigation could be lost with the opportunity to record it. This potential effect will be mitigated during the construction phase by recording any evidence of the track and field systems during excavation works. By implementing this measure the Project will not result in a significant effect on heritage or archaeological features.

The Site is also suitably distant from above ground heritage assets (such as listed buildings) to avoid any indirect visual impacts on their setting.

The Preston New Road and Roseacre Wood Sites are sufficiently distant from one another that their combined impacts on heritage features will not result in a greater combined effect than individually.

7.1 Introduction

1. This chapter assesses the likely significant effects on archaeology and cultural heritage assets resulting from the construction, operation and decommissioning of the proposed exploration compound at the Site, the construction of associated access routes and the installation of microseismic arrays.

2. Cultural Heritage constraints were factored in to the selection process which identified the Site. As a result of the selection process, the Site is located in an area where archaeological potential is uncertain. The process of developing appropriate evaluation and mitigation methodologies will be undertaken in consultation with Lancashire County Archaeology Service (LCAS).

7.2 Key Development Issues

3. The key development issue for archaeology and cultural heritage will be the effects of works to construct the well pad, pipeline connection and access track on, until now, unidentified archaeological deposits within the footprint of the surface works. If archaeological deposits are encountered, the effects on this heritage resource have the potential to be major in scale and permanent although the remains most likely to be encountered are of low heritage value and the overall effect therefore only moderately

adverse. All of the other potential effects will be not be permanent and are likely to be of lesser magnitude.

7.3 Scoping and Consultation

4. An EIA Scoping Report was issued for comment on 6 February 2014 and consultation with Lancashire County Council took place on 11 February and 7 March 2014. The Lancashire County Archaeology Service response to the Scoping Report and comments expressed during consultation are summarised in Table 7.1 below.

Table 7.1. Archaeology and Cultural Heritage scoping and consultation overview

Consultee	Comment	Response
Lancashire County Archaeological Service	Proposed methodology to be used in the assessment of the likely impacts on Archaeology & Cultural Heritage (Section 5.2 of the EIA Scoping Report) does meet with LCAS approval.	No response
Lancashire County Archaeological Service	Discussion of the site selection process within the ES text would be useful.	See paragraph 2 above and Scheme Description (chapter 4).
Lancashire County Archaeological Service	A robust system of notification should form part of any site based mitigation	Mitigation measures are discussed at Section 9 of this Chapter.
Landscape Unit Lancashire County Council	Distinction between Historic Landscape Characterisation and Local Landscape Characterisation should be made	The distinction Historic Landscape and Local Landscape characterisation is discussed in Appendix G.

7.4 Methodology

7.4.1 Guidance

5. The assessment of construction and operational effects was undertaken using professional judgement, with reference to a number of guidance documents:

- Institute for Archaeologists Standard and Guidance for Archaeological Desk Based Assessments;
- Design Manual for Roads and Bridges Volume 11, Section 3, Part 2 (DMRB); and.
- The setting of Heritage Assets, English Heritage 2011.

6. It should be noted that these documents are guidance only, and there is no statutory requirement to utilise any particular methodology for the assessment of impacts on heritage assets.

7.4.2 Asset Significance

7. Table 7.2 describes the asset significance criteria used in the assessment, adapted from the criteria set out in DMRB.

Table 7.2 **:**Value of archaeological assets

Asset Significance	**Typical Descriptors**
Very High	World Heritage Sites (including nominated sites). Assets of acknowledged international importance. Assets that can contribute significantly to acknowledged international research objectives Grade I Registered Parks and Gardens
High	Nationally important assets, including Scheduled Monuments, Grade I and II* Listed Buildings Assets with the potential to contribute to national research objectives
Medium	Grade II Listed Buildings Assets with the potential to contribute to regional research objectives Conservation Areas Grade II Registered Parks and Gardens
Low	Assets compromised by poor preservation and/or poor survival of contextual associations. Assets of limited value, but with potential to contribute to local research objectives.
Negligible	Assets with very little or no surviving heritage interest.

7.4.3 Magnitude of change

8. The approach used to assess significance of impact is determined by two variables; the significance of the asset and the magnitude of change upon the asset. This takes into account the severity of impact of the Project, together with the vulnerability of the receptor to change.

9. Table 7.3 summarises the type of change and its magnitude, according to the DMRB methodology.

Table 7.3 : Magnitude of change

Magnitude of Change	**Description of Change**
Major	Complete destruction/demolition of site or feature. Change to the site or feature resulting in a fundamental change in our ability to understand and appreciate the resource and its historical context and setting.
Moderate	Change to the site or feature resulting in an appreciable change in our ability to understand and appreciate the resource and its historical context and setting.
Minor	Change to the site or feature resulting in a small change in our ability to understand and appreciate the resource and its historical context and setting.
Negligible	Negligible change or no material change to the site or feature. No real change in our ability to understand and appreciate the resource and its historical context and setting.
No Change	No change

7.4.4 Significance of effect

10. According to DMRB, significance of effect upon the cultural heritage resource is assessed according to the matrix approach described by Table 7.4. The effects may be either adverse or beneficial, depending on the nature of the impact. It should be noted that the initial assessment is made for the Project without mitigation; the residual effect as a result

of mitigation is determined separately. Where the matrix suggests more than one likely outcome, for instance slight or moderate, professional judgement would be used in conjunction with the descriptors in Table 7.3, to arrive at an appropriate result.

Table 7.4 :Significance of effect

		No Change	Negligible	Minor	Moderate	Major
ENVIRONMENTAL VALUE	Very High	Neutral	Slight	Moderate or Large	Large or Very Large	Very Large
	High	Neutral	Slight	Slight or Moderate	Moderate or Large	Large or Very Large
	Medium	Neutral	Neutral or Slight	Slight	Moderate	Moderate or Large
	Low	Neutral	Neutral or Slight	Neutral or Slight	Slight	Slight or Moderate
	Negligible	Neutral	Neutral	Neutral or Slight	Neutral or Slight	Slight

7.4.5 Evaluation of effect

11. The significance of the effects on the heritage resource based on evaluation criteria would be assessed as described by Table 7.5 below.

Table 7.5 :Evaluation criteria

Significance of Effect	**Effect**
Very large adverse	Partial or total loss of a site of Very High Importance.
Large adverse	Result in the total, or almost total, loss of heritage assets. Be highly intrusive and would seriously damage the setting of the heritage resource such that its context is seriously compromised and can no longer be appreciated or understood. Be strongly at variance with the form scale and pattern of a heritage resource or conservation area. Be in serious conflict with government policy for the protection of the heritage resource.
Moderate adverse	Be out of scale with or at odds with the scale pattern or form of the heritage resource or conservation area. Be intrusive in the setting (context) and adversely affect the appreciation and understanding of the resource. Result in loss of features such that their integrity of the heritage resource is compromised, but not destroyed. Be in conflict with local or regional policies for the protection of the heritage.

Significance of Effect	Effect
Slight adverse	Have a detrimental impact on the context of a heritage feature such that its integrity is compromised and appreciation and understanding of it is diminished. Not fit perfectly with the form scale pattern and character of a heritage resource or conservation area. Be in conflict with local policies for the protection of the local character of the heritage resource.
Neutral	Maintain existing historic features in the townscape. Have no appreciable impacts either beneficial or adverse on any known or potential heritage assets. Result in a balance of beneficial and adverse impacts. Not result in severance or loss of integrity context or understanding within a historic landscape. Not be in conflict with and do not contribute to policies for the protection or enhancement of the heritage.

7.4.6 Baseline methodology

12. Guidance issued by English Heritage, the Highways Agency and the Institute for Archaeologists on cultural heritage assessment specifies the documentary, cartographic and cultural heritage sources to be consulted as a minimum[57]. A range of documentary, cartographic and archaeological sources were consulted to provide a robust baseline for assessment. Sources included:

- Material supplied by Lancashire Historic Environment Record[58] (LHER)(see the gazetteer in Appendix G);
- Online information from English Heritage Archive (formerly NMR)(see the gazetteer in Appendix G);
- Material held at Lancashire Record Office Preston;
- Information from the Lancashire Historic Landscape Characterisation Programme;
- Published sources pertaining to the history of Amounderness and the Fylde in particular R Middleton et al 1995 The Wetlands of North Lancashire;
- Historic maps from online sources;
- Additional online documentary sources were reviewed, such as the archive source British History Online (http://www.british-history.ac.uk/); and
- A site walkover visits undertaken on 7 and 8 January 2014.

13. For the purposes of baseline data gathering a study area of 1km radius from the Site was defined for archaeological assets and a study area of 5km for listed buildings, conservation areas, registered parks and gardens, registered battlefields and scheduled monuments.

[57] See footnotes 1-3 above
[58] Lancashire HER material was provided for a wide extent of the Fylde at site selection stage. The baseline search area from which data was extracted for the Preston New Road site was defined by a radius of 1km from the Preston New Road proposed compound limits.

7.4.7 Assessment methodology

14. Effects resulting from the Project may be direct or indirect:

- Direct effects are those that arise as a straightforward consequence of the Project. Direct effects may be caused by a range of activities associated with the construction of the well pad, access track and seismic arrays; for example, the removal of existing ground for the preparation of the well pad or drainage and utility connections which may then truncate the potential subsurface archaeological resource.
- Indirect effects are those that arise from the Project via a complex route, where the connection between the Project and the effect is complicated, unpredictable or remote. For example, changes in local land drainage caused by the scheme could affect palaeo-environmental deposits through dewatering at a distance from the Site.

15. All likely significant effects (direct or indirect) have been assessed in terms of their duration (temporary or permanent) and nature (adverse or beneficial):

- Adverse effects are those that detract from the value of a cultural heritage asset. This may be through a reduction in, or disruption of, valuable characterising components or patterns; for example, the removal of archaeological below ground deposits.
- Beneficial effects are those that contribute to the value of a cultural heritage asset. This may be through the introduction of new, positive attributes; for example, through improved understanding of the asset, improved setting and increased public access.

16. The potential for a cultural heritage asset to experience an effect from a construction or operational effect is then assessed, using a combined understanding of the archaeological baseline, the design and nature of the Project, all available geotechnical information and any information derived through consultation with the relevant authorities, as well as professional judgement.

17. The assessed effect upon a cultural heritage asset resulting from the impacts deriving from the Project is then presented on a five-point scale ranging from neutral to major adverse. For the purposes of this assessment slight or neutral effects are not considered significant.

7.5 Assumptions and limitations

18. The assessment is based on the design details available at the time of preparing the ES. The LHER is continually being updated and this work reflects the data available in July 2013). A request to LCAS identified that no relevant work has been carried out within the study area the results.

7.6 Baseline

19. The cultural heritage baseline was compiled from records held by the LHER. Numbers quoted in the following text (for example, PRN761) refer to the number allocated on the LHER. A gazetteer of archaeological and built heritage features has been prepared and is presented in Appendix G. These sites, features and buildings are mapped (Figure 2, Appendix G). For the establishment of the baseline, human occupation of the British Isles has been divided into the following time periods as defined by English Heritage (http://pastscape.org.uk/TextPage.aspx) (Table 7.6).

Table 7.6 Prehistoric and Historic Time Periods[59]

Period name	Date range	Additional periods, where needed
Palaeolithic	500,000 – 10,000BC	
Mesolithic	10,000 – 4,000BC	
Neolithic	4,000 – 2,200BC	
Bronze age	2,200 – 700BC	
Iron age	700BC – AD43	
Romano-British	AD43 - 410	
Early medieval (Anglo-Saxon)	410 - 1066	
Medieval	1066 - 1540	
Post-medieval	1540 - 1901	Tudor - 1485 - 1603 Elizabethan - 1558 - 1603 Stuart - 1603 – 1714 (Jacobean 1603 – 1625) Hanoverian - 1714 – 1837 (Georgian 1714 – 1830) Victorian - 1837 - 1901
20th Century	1901 - 2000	
21st Century	2001 - 2100	

20. The Site is, in common with much of the surrounding area, currently pasture land. The site lies in the civil parish of Westby with Plumptons. For details about the geology of the Site see Chapter 11 (Hydrogeology and Ground Gases) and Chapter 13 (Land Use).

7.6.1 Prehistoric

21. The earliest evidence for human activity in the Fylde area dates to the late Upper Palaeolithic (c16,000-8,000 BC). The most famous find being that of an elk at Poulton-le-Fylde in 1970. The remains were found in peat, the body having flint points embedded in its leg and ribs, indicating that human hunting groups were present in the area c. 13,417-11,769 BC.

22. .Towards the end of the Mesolithic period, parts of the Fylde were submerged by the Lytham VI marine transgression at the height of which Blackpool and Lytham would have been islands. This had a significant impact on the location of late Mesolithic and Early Neolithic settlement in the Fylde which appears to be concentrated in coastal areas. Traces of Early Mesolithic presence have been found north of the Site in Over Wyre.

23. A small scatter of flints (LA54) and two isolated finds (LA53 and LA56) have been found c 800m to the south of the Site. A further small scatter of flints (LA68) has also been recovered c 900m to the northwest. The material recovered was of Neolithic to Early Bronze Age date.

[59] Based on the Definition of Cultural Heritage, HA DMRB Vol 11 Sect 3 Part 2 HA 208/07 – these time periods differ in detail from those used by LHER

24. In many respects the succeeding Bronze Age can be seen as a period of consolidation and continuation. The palaeoenvironmental record in the Fylde shows little distinction between the vegetation of the Bronze Age and that of the Neolithic period, with a continuing pattern of temporary woodland clearance episodes followed by regeneration. The only difference is that these episodes were possibly more marked and cereal cultivation is less frequently recorded in the Bronze Age[60].

25. A probable Bronze Age burial mound was discovered at Weeton Heads Lane, c2.5km north east of the Site, in the 19th Century. The Weeton Heads Lane barrow appears to form the focus of a concentration of finds of Bronze Age date suggesting the presence of further unrecognized monuments in the immediate vicinity. Finds of middle to late Bronze Age date are otherwise scarce in the Fylde and none are known within 1km of the Site.

26. There was a sharp downturn in climatic conditions in the first millennium BC, with a significant expansion of wetlands within the range of *c* 900-400 BC. Archaeological evidence for Iron Age activity in the Fylde is limited[61]. However, palaeoenvironmental evidence[62] suggests extensive clearance and arable cultivation in the late Iron Age however there is a dearth of artefactual or structural evidence to match, and none from the Site or its immediate vicinity.

7.6.2 Roman

27. In common with the pattern observed elsewhere in Britain it is probable that the late Iron Age settlement pattern remained largely unchanged with the arrival of the Roman army in the later 1st century AD[63]. The fort at Dowbridge south east of Kirkham[64] was preceded by temporary camps and a fortlet, with the first activity on the Site possibly occurring as early as the late 60s AD. A road linked the Kirkham fort to the fort at Ribchester.[65] It is also suggested that there was a port to the south at Freckleton (*Portus Setantiorum*[66]). The majority of Roman finds in the Fylde are concentrated around Kirkham and it has been suggested that the 'fort was established and run within a thinly occupied landscape'[67]. There are no known finds of Roman material from within 1km of the Site.

7.6.3 Early Medieval

28. Little is known of settlement patterns in the Fylde during the centuries immediately after the end of Roman administration. However, pre-Saxon elements survive in place names such as Ecclestones and Inskip[68] and it is possible that an estate administrative centre was

[60] See Appendix G 1.6 Cooke 2008, p12
[61] See Middletone et al p and Brennand, M 2006 p51ff
[62] Cooke 2008 p14
[63] See Cooke 2008 p 17
[64] Howard-Davis, C and Buxton, K 2000
[65] The proposed line of this road northwards from Kirkham, at present entirely hypothetical, runs approximately south to north at a distance of c.7.5km west of the site at Roseacre Wood.
[66] The site of *portus Setantiorum* has yet to be positively identified and has been located as far afield as Windermere (Brennand M 2006 p62) with an alternative possible location in the Fylde at Fleetwood.
[67] Middleton, R et al 1995 p113 – the sparse distribution of Roman coins includes a coin of Gallienus found near Treales.
[68] Inskip = 'island where wicker baskets are made'.

established at Treales in the 7th century[69]. A settlement at Kirkham is also referred to in the Domesday Book of 1086.

29. Although the early medieval period seems to have seen a period of drier conditions in the 4th to 6th centuries it is probable that the valley bottoms and floodplains were sufficiently wet to create the appearance of islands[70].This is notable because Inskip and Kirkham are both to be found on raised ground .

30. Excavated evidence from the early medieval period is scarce. There is no evidence of early medieval activity within the study area.

7.6.4 Medieval

31. Before 1066 Westby and Plumpton formed part of the lordship of Earl Tostig. Both Westby (Westbi) and Plumpton (Pluntun) are noted in the Domesday Book - their names are recorded in their modern forms by as early as 1226 although the latter also appears as Fieldplumpton.

32. In 1323 at Little Fieldplumpton there were eight cottages and 96 acres of arable land held by tenants at will[71]. The village was relocated during the course of extensive 'improvements' in the 19th century. However an indication of the previous location and extent of the settlement of Little Plumpton is provided by earthwork remains east of the Site close to the A583 (PRN15220) and the extensive remains of ridge and furrow noted in the field to the east of the Site during the walk over survey.

7.6.5 Post Medieval and Later

33. The Tudor antiquarian William Camden[72] in describing the Fylde notes "…this part yieldeth plenty of oats but is not so apt to bear barley. However it is full of fresh pastures…". The Fylde was "once the wheatfield of Amounderness"[73] although by the early 20th century emphasis had shifted to pasture with 1,920 acres of permanent grass in the parish as against 1,157 of arable[74]. The change of use from arable to pasture seems to have taken place after 1850[75] and a snapshot of land use within the study area prior to the change is provided by the details contained within the schedule of the tithe map for the township of Westby with Plumpton prepared in 1840 (see Table 2 at Appendix G):

34. The land in the immediate vicinity of the Site, has been characterised in the Lancashire Historic Landscape Characterisation Assessment as Modern Enclosure (see Appendix G Figure 3).

35. Transformation of the wetlands in the hinterland of Blackpool began in the 18th century with the digging of Main Dyke in 1731 and continued into the 19th century. The Clifton family of Lytham were prominent local landowners and agricultural improvers. Thomas Clifton in particular transformed Little Plumpton in the mid-1840s replacing the village with a single large farmstead and estate workers' cottages, rationalising the field pattern

[69] Middleton et al 1995 p 113 based on an interpretation of the name as 'township of the court'.
[70] Middleton, R et al 1995 p113
[71] Inq. p.m. 17 Edw. II, no. 32 as cited in VCH Lancashire Volume 7 p174-6
[72] William Camden, 1551-1623, compiled his topographical and historical survey *Britannia* from 1577.
[73] VCH Lancashire 7 p68
[74] Ibid p143 quoting 1905 Board of Agriculture figures.
[75] Ibid p 183

into large blocks and shifting the focus further away from arable use to pasture[76]. Comparison of the 1840 tithe map with later Ordnance Survey maps shows the process of re-organisation and consolidation.

7.6.6 Designated Assets

36. There are no World Heritage Sites, Scheduled Monuments, Registered Parks and Gardens, Registered Battlefields, Listed Buildings or Conservation Areas within the 1km study area.

37. There are 34 Listed buildings within the 5km radius study area (see Table 3 at Appendix G). With the exception of Lytham Hall (I) and an associated dovecote (II*) all of the listed buildings within the 5km radius study area are Grade II. Two Conservation Areas fall within the wider study area – St Anne's Road East, 4.5kms south west of the Site and Wrea Green 2.3km to the south east. Lytham Hall Gardens (Grade II Registered Park) fall partly within the 5km radius study area.

7.6.7 Site Visit

38. A site visit was conducted on 7th and 8th January 2014. Access to the Site was unrestricted and the weather was clear and dry (see Appendix G Figures 7.6- 7.9).

39. No extant earthworks were visible in the area of the proposed compound and no surface scatters of finds were noted in the field to the south of the A583 due to the current land use. However, well-marked remains of ridge and furrow were noted in the adjacent field to the east (see Figure 7.8). The ridge and furrow did not extend into the field within which the proposed compound will be located and given the formerly well-watered nature of the area it is likely that the strip fields associated with the settlement of Little Plumpton re-located by Thomas Clifton in 1845 were confined to the slightly higher ground to the east.

40. Marl pits noted on historic OS mapping survive as water filled features in the fields both to north and south of the A583.

7.7 Assessment

7.7.1 Construction of Well Pad and Access

41. There are no known designated heritage assets within the footprint of the Site or in the near vicinity which would be affected by the proposed construction of well pad and access route. There is a slight possibility that hitherto unknown prehistoric assets, most probably of Bronze Age date, might be encountered. If encountered, these are likely to take the form of artefact scatters. Assets of this type would be of local interest, likely to survive in a partially fragmented state and be overall of *low* heritage value.

42. The Site is to be located on an area of former moss enclosed and drained in the late 18th or early 19th Century. It is likely that any former peat deposits have been significantly degraded in the intervening period and the ability of the deposits to preserve palaeoenvironmental evidence is negligible.

[76] See Winchester, A 2006 p93 and passim.

43. The effects from the construction of the well pad and access track would principally come from topsoil clearance and excavation which would expose or remove potential archaeological assets. The effects would be greatest where excavation was deepest, for example in the area of the drilling cellars or drainage ditches, and least where excavation shallowest, for example in the preparation of the access route. The magnitude of this effect would be *major*. The effect would be *slight* or *moderate adverse* and *permanent* representing a **significant** effect.

7.7.2 Installation of Surface and Buried Arrays

Surface array

44. None of the proposed locations for traffic light surface array seismometers falls within the boundary of a designated heritage asset one of the proposed locations falls within 100m of non-designated asset. It is possible that hitherto unknown archaeological assets are present at the proposed locations. The pattern of assets in the vicinity of the Site would suggest that if present they would comprise: artefact scatters of prehistoric, medieval and later date; medieval and later agricultural activity or peat deposits containing palaeoenvironmental data. Remains of this nature would be of *low* heritage value.

45. The installation of the array would involve the excavation of a pit to a depth of approximately 0.80m. The effect on potential hitherto unknown archaeological assets would be limited to the area of the pit that will penetrate topsoil and expose or partially remove any assets that may be present depending on the depth of overlying topsoil. The magnitude of these effects are likely to be *negligible*. The effect would be *neutral* or *slight* and *permanent.* The effect is therefore **not significant**.

Buried array

46. None of the eighty proposed locations for the buried arrays falls within the boundary of designated heritage assets. However 10 of the proposed locations fall within 100m of a non-designated assets or findspot and one within 100m of a Listed Building, Willow Cottage (LBII ref 1072003) (see Appendix G Table 4)

47. It is possible that hitherto unknown archaeological assets are present at the proposed locations. The pattern of assets in the vicinity of the Site suggests that, if present, such remains would comprise either artefact scatters of prehistoric, medieval and later date or would represent medieval and later agricultural activity or would comprise peat deposits containing palaeoenvironmental data. Remains of this nature would be of *low* heritage value.

48. The installation of the array would involve the of a 100m deep borehole. The effect on potential hitherto unknown archaeological remains would be limited to the diameter of the core which can be expected to penetrate the full depth of any potential deposits and the area of the inspection chamber which might not, depending on the depth of overlying topsoil. These effects will be *negligible* in magnitude. The effect would be *neutral* or *slight adverse* and is **not significant** effect. The effect will be permanent.

7.7.3 Drilling

Mobilisation

49. The mobilisation for drilling will involve vehicle movements to and from the Site. Vehicle movements have the potential to produce an effect on heritage assets such as

listed buildings and conservation areas through an increase in noise and vibration. However there are no listed buildings or conservation areas within the immediate vicinity of the Site and the proposed route from the M55 to the Site does not pass near to any listed buildings or through a Conservation Area.

Drilling

50. Assessment of cultural heritage receptors has involved cross reference with the LVIA Chapter relating to setting issues of designated built heritage and registered landscape receptors. See Chapter 14 for details.

7.7.4 Hydraulic Fracturing and initial flow testing

51. Effects are the same as drilling above.

7.7.5 Extended Flow Testing

Construction

52. It is intended that in the event of Extended Flow Testing the gas produced will be removed from the Site via a connection to the gas grid). The connection will take the form of a trenched pipeline. Excavation of a pipeline trench has the potential to have an effect on subsurface archaeological assets should they be present.

53. The proposed route for the connection is described in Chapter 4.

54. There are no known heritage assets on the proposed route of the mains connection. However, there is a slight possibility that hitherto unknown prehistoric remains, most probably of Bronze Age date, might be encountered. Remains, if encountered, are likely to take the form of artefact scatters. Remains of this type would be of local interest, likely to survive in a partially fragmented state and overall of *low* heritage value.

55. The effects from the construction of the well pad and access track would principally come from topsoil clearance and excavation which would expose or remove potential archaeological features or deposits. The effects would be greatest where excavation was deepest, for example in the area of the drilling cellar or drainage ditches, and least where excavation shallowest, for example in the preparation of the access route. The magnitude of this effect would be *major*. The effect would be *slight* or *moderate adverse* and *permanent* representing a significant effect.

Operation

56. No significant effect.

7.7.6 Decommissioning and Restoration

Extended Well Testing Infrastructure

57. The effect of decommissioning Well Testing Infrastructure would be limited to additional vehicle movements which might have an effect on receptors such as listed buildings and conservation areas at a distance from Site the as noted above in the mobilisation phase.

Exploration well, pad and access track

58. As above.

7.8 Cumulative and Interactive Effects

59. Given that activities at the Site will be conducted in parallel with those at the Roseacre Wood Site, there is the potential for a cumulative effect. The cumulative effects of construction are not likely to be significant in view of the substantial separation between the two sites.

60. Cumulative effects from the traffic associated with both sites are not likely. The only section of the road network where both Projects will have an effect is the M55 where there are no heritage receptors that could be affected.

61. The installation of the seismic arrays is unlikely to result in a significant heritage effect in view of the negligible impact at each location and the substantial extent of the array spread.

62. There are no known development projects which are likely to have a cumulative or interactive effect when combined with the proposed activities at the Site.

7.9 Mitigation Measures

7.9.1 Construction of Well Pad, Access track and connection to gas grid

63. The potentially significant effects from construction of the well pad and access track can be mitigated by implementing a programme of archaeological works to preserve by record any remains within those areas. The review of the heritage baseline does not support the requirement for pre-construction evaluation of the site. It is concluded that the most appropriate way to implement a scheme of investigation would be to carry out a strip, map and record exercise during the excavation of the topsoil if the monitoring archaeologist identifies any features requiring further investigation.

7.9.2 Installation of Surface and Buried Arrays

Surface network

64. The assessed effects derived from the installation of the surface array represent a less than significant effect and no mitigation is proposed.

Buried array

65. No mitigation required.

7.9.3 All other Project activities

66. No mitigation required.

7.10 Residual Effects

67. All significant effects will be mitigated. It is not proposed to mitigate the installation of buried and surface arrays as the effect has been assessed as **not significant.** In this case the Residual Effect are *neutral* or slight adverse.

7.11 Assessment Summary Matrix

68. The Assessment Summary Matrix below addresses permanent effects only.

Table 7.7. Archaeology and cultural heritage assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad and Access			
Exposure or removal of hitherto unknown archaeological remains	**Significant**	Archaeological strip, map and record	**Not Significant**
Installation of the Surface and Buried arrays			
Removal of hitherto unknown archaeological remains	**Not Significant**	No mitigation required	**Not Significant**
Drilling			
Not applicable	**Not Significant**	Not required.	**Not Significant**
Hydraulic fracturing			
Not applicable	**Not Significant**	Not required.	**Not Significant**
Initial Flow Testing			
Not applicable	**Not Significant**	Not required.	**Not Significant**
Extended Flow Testing			
Removal of hitherto unknown archaeological remains in pipeline trench	**Significant**	Archaeological strip, mao and record.	**Not Significant**
Decommissioning and Restoration			
Not applicable	**Not Significant**	Not required.	**Not Significant**

8 Greenhouse Gas Emissions

Chapter Summary- Greenhouse Gas Emissions

This chapter assesses calculates and describes the potential greenhouse gas emissions (GHG) from the Project. It does this by taking data about the Project (e.g. quantity of gas burnt in the flares and vehicle movements) and applies factors that allow the GHG emissions from the Project to be calculated.

There is no methodology to determine the significance of the emissions associated with the Project. However, although the significance cannot be assessed the assessment compares the greenhouse gas emissions from the Project to UK national GHG emissions for 2012 (which is the most recent year that the government has published data for).

The assessment has used data provided by Cuadrilla from previous projects on the amount of fuel or energy used. Where this data was not available other sources of information have been used. Where this is the case, ranges have been applied where possible. In addition, more than one source of emission factors have been applied to provide a ranged result where possible, this is to make allowance for uncertainties associated with the project.

The greatest source (73%) of the project GHG emissions come from burning the gas in the flare. The total Project GHG emissions could be between 118,418 (lower range) to 124,397 (higher range) tCO_2e. The higher range is the equivalent of 0.002% of the current UK Carbon Budget set by the government and as such the Project's potential contribution to national GHG emissions is negligible. Furthermore, due to the conservative nature of the assessment there is potential for the actual GHG emissions to be even smaller.

8.1 Introduction

1. This chapter presents an assessment of greenhouse gas (GHG) emissions associated with the Project. The scope of the assessment is confined to the exploration stage of the natural gas extraction process and relates solely to the activities described in Chapter 4.

8.2 Key Development Issues

2. Both direct and indirect GHG emissions have been assessed. Direct emissions are GHGs emitted directly by activities associated with the Project, such as the combustion of fossil fuels by on-site generators or through the flares. Indirect emissions consist of GHGs emitted outside of the direct influence of the Project (either further up or down the supply chain). For example, GHG emissions associated with the production, extraction, refining and transport of diesel used to power generators and trucks (referred to in this assessment as well-to-tank), or the treatment of flowback fluid are defined as indirect emissions. A more detailed summary of emission sources associated with the Project, and whether or not they are direct or indirect, is included in Table 8.2.

8.3 Scoping and Consultation

3. The GHG emissions section of the Scoping Report[77] outlined the proposed approach for assessment of GHG emissions. Further to this, the assessment has taken into account the

[77] Submitted to Lancashire County Council on 4th February 2014.

Scoping Opinion from Lancashire County Council (LCC) dated 11th March 2014, and stakeholders, set out in Table 8.1 below.

Table 8.1. Carbon scoping and consultation overview.

Consultee	Comment	Response
Natural England	The ES should identify how the development's effects on the natural environment will be influenced by climate change and how ecological networks will be maintained.	Given the duration of the project (max. 6 years in total) the extent of significant climatic changes occurring is low. Impacts on ecological networks are assessed in chapter 10 of this ES.
CPRE Lancashire	The extent of fugitive emissions and potential impacts on atmospheric methane concentration should be understood and assessed as part of the EIA.	The potential impact from fugitive emissions are assessed within this chapter, see section 8.7.
Environment Agency	We will expect the applicant to demonstrate that any fugitive emissions of methane from the site will be contained in full and for this to be demonstrated through the EIA process. The ES should include details of how the applicant intends to achieve this.	The potential impact from fugitive emissions are assessed within this chapter, see section 8.7.
Public Health England	The assessment should fully account for fugitive emissions, including specific hydrocarbon concentrations and emissions of unburned gas due to leakage, and the potential odour impact and effect on greenhouse gases.	The potential impact from fugitive emissions are assessed within this chapter, see section 8.7.

8.4 Methodology

4. This section explains the approach to GHG assessment. The total GHG emission of the Project is referred to as the 'carbon footprint'. The scope of the assessment includes all of the activities described in Chapter 4 of this ES.

5. The carbon footprint includes both direct and indirect emissions associated with the Project. For each emission source, more than one conversion factor was used, where possible, to provide an upper and lower ranged result, and to account for any uncertainty associated with the input data based on different conversion factors. Sources of conversion factors used in this assessment include Defra/DECC[78], GHG Protocol[79], ICE[80] and United States Energy Information Administration[81]. Where assumptions have been used in the footprint, such as the daily gas flow rate during flaring, the assessment has adopted a worst-case scenario approach. A full list of assumptions used to create the carbon footprint is included in Appendix H.

[78] Defra (2012, 2013) Conversion Factors for Company Reporting.
[79] World Resources Institute (2008) GHG Protocol tool for stationary combustion. Version 4.
[80] ICE Inventory of Carbon and Energy Version 2.0.
[81] US Energy Information Administration: Carbon Dioxide Emissions Coefficients by Fuel.

6. The carbon footprint is reported as tonnes of CO_2 equivalent (tCO_2e)[82]. This takes into account the six main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydroflurocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Table 8.2 below summarises the emission sources occurring at each stage of the Project.

[82] The OECD define a CO_2 equivalent as follows. "Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tons of methane is equivalent to emissions of 21 million metric tons of carbon dioxide. http://stats.oecd.org/glossary/detail.asp?ID=285

Table 8.2: GHG emission sources matrix.

		Direct emissions					Indirect or embedded emissions					
		Logistics		Site emissions			Well-to-tank (WTT) of fossil fuel	Materials	Water		Waste	
		Transportation	Staff travel	On-site machinery	Flaring	Fugitive emissions			Process	Welfare	Waste water	Solid waste
		Transportation of materials, machinery and waste to and from site.	Staff and visitors travelling to and from site.	Such as diesel engines used for drilling, hydraulic fracturing and on-site electricity generation.	The flaring of natural gas including methane emissions resulting from incomplete combustion.	Unintentional releases of gas.	Emissions associated with the production of fuel (petrol / diesel) that is used on the Project.	The production of materials used in the Project, including granular fill, drilling mud, cement, steel casing, sand and chemicals.	Water used in the Project, supplied through mains water system.	Water used for on-site welfare, supplied through mains water system.	The treatment of waste water resulting from the Project.	The treatment of solid waste including inert, non-hazardous and hazardous waste.
On-site	Construction	✓	✓	✓			✓	✓		**	**	✓
	Drilling	✓	✓	✓			✓	✓	✓	✓	✓	✓
	Hydraulic fracturing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Initial flow testing	✓	✓	✓	✓	✓	✓			✓	✓	✓
	Extended flow testing	✓	✓	✓	*	✓	✓			**	**	✓
	Decommissioning and restoration	✓	✓	✓			✓			**	**	✓
Off-site	Installation of surface network & buried array	✓	✓	✓						**	**	✓

*During extended flow testing, the well(s) will be connected to the gas mains. An emergency flare will be present but only used if required. If gas has to be flared during extended flow testing the impacts from any emissions will be negligible, therefore it will not be included in the quantitative assessment.
**Indicates where emissions are considered negligible.

7. The following sections describe the assessment approaches used for the baseline, construction of the well pad, installation of surface and buried array, operation and decommissioning of the Project.

8.4.1 Baseline methodology

8. The baseline GHG emissions at the Site (i.e. without the Project) are negligible in its current state as an agricultural field. However, to allow the quantified GHG emissions associated with the Project to be compared to other UK emissions, contextual baseline data has been reviewed and collated. This review included the Department of Energy and Climate Change (DECC) UK GHG emissions 2012, National Planning Policy Framework, DECC energy trends[83] and DECC 2012 UK GHG by fuel type and end-user[84]. The following aspects have been covered as part of the baseline assessment:

- The international, European and national policy background;
- National GHG emissions;
- UK energy statistics and trends; and
- Natural gas from shale's potential impact on the carbon intensity of UK energy.

9. This assessment is only concerned with the GHG emissions from the exploratory and appraisal stages of the natural gas extraction process. On this basis, making baseline comparisons to UK projected emissions associated with energy generation/ production is not appropriate. However, should this Project demonstrate that shale gas production is viable in the Fylde then this type of comparative carbon footprint analysis may be required as part of future EIAs.

8.4.2 Assessment methodology for the effects from installation of surface and buried array

10. The main emission sources associated with the installation of surface network are described in Table 8.2 and Appendix H.

8.4.3 Assessment methodology for the effects from construction

11. The key parameters, such as duration of this element of the Project can be found in Appendix B. The main emission sources associated with the construction phase of the Project are described in Table 8.2 and Appendix H.

8.4.4 Assessment methodology for operational effects

8.4.4.1 Drilling

12. The main emission sources associated with drilling are described in Table 8.2. The methodology used to calculate emissions from transportation, staff travel, on-site machinery, well-to-tank (WTT) emissions, materials, water and waste is the same as construction and can be found in Appendix H.

[83] Department of Energy & Climate Change (2013) Energy Trends
[84] Department of Energy & Climate Change (2012) 2012 UK GHG, provisional figures and 2011 UK GHG, final figures by fuel type and end-users

13. During drilling, a mud gas separator will be used so that if gas is entrained in the mud it can be vented safely. Although venting might occur, its duration would be short-lived and emission impact will be negligible; therefore this is not included in the quantitative assessment.

8.4.4.2 Hydraulic fracturing

14. The main emission sources associated with hydraulic fracturing are described in Table 8.2 above. The methodology used to calculate emissions from transportation, staff travel, on-site machinery, WTT, materials, water and waste is the same as construction and can be found in Appendix H.

15. The methodologies for assessing flaring and fugitive emissions are detailed in Appendix H. Although these two types of emissions occur during both hydraulic fracturing and initial flow testing, their effects have been assessed as a whole under initial flow testing.

8.4.4.3 Initial flow testing

16. The main sources of emissions are described in Table 8.2 above. The methodology used to calculate emissions from transportation, staff travel, on-site machinery, WTT, water and waste can be found in Appendix H.

17. The methodology used to calculate flaring and fugitive emissions can be found in Appendix H. Flaring and fugitive emissions associated with the Project have been modelled and assessed as a whole under the Initial Flow Testing phase. Therefore, they will not be covered under the assessments for Hydraulic Fracturing and Extended Flow Testing in this report.

8.4.4.4 Extended flow testing

18. During this period, the well will be connected to the gas mains, therefore no flaring would occur. However, a small flare stack will be in place for safety and emergency reasons only. This has been included in Table 8.2 above.

19. The methodology used to calculate emissions from transportation, staff travel, on-site machinery, WTT and waste can be found in Appendix H.

8.4.5 Assessment methodology for suspension, decommissioning and restoration effects

20. The sources of emission for both suspension and decommissioning are as described in Table 8.2 and Appendix H.

8.5 Assumptions and limitations

8.5.1 Data gaps and assumptions

21. The data used in the assessment is based on the knowledge and experience that Cuadrilla have gained from drilling exploration wells and undertaking hydraulic fracturing in the UK. This represents the best available data at the time of assessment. As a result secondary data sources (such as GHG emissions in published data) have not had to be used.

22. Although the quantities of additives (used in addition to sand and water) in the hydraulic fracturing fluid are known there were no relevant greenhouse gas emissions factors for these materials (either in the Defra emissions factors or the University of Bath's Inventory of Carbon and Energy). Therefore the greenhouse gas emissions presented in this chapter do not included the embedded emissions associated with manufacture of the additives. However, it is concluded that this is not a major problem for the assessment because the total quantity of additives that would be used is small in comparison with the quantity of diesel fuel consumed and the amount of gas burnt in the flares.

8.5.2 Embedded mitigation

23. Embedded mitigation measures will have beneficial effects on the Project's carbon footprint and have been reflected in the calculations of this assessment. A list of these mitigation measures is provided below:

- Use and maintenance of all equipment and pipework in accordance with the manufacturers specifications;
- Undertake hydrostatic pressure testing of all pipework and equipment used to process or move the gas around the Site. This testing is used to identify potential leaks e.g. connections between pipes. It is carried out before the equipment is used to confirm that all seals and connections are working before the system is contains gas.
- The use of an enclosed completions system which separates gas, solids and liquids so that the gas can be burnt via the flare instead of being vented from tanks or lagoons;
- Flaring of gas once separated from the flowback fluid via the enclosed completions equipment; and
- Fugitive emissions monitoring will be undertaken across the site at regular intervals. If fugitive emissions were to be found measures to fix the leak or replace faulty equipment would be undertaken to prevent the leak from continuing.

8.6 Baseline

8.6.1 Climate change policies and GHG targets

8.6.1.1 Europe

24. The EU Emission Trading Scheme (EU ETS) is an EU-wide cap-and-trade mechanism operates in the 28 EU countries and the three EEA-EFTA states (Norway, Lichtenstein and Iceland). The scheme sets total amount of allowable annual GHG emission for energy intense industries and commercial flights. The scheme covers around 45% of the EU's GHGs. According to the Environment Agency, emissions from flaring are covered under EU ETS.

25. To date, two operational phases of the EU ETS have been delivered. The current phase, phase three, will run from 2013 to 2020 and is likely to coincide with the delivery of the Project. By the end of the second phase in 2012, the actual allocation to UK installations covered by the EU ETS was confirmed to be 229 $MtCO_2$[85]. Taking into account of a EU commitment of 1.74% reduction of available allowance each year during phase three, by the middle of phase three (2016) the UK allocation may be reduced to a level of approximately 213 $MtCO_2$.

[85] DECC (2014) EU Emissions Trading System. Available from: www.gov.uk.

26. The European Commission has issued guidance on "integrating Climate Change and Biodiversity into Environmental Impact Assessment" to help improve the systematic integration of both biodiversity and climate change within EIAs. In terms of GHG emissions it states that the direct impact from construction operation and perhaps decommissioning should be assessed, as well as from land use, land use change and forestry. Indirect impacts might include energy demand, supporting infrastructure and personal travel and freight transport.

8.6.1.2 National

The Climate Change Act

27. The Climate Change Act (2008) establishes a framework for the UK to achieve its long-term goals of reducing GHG emissions by at least 80% from 1990 levels by 2050 and to ensure that steps are taken towards adapting to the impact of climate change. An interim target of 34% reduction from 1990 by 2020 has also been agreed. Some of the key measures provided by the CCA include:

- Decarbonising the grid supply, such as renewable source of energy;
- Cleaner transport modes such as electric and hybrid vehicles;
- Energy efficiency measures in the built environment; and
- Behavioural changes.

The Carbon Plan, 2011

28. The Carbon Plan[86] sets out the Government's plans for achieving the GHG emissions reductions committed to in the Climate Change Act and the first four carbon budgets. The strategy for energy as set out in the Carbon Plan includes:

- Reduce emissions from electricity generation through increasing the use of gas instead of coal, and more generation from renewable sources;
- Support the deployment of major low carbon technologies through providing financial incentives; and
- Support the development of less mature renewable technologies such as marine and offshore technologies.

The second carbon budget

29. Carbon budgets were introduced as part of the Climate Change Act 2008. The first four 5-year budgets have been set in law from 2008-2027. The budgets are split into traded and non-traded carbon. A limit on UK carbon emissions is imposed for each 5-year period, which means that where emissions rise in one sector, the UK will have to achieve corresponding falls in another.

30. Some of the GHG emissions associated with the Project will fall under the non-traded sector. Under the second carbon budget period, which runs between 2013 and 2017, the non-traded sector has a budget of 2,782 $MtCO_2e$[87].

[86] HM Government (2011) The Carbon Plan: Delivering our low carbon future. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47613/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf
[87] *Ibid* page 3.

National and regional planning policies

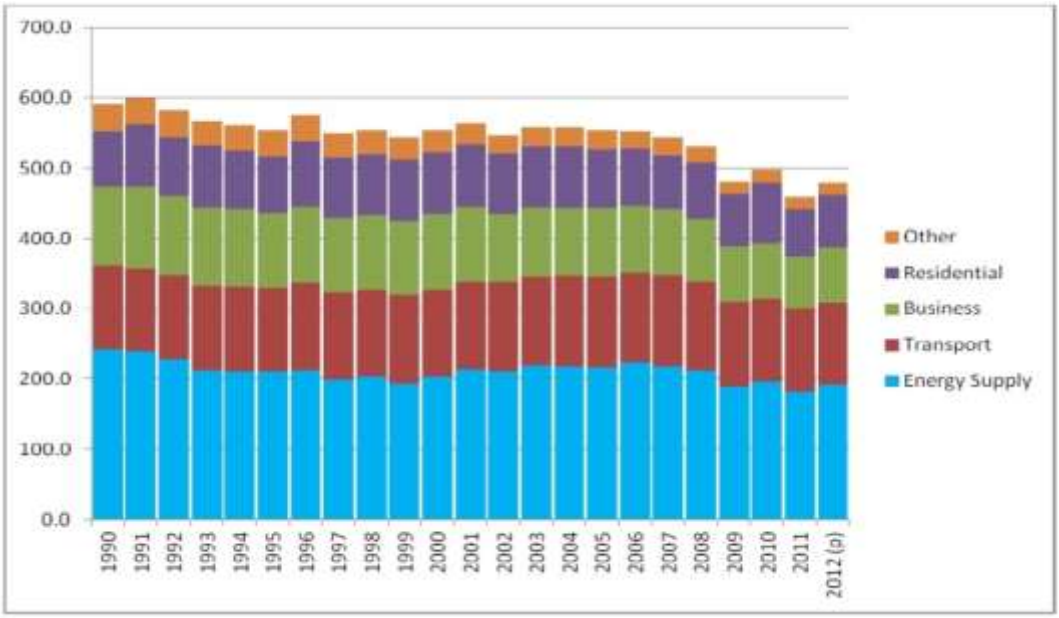
31. The National Planning Policy Framework[88] sets out the core principles for delivering sustainable development. One of the principles is '*meeting the challenge of climate change, flooding and coastal change*'. To support the move to a low carbon future, local planning authorities should encourage developments that contribute towards the UK's GHG reduction target.

Lancashire County Council's climate change strategy[89] sets out the regional long-term objective to achieve a 'low carbon and well adapted Lancashire by 2020'. It recognised that one of the means to achieve this is to decarbonise the existing regional energy supply.

8.6.2 UK GHG emissions

32. Figure 8.1 below shows the carbon dioxide emissions by source between 1990 and 2012. According to DECC's statistical release on UK GHG emissions[90] the energy supply sector was the largest contributor to the increase in CO_2 emissions between 2011 and 2012. Emissions from this sector were provisionally estimated to be 192.1 Mt in 2012, an increase of around 5% compared to 2011.

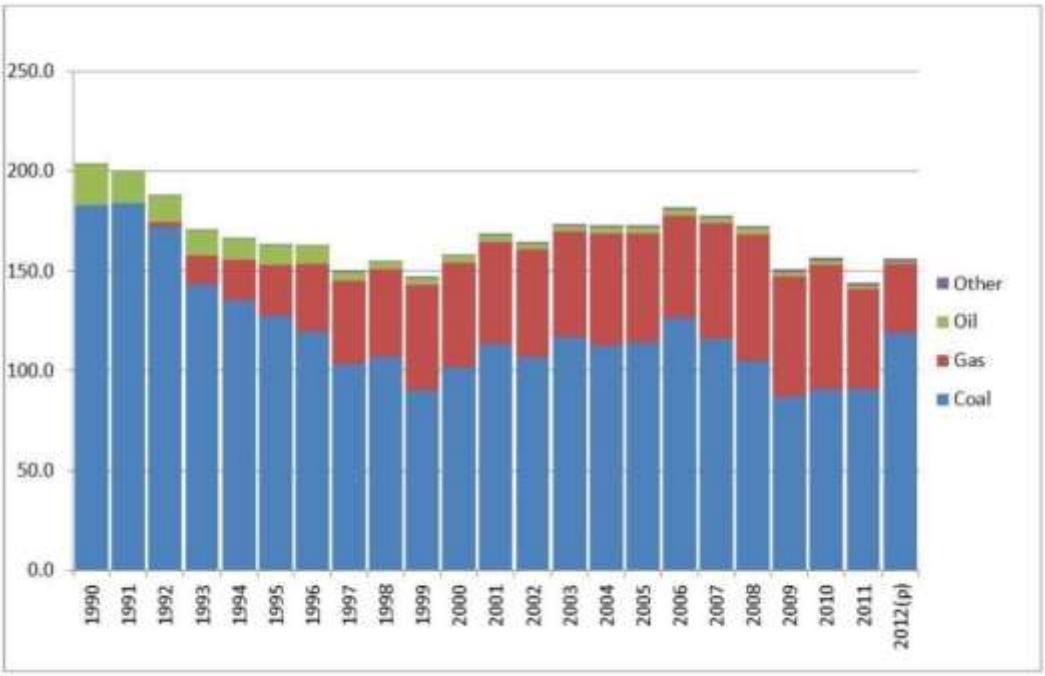
Figure 8.1: Carbon dioxide emissions by source in Mt, 1990-2012 (source: DECC).



33. The increase in emissions from this sector since 2010 can almost entirely be attributed to power stations. Although demand for electricity was broadly unchanged, there was a substantial change in the make-up of fuel used at power stations for electricity generation, with significantly less gas and significantly more coal being used. The figure below illustrates the impact on emissions of the change in the fuel mix for electricity generation between 1990 and 2012.

[88] Communities and Local Government (2012) National Planning Policy Framework.
[89] Lancashire County Council (2009) The Lancashire Climate Change Strategy 2009 – 2020.
[90] DECC (2013) Statistical Release: 2012 UK GHG emissions, provisional figures and 2011 UK GHG emissions, final figures by fuel type and end-user.

Figure 8.2: Carbon dioxide emissions from electricity generation in $MtCO_2e$ between 1990 and 2012. (source: DECC)



8.7 Assessment

34. This section discusses the results of the assessment. Overall findings are presented first, followed by a breakdown of each stage of the Project.

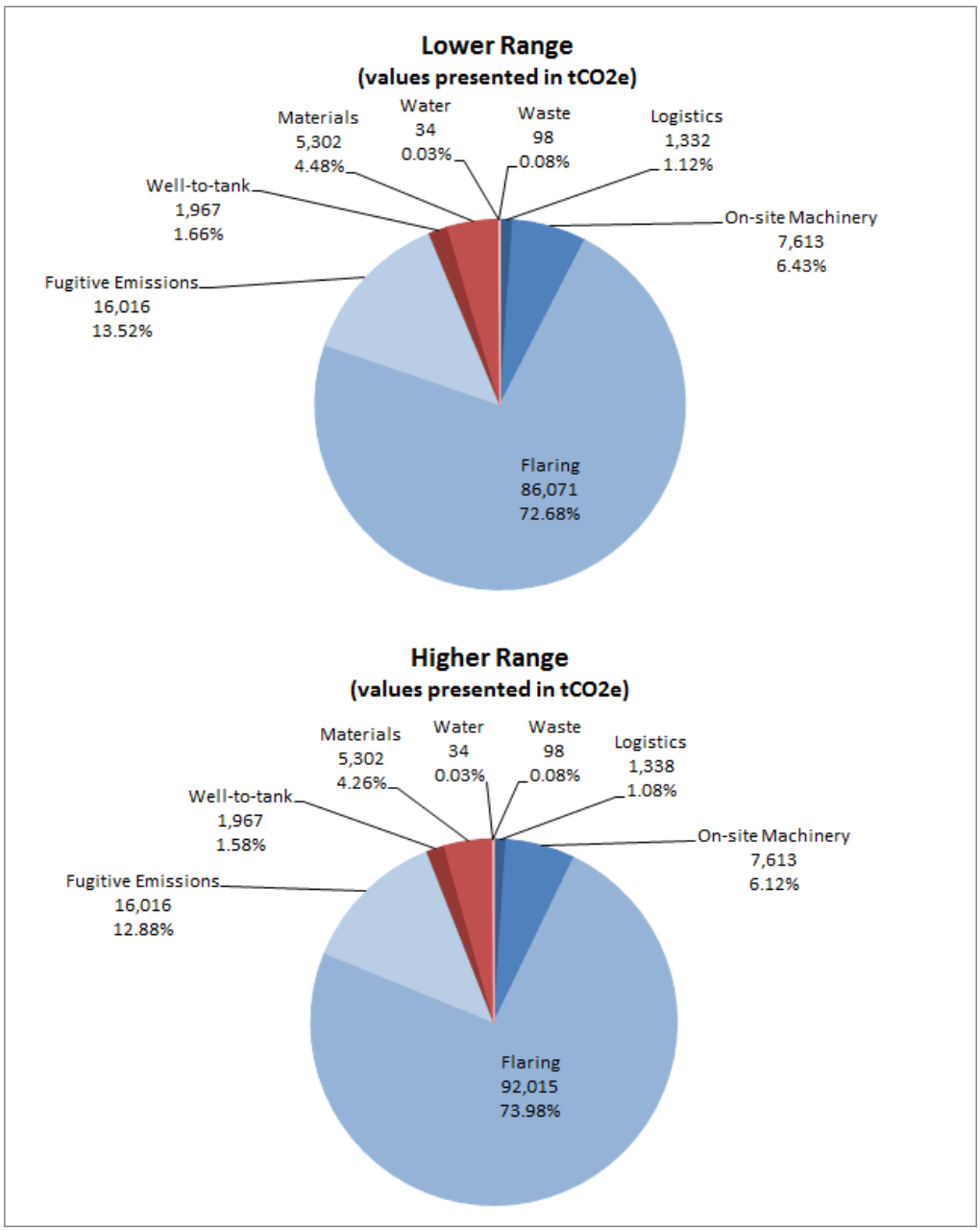
35. The anticipated total GHG emissions associated with the Project is assessed as being in the range of 118,435 to 124,386 tCO_2e. It should be noted that these impacts are only for the exploration stage (i.e. the 6 year period identified in section 4.3.2. This is made up of approximately 94% direct emissions and 6% indirect emissions. Table 4 below provides upper and lower ranges and average results, for each of the emission sources.

Table 8.3 GHG emissions by source (ranged result in tCO_2e).

Emission source	Lower range	Upper range	Average
Logistics	1,335	1,341	1,338
On-site machinery	7,613	7,613	7,613
Flaring	86,071	92,015	89,043
Fugitive emissions	16,016	16,016	16,016
Direct Emissions Subtotal	***111,034***	***116,985***	***114,009***
Well-to-tank	1,968	1,968	1,968
Materials	5,302	5,302	5,302
Water	34	34	34
Waste	98	98	98
Indirect Emissions Subtotal	***7,401***	***7,401***	***7,401***
Total	**118,435**	**124,386**	**121,410**

36. Figure 8.3 below shows the range of GHG emissions by emission source for all of the activities associated with the Project. Approximately 70% of the Project greenhouse gas emissions can be attributed to flaring, which will be captured under the EU ETS. With the embedded mitigation measures that are proposed fugitive gas emissions from the Site are expected to consist of un-combusted methane as a result of incomplete combustion in the flare, accounting for 13% of the total emissions. The embedded mitigation measures proposed are known to achieve an estimated reduction in fugitive emissions of 97% - 98%[91]. Amongst indirect emission sources, materials are the most significant, contributing to 4% of the Project carbon footprint.

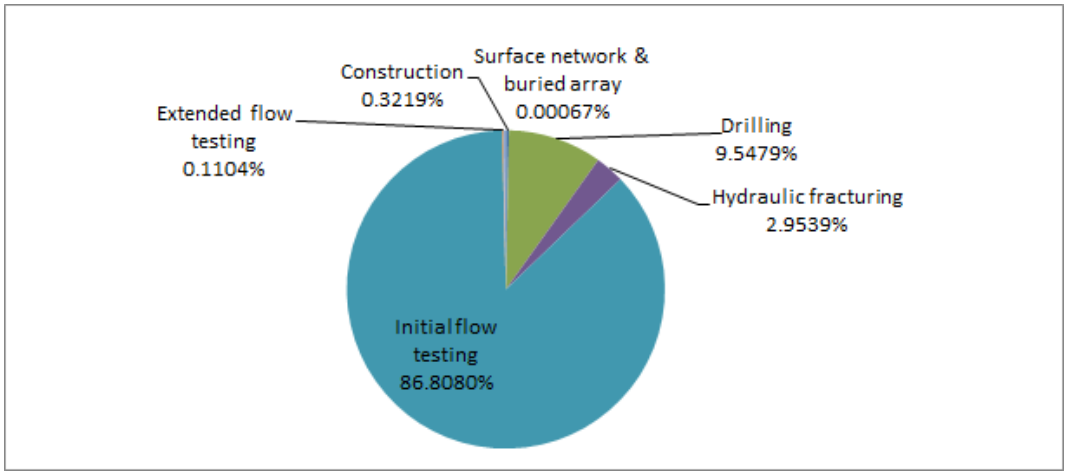
Figure 8.3 Percentage GHG emissions by source for the entire Project.



[91] Allen *et al*. (2013) Measurements of methane emissions at natural gas production sites in the United States.

37. Figure 8.4 shows GHG emission by Project stage. Initial flow testing is the most significant contributor due to flaring, accounting for approximately 87% of the Project carbon footprint. The drilling stage is the second largest contributor, accounting for approximately 10% of total emissions. The remaining stages collectively account for approximately 3%.

Figure 8.4 GHG emissions by Project stage (graph showing an average of lower and higher range).



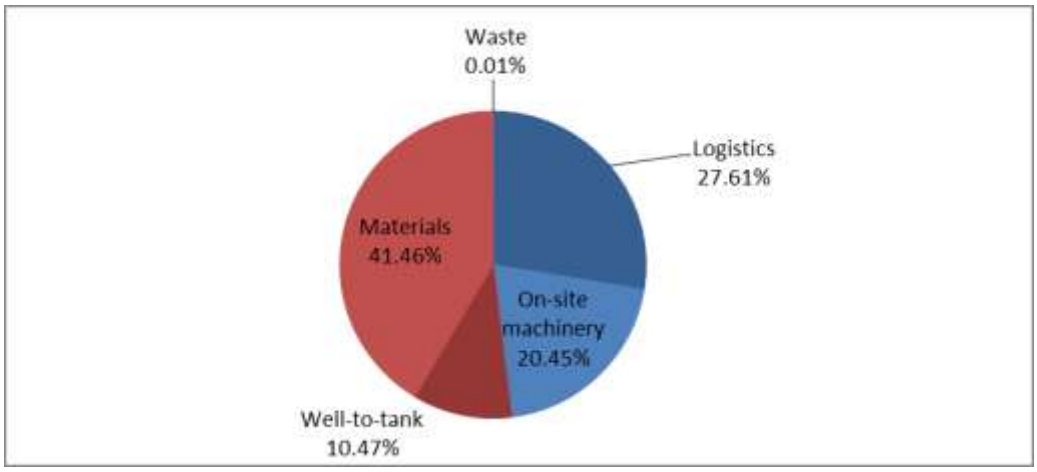
8.7.1 Construction of Well Pad and Access

38. GHG emissions associated with the construction of well pad and access track are listed in Table 8.4. The total emissions are approximately 391 tCO_2e, of which 48% are direct emissions and 52% are indirect emissions. The most significant emission sources at this stage are logistics and materials (primarily importing crushed stone to construct the access track and well pad), accounting for 28% and 41% respectively. This is closely followed by on-site machinery at 20%.

Table 8.4: GHG emissions during construction (tCO_2e).

Emission source	Lower range	Upper range	Average
Logistics	107.6	108.1	107.9
On-site machinery	80(average)	80(average)	80
Direct Emissions Subtotal	**187.6**	**188.1**	**187.8**
Well-to-tank	41(average)	41(average)	41
Materials	162(average)	162(average)	162
Waste	0.1(average)	0.1(average)	0.1
Indirect Emissions Subtotal	**203**	**203**	**203**
Total	**390.5**	**391.0**	**390.8**

Figure 8.5: Percentage GHG emissions by source for construction.



8.7.2 Installation of Surface and Buried Arrays

39. GHG emissions associated with the installation of surface and buried array are listed in Table 8.5. The total emissions are approximately 42.5 tCO_2e, of which the largest emission source is logistics. The GHG emission from this stage is relatively small, accounting for less than 1% of the Project carbon footprint.

Table 8.5 GHG emissions during the installation of surface and buried array (tCO_2e).

Emission source	Lower range	Upper range	Average
Logistics	3.5	3.6	3.6
On-site machinery	38 (average)	38 (average)	38.1
Direct Emissions Subtotal	**41.6**	**41.7**	**41.7**
Well-to-tank	0.8 (average)	0.8 (average)	0.8
Waste	Not applicable.		
Indirect Emissions Subtotal	**0.3 (average)**	**0.3 (average)**	**0.3**
Total	**1.4**	**1.5**	**1.4**

8.7.3 Drilling

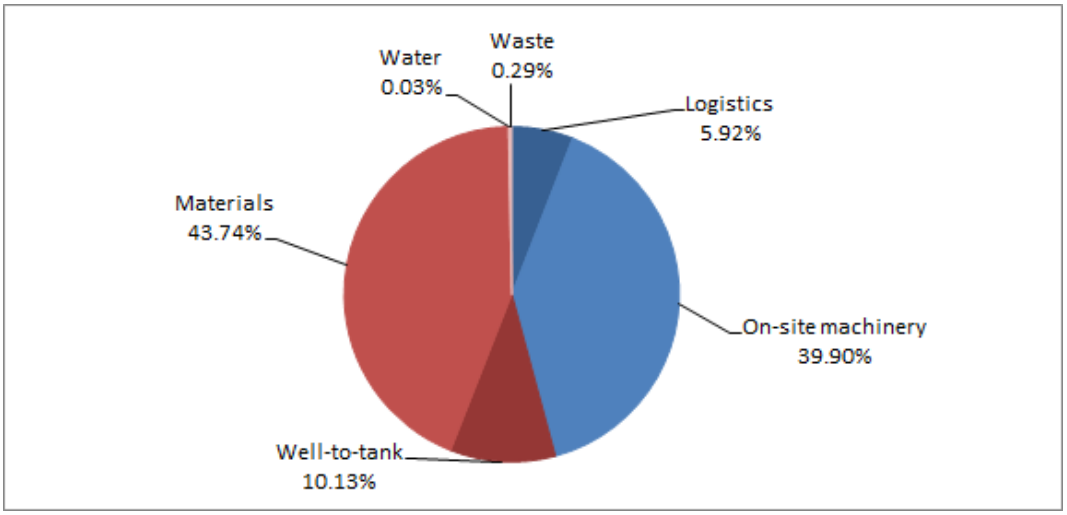
40. GHG emissions associated with drilling are listed in Table 8.6. The total emissions are approximately 11,592 tCO_2e, of which 46% are direct emissions and 54% are indirect emissions. The most significant emission sources at this stage are on-site machinery and materials, which both account for about 40% of the total drilling emissions. This is followed by well-to-tank emissions at 10% and logistics at 6%.

Table 8.6: GHG emissions during drilling (tCO_2e) for all four wells.

Emission source	Lower range	Upper range	Average
Logistics	684	688	686
On-site machinery	4,625 (average)	4,625 (average)	4,625
Direct Emissions Subtotal	**5,309**	**5,312**	**5,311**
Well-to-tank	1,174 (average)	1,174 (average)	1,174

Emission source	Lower range	Upper range	Average
Materials	5,070 (average)	5,070 (average)	5,070
Water	3 (average)	3 (average)	3
Waste	33 (average)	33 (average)	33
Indirect Emissions Subtotal	**6,281 (average)**	**6,281 (average)**	**6,281**
Total	**11,590**	**11,593**	**11,592**

Figure 8.6: Percentage emissions by source for drilling.



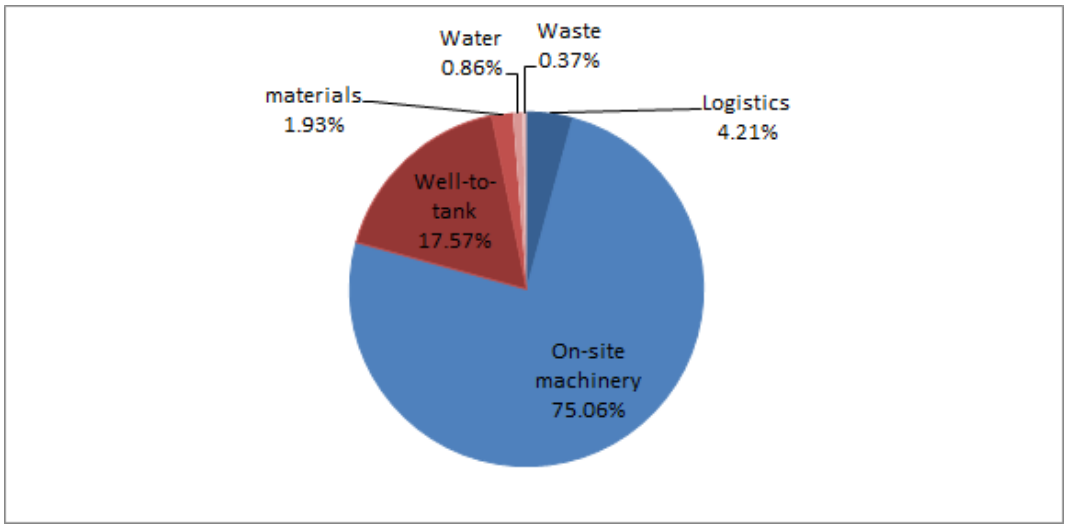
8.7.4 Hydraulic Fracturing

41. GHG emissions attributable to hydraulic fracturing are listed in Table 8.7. The total emissions are approximately 3,581 tCO_2e, of which 79% are direct emissions and 21% are indirect emissions. On-site machinery is the largest emission source at this phase of the development at 75%. This is followed by well-to-tank at 18%, logistics at 4% and materials at 2%.

Table 8.7: GHG emissions during hydraulic fracturing (tCO_2e) for all four wells.

Emission source	Lower range	Upper range	Average
Logistics	150	152	151
On-site machinery	2,692 (average)	2,692 (average)	2,692
Direct Emissions Subtotal	**2,842**	**2,843**	**2,843**
Well-to-tank	630 (average)	630 (average)	630
Materials	69 (average)	69 (average)	69
Water	31 (average)	31 (average)	31
Waste	13 (average)	13 (average)	13
Indirect Emissions Subtotal	744 (average)	744 (average)	744
Total	**3,581**	**3,582**	**3,582**

Figure 8.7: Percentage GHG emissions by source for hydraulic fracturing.



8.7.5 Initial flow testing

42. GHG emissions associated with initial flow testing are listed in Table 8.8. The total emissions are approximately 105,391 tCO_2e, of which more than 99% are direct emissions. The most significant emission source at this stage is flaring, accounting for over 84% of initial flow testing emissions. Based on a fugitive methane emission rate of 2%[92] (by volume) GHG emissions from this source are estimated to amount to approximately 15% of all GHG emissions associated with the project (see Figure 8.3).

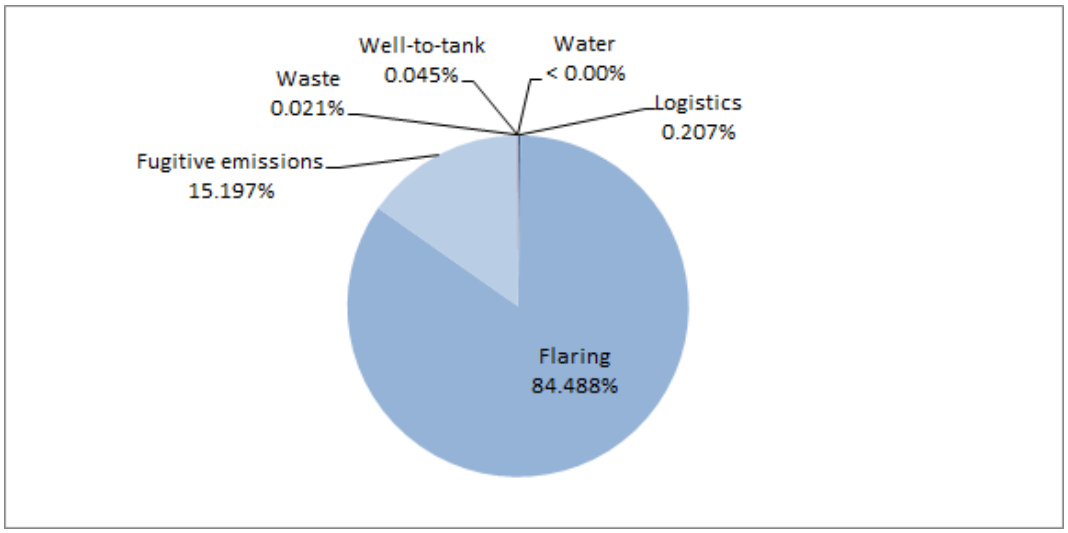
43. Flaring is a necessary part of the the Project because it allows the quantity and rate at which natural gas from the shale rock to be determined. Using this information Cuadrilla can determine an initial production rate for the shale rock and use this data to evaluate the potential natural gas resources in the shale.

Table 8.8: GHG emissions during flow testing (tCO_2e) for all four wells.

Emission source	Lower range	Upper range	Average
Logistics	218	219	218
On-site machinery	45	45	45
Flaring	86,071	92,015	89,043
Fugitive emissions	16,016	16,016	16,016
Direct Emissions Subtotal	***102,350***	***108,295***	***105,322***
Well-to-tank	47	47	47
Water	0.1	0.1	0.1
Waste	22	22	22
Indirect Emissions Subtotal	***69***	***69***	***69***
Total	**102,418**	**108,363**	**105,391**

[92] See appendix H; Table 16: Allen *et al*. (2013) Measurements of methane emissions at natural gas production sites in the United States. NB this study has been selected since it focuses on the well completion stage of shale gas exploration rather than the whole lifecycle of production wells. The study sampled 27 well completions across four geographical regions of shale formation in the US.

Figure 8.8: Percentage GHG emissions by source for flow resting.



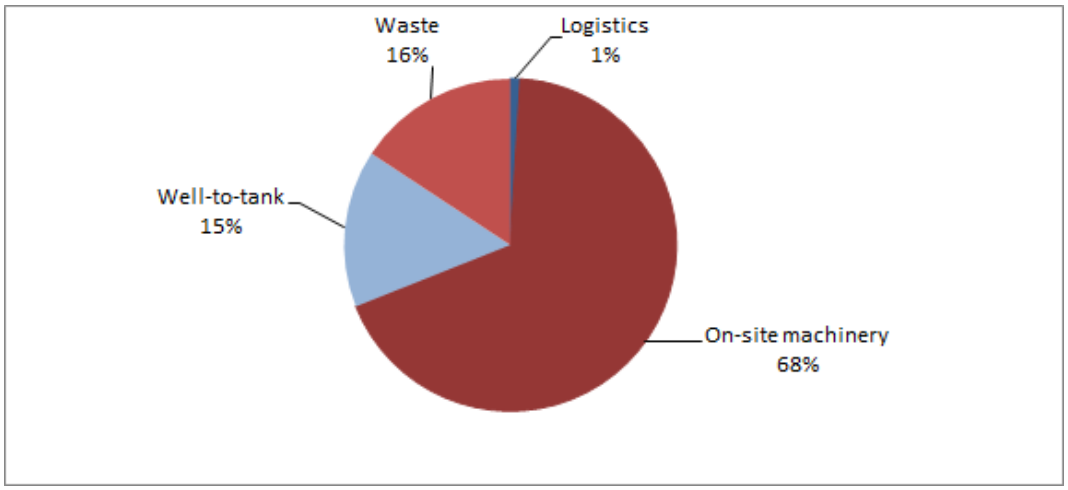
8.7.6 Extended flow testing

44. GHG emissions associated to Extended Flow Testing are listed in Table 8.9. The total emissions are approximately 134 tCO_2e, of which 69% are direct emissions and 31% are indirect emissions.

Table 8.9: GHG emissions during extended well testing (tCO_2e) for all four wells

Emission source	Lower range	Upper range	Average
Logistics	1.3 (average)	1.3 (average)	1.3
On-site machinery	91.1(average)	91.1 (average)	91.1
Direct Emissions Subtotal	92.4 (average)	92.4 (average)	92.4
Well-to-tank	20.5 (average)	20.5 (average)	20.5
Waste	21.1	21.1	21.1
Indirect Emissions Subtotal	41.6	41.6	41.6
Total	134.0	134.0	134.0

Figure 8.9: Percentage GHG emissions by source for extended well testing.



8.7.7 Decommissioning and Restoration

45. GHG emissions associated with decommissioning and restoration are listed in Table 8.10. The total emissions are approximately 312.3 tCO_2e, which is largely made up of logistics and on-site machinery emissions. The GHG emission from this stage is relatively small, accounting for less than 1% of the Project carbon footprint.

Table 8.10: GHG emissions during decommissioning and restoration (tCO_2e).

Emission source	Lower range	Upper range	Average
Logistics	169.5	170.2	169.9
On-site machinery	80	80	80
Direct Emissions Subtotal	***249.4***	***250.2***	***249.8***
Well-to-tank	54	54	54
Waste	8.3	8.3	8.3
Indirect Emissions Subtotal	***62***	***62***	***62***
Total	**311.9**	**312.7**	**312.3**

8.8 Cumulative and Interactive Effects

8.8.1 Preston New Road and Roseacre Wood

46. The assessment of cumulative GHG effects has taken into consideration of the proposed natural gas exploration project at Roseacre Wood. The Roseacre Wood Project involves the same activities as this Project. Their combined emissions have been calculated as twice their individual emissions. Assuming both projects would take place within the same Carbon Budget period, the cumulative carbon footprint would still be relatively insignificant and accounts for less than 0.002% of the UK Carbon Budget and just under 0.1% of the projected EU ETS UK allocation at 2016 level (mid-point of EU ETS Phase 3).

8.8.2 Other developments

47. A qualitative assessment has been carried out on the combined effect of other proposed development in the area and this Project on the UK GHG emissions. Taking into consideration of the natures and scales of the developments reviewed, it is considered unlikely that they will make a noticeable impact on the UK Carbon Budget both individually and cumulatively.

48. Although information is insufficient at present to allow a quantitative assessment, the result of this ES may contribute to quantitative cumulative assessment of future projects in this area.

8.9 Mitigation Measures

49. A list of embedded mitigations has been described in Chapter 4. The effects of these mitigation measures have been incorporated into this assessment. This section describes the additional mitigation measures proposed to minimise or eliminate significant

environmental effects. Only mitigation measures that may have an effect on the Project's GHG emissions are included here.

8.9.1 Installation of Surface and Buried Arrays

50. No additional GHG emission mitigation measures have been identified.

8.9.2 Construction of Well Pad and Access

Table 8.11: Construction of well pad mitigation measures.

Topic area	Effect	Mitigation	Effect on GHG
Resource and waste	Waste minimisation.	Review opportunities to source stone for the wellpad and access track from secondary aggregate sources (rather primary/virgin aggregates).	The re-use, recycle and recovery of inert and non-hazardous waste would generate fewer GHG emissions compared to treatment or landfill. This will have a positive effect on the Project's GHG emissions.

8.9.3 Installation of Surface and Buried Arrays

51. No additional GHG emission mitigation measures have been identified.

8.9.4 Drilling

Table 8.12: Drilling mitigation measures.

Topic area	Effect	Mitigation	Effect on GHG
Resources and waste	Generation and disposal of waste.	Identify opportunities for off-site re-use, recycling and recovery of inert waste. Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Reuse, recycle and recovery of inert and non-hazardous waste has less GHG emissions associated to them compares to if the waste was to be landfilled. This will have a positive effect on the Project's GHG emissions.
Transport	Traffic movement generated from the Project.	Where practicable equipment that is used will remain on Site between uses, rather than being brought to and from Site.	By keeping equipment on-site wherever practicable, the number of traffic movement may be reduced, hence reducing the associated GHG emissions.

8.9.5 Hydraulic Fracturing

Table 8.13: Hydraulic fracturing mitigation measures.

Topic area	Effect	Mitigation	Effect on GHG
Transport	Traffic movement generated from the Project.	Where practicable, equipment that is used will remain on Site between uses, rather than	By keeping equipment on-site wherever practicable, the number of traffic movement may be reduced,

Topic area	Effect	Mitigation	Effect on GHG
		being brought to and from Site.	hence reducing the associated GHG emissions.

8.9.6 Initial Flow Testing, Extended flow testing, decommissioning and restoration

52. No additional GHG emission mitigation measures have been identified.

8.10 Residual Effects

53. The mitigation measures summarised in section 8.9 will reduce the Project's GHG emissions wherever practicable. Detailed quantitative assessment of the residual effects has not been undertaken, however the residual GHG emissions of the Project are estimated to be less than 0.002% of the UK Carbon Budget and just under 0.1% of the projected EU ETS UK allocation at 2016 levels (mid-point of EU ETS Phase 3).

8.11 Assessment Summary

54. This section of the report provides a summary of the assessment outcomes.

55. The Project carbon footprint is 118,418 to 124,367 tCO_2e. This is made up of approximately 94% direct emissions and 6% indirect emissions.

56. 73% of the Project carbon footprint can be attributed to flaring, which will be accounted for under the EU ETS.

9 Community and socio-economics

Chapter Summary- Community and socio-economics

This chapter assesses the community and socio-economic effects of the Project. The area of the proposed works is situated in the east of the Fylde borough. This area is mainly rural in character with various different types of farming activity, including intensive market gardening and extensive arable and dairy farming.

The Site is in a rural area of Fylde, surrounded by open farm land and a number of small businesses within 1km of the Site including a garden centre, catteries and a caravan park. The area is relatively affluent and is in a low population density area. However the growing population will necessitate employment opportunities into the future, particularly in the context of increasing levels of employment benefit claimants. The major existing and potential employment land areas in the borough are located away from the Site. The ward has limited provision of community infrastructure due to the small size of the population and the agricultural nature of the area. The local area does not contain any of the existing or potential housing supply identified in the Five Year Housing Supply Statement.

Although this is a temporary exploration project lasting six years it has the potential to have the following beneficial effects:

- Direct, indirect and induced job creation in the local Lancashire area;
- Opportunities for local businesses to provide services to the project (e.g. construction of the wellpad and access track; transportation of materials and equipment and site welfare facilities);
- Expenditure in local hotels and restaurants by people working on the project but do not live locally; and
- Community benefit payments for each well that is hydraulically fractured. (It is acknowledged that such payments are not a material consideration in deciding whether to grant planning permission and are not presented as such, but they would be a positive effect flowing from the development which is properly to be assessed when considering the socio-economic effects).

Recent experience has shown that drill sites can attract public attention and a degree of protest. The risk of criminal activity is thought to be minimal, although arrests have been noted at other protest sites. Should this occur, it is assumed that public order and people management will be maintained by the local police force, with full cooperation and engagement from Cuadrilla, reducing the impact on the crime and public safety in the area. The assessment has concluded that the Project will not have any significant adverse effects are on this topic area.

9.1 Introduction

1. This chapter examines the likely significant community and socio-economic effects as a result of the Project. The assessment looks at the receiving community and socio-economic context in terms of:

- Population;
- Wealth and deprivation;
- Industrial structure;
- Community infrastructure;

- Housing;
- Education and skills;
- Crime and public safety; and
- Public rights of ways.

2. The assessment also looks at the effects of the scheme on the following community and socio-economic considerations (distinctions in brackets):

- Employment (socio-economic factor);
- The wider economy (socio-economic factor);
- Public access (community factor); and
- Crime and public safety (community factor).

3. The above topics have been assessed both in terms of any beneficial and adverse effects in the context of the local community and socio-economic baseline. Effects have been examined at the construction, operational and decommissioning stages of the development, where appropriate.

9.2 Key Development Issues

4. The temporary exploration works at Preston New Road will have a number of community and socio-economic effects. In summary these will consist of:

- Temporary loss of local amenity value through Site activities, traffic and influx of population area
- Employment generation, with direct employment for initial exploration wells predominantly drawn from beyond the local area, but with indirect and induced effects from local spending and the influx of population on Site (local supporting industry, hotels and subsistence for example[93]);
- Increased spending in the agriculture sector from increased landowner income;
- Opportunity costs from loss of in use agricultural land;
- Community disturbance from any protest activities, or Site works.
- Effects of increased local spending from the community benefit payment from Cuadrilla via the Community Foundation for Lancashire to local communities. (It is acknowledged that such payments are not a material consideration in deciding whether to grant planning permission and are not presented as such, but they would be a positive effect flowing from the development which is properly to be assessed when considering the socio-economic effects).

9.3 Scoping and Consultation

5. The community and socio-economic section of the submitted scoping report outlined the proposed approach for the assessment. No comments were received on the LCC Scoping response.

6. In addition to the scoping stage of the EIA, Arup has been in public consultation for ERA and EIA and conducted a number of site visits that has informed understanding of issues for this assessment.

[93] Institute of Directors (2013). Infrastructure for Business – getting shale gas working Table 17. http://www.iod.com/~/media/Documents/PDFs/Influencing/Infrastructure/IoD_Getting_shale_gas_working_MAIN_REPORT.pdf

9.4 Methodology

9.4.1 Introduction

7. The assessment has used qualitative and quantitative techniques to assess the community and socio-economic effects of the development. The assessment is based on the *Good Practice Guide on Environmental Assessment*[94], the government's Green Book for Appraisal and Evaluation[95] (hereafter, the *Green Book*) as well as professional judgement and experience gained on similar development projects.

8. The assessment looked at the net effect of the project, i.e. the effects of the project minus what would have occurred anyway. This gives the net additional effect of the project as opposed to the gross effect.

9. A number of different geographical comparator areas are examined throughout the assessment:

- The Site: the area defined in the scheme description of this ES:
- The *'Lower Layer Super Output Areas' (LSOAs)*. The ONS calls these neighbourhoods and states that these areas contain roughly 1,500 people or 400 households[96];
- The *'Middle Layer Super Output Areas' (MSOAs)*. The ONS states that these areas contain roughly 7,200 people or 2,000 households[2];
- Fylde: the wider borough area.;
- Lancashire / sub-region; and
- North West region.

9.4.2 Baseline methodology

10. This section describes the existing community and socio-economic characteristics at the Preston New Road Site and in the surrounding area before any further development has taken place (see Table 9.1). The baseline describes the following, at the various geographic scales outlined in the previous section.

Table 9.1: Explanation of why baseline elements are considered

Assessment	Considered due to
Current Site use and the surroundings	This will affect the sensitivity of the Site for exploration use. Understanding this helps draw conclusions on the suitability of the Site, and the sensitivity to impacts
Population	Population and population density will help illustrate how suitable (or not) the Site and the surrounding area is for exploration use, with the assumption being that a more densely populated area brings with it more potential instances for incompatible land use.
Wealth and deprivation	This will help in understanding the sensitivity of the Site to investment, with less wealthy or more deprived areas potentially being more sensitive to certain types of investment/interventions.
Industrial structure	This will help illustrate the nature of the local economy, and the types of existing jobs in the local area.
Community	This will help understand land uses / developments in the local area that may

[94] Department of the Environment, Preparation of Environmental Statement for Planning Projects
[95] HM Treasury, 2011 ; *The Green Book: Appraisal and Evaluation in Central Government*; London TSO
[96] http://www.neighbourhood.statistics.gov.uk/dissemination/

Assessment	Considered due to
infrastructure	be sensitive to exploration works. Further, it may be necessary to understand capacity, should population in the area change for a sustained period (subsequently increasing demand for community infrastructure).
Housing	This will illustrate the quantity of houses in the vicinity and any forthcoming strategic housing sites.
Education and skills	This illustrates the level of training in the local labour market and is an indicator of potential affluence/deprivation.
Crime and public safety	This illustrates the sensitivity of local area to activities which may affect crime levels or public safety in the local area.
Public rights of way	This illustrates the extent of local public access to recreational resource, and can indicate sensitivity to disturbance from works.

11. A summary is provided at the end of the baseline section drawing links between the findings and the project.

9.4.3 Assessment methodology for the effects from construction

12. The assessment drew on the principles set out in the government's Green Book[95]. Specifically this meant *assessment areas* had to be selected, high-level objectives drawn up for each assessment area, and the likely costs and benefits detailed. This appraisal differs from Green Book guidance in that different options are not assessed against each other. This is due to this assessment forming part of an EIA for one selected option; i.e. shale gas exploration at the Site.

13. Construction was assessed as the physical act of mobilising and beginning works on Site. It was also assessed as the stage whereby the Site becomes classified as an exploration Site. This distinction is important because it allows full consideration of costs (and, crucially, opportunity costs) and benefits associated with the decision to proceed at this Site. In this sense, construction also represents the *decision to proceed* stage.

14. The *assessment areas*, the objectives and the methods used to understand effects are set out below in . The assessments include a review of costs and benefits that will be predominantly qualitative and consider the project stages beyond mobilisation.

15. Any stages, and associated costs, incurred prior to this are considered as *sunk costs*, which have already been incurred (this is in line with best practice (Green Book) guidance). It is therefore likely that there are some impacts (when considered on a 'with' and 'without' basis) that have occurred that are outside of this assessment. These might include any scoping or site identification work, design work, consultancy work or geological survey work that has led up to the works on Site, which this assessment is concerned with.

Table 9.2: Assessment areas, objectives and methods for assessment of operational activities.

Assessment area	Assessment objective	Methods used
Employment	Assess the extent to which employment creation is maximised.	A qualitative commentary is given on the employment requirements of the works at different stages. This is supported by estimated worker numbers for given phases of the exploration works, provided by Cuadrilla. These worker numbers have been used to estimate total Full Time Equivalent (FTE) employment generation. This is done in the assessment by first calculating the total job years (the cumulative total number of 220 day years spent on Site by all employees). The above figure is then divided by 10, to give the number of 10 year full time jobs, carried out over the lifetime of the Project. This is in line with a typical approach used on construction projects, where total employment is often made up of many people doing short term assignments. As the project is actually six years in length (not 10), the FTE job creation over six years is also presented for information. This approach avoids overstating the employment generation (i.e. it does not just quote the total number of shifts, and claim them as full time employment positions), and at the same time accounts for the cumulative benefits of all jobs on Site, across the lifetime. The above calculation gives a gross employment generation figure. After this a net employment generation figure is given by accounting for additionality factors97. The assessment seeks to estimate localised (Lancashire level) employment impacts by defined employment stages. Leakage and multiplier factors are applied to gross employment levels. The factors and the assumptions behind them are explained in Section 9.7. Displacement and substitution are not accounted for, as no jobs are being lost/offset from the elsewhere. Deadweight is not accounted for, as none of the employment benefit on the site, or in the supply chain would occur without this scheme. The assessment will also provide commentary on employment impacts felt beyond the local area.
Wider economic effects	Assess the ways that economic effects occur, relating outcomes to specific aspects of the project.	A qualitative assessment has been carried out examining the effects of the works on the economy of the local area; in particular the sectors of the economy identified during scoping.
Public access and recreational amenity	Assess how costs in this area can be minimised, and benefits maximised.	A qualitative assessment has been carried out examining the effects on the local access to open space and recreational facilities.

[97] Additionality factors are used help understand the net employment generation. The consist of: leakage which accounts for the proportion of the benefit felt elsewhere; economic multipliers which account for the further activity/employment beyond the project (indirect supply chain effects, or induced effects from employees direct spending); displacement/substitution which show how much benefit is being offset by reductions of benefit (e.g. employment) elsewhere; and deadweight, which accounts for that which would have occurred anyway (without the project).

Assessment area	Assessment objective	Methods used
Crime and Public Safety	Assess how costs in this area can be minimised, and benefits maximised.	A qualitative assessment of the crime and public safety effects from the works has been included.

9.4.4 Assessment methodology for the effects from installation of surface network and buried array

16. The same assessment areas highlighted in the previous section will be considered for the installation of the surface and buried arrays. The same objectives were tested and the same methodologies used.

9.4.5 Assessment methodology for operational effects

17. The operational effects section considers the following:

- Mobilisation of on-Site workers;
- Drilling;
- Well testing;
- Hydraulic fracturing and flow testing; and
- Extended flow testing.

18. The same assessment areas from the previous section (construction) will be considered for the operational phase. The same objectives were tested and the same methodologies used.

9.4.6 Assessment methodology, decommissioning and restoration effects

19. The same assessment areas highlighted in the construction section will be considered for the decommissioning stage. The same objectives were tested and the same methodologies used. The decommissioning phase considers decommissioning and restoration.

9.4.7 Significance criteria for assessments

20. There are no established guidelines for assessing the significance of community and socio-economic effects. The DCLG consultation paper *Environmental Impact Assessment: A guide to good practice and procedures* states that significance is a function of

- Value of the resource;
- Magnitude of the impact;
- Duration;
- Reversibility; and
- Number of sensitive receptors.

21. With the above in mind, experience and professional judgment based on knowledge of the Project and receiving environment have been employed to attribute significance to the effects identified.

22. The sensitivity of receptors[98] has been assessed by taking into account the capacity of the affected receptor to continue to function effectively. On this basis sensitivity is deemed high, medium or low.

23. After consideration of the costs and benefits and the overarching objective (as described above), effects have been identified as **beneficial** (a net positive effect), **negligible** (all negligible effects are considered *insignificant*) or **adverse** (a net negative effect). The effect magnitude has been expressed as low, medium or high for beneficial or adverse effects only, based on the considerations listed in the bullet points above and professional judgement. The language chosen to express the effects and their magnitude is consistent with that used in EIA.

24. The overall significance of the effect is a product of the magnitude of the effects and the sensitivity of the receptor.

25. Effects will be considered to be significant if both impact magnitude and receptor sensitivity are high or medium. Effects will also be considered significant if:

    - Magnitude of the impact is high and receptor sensitivity is low, or
    - Receptor sensitivity is high and impact magnitude is low.

26. Significance equates to both adverse and beneficial effects. Any negligible effects will be considered not significant.

9.5 Assumptions and Limitations

27. It is assumed that all data used for this assessment (source and dates given throughout) is representative and up to date at the time of assessment. It should be noted that the most detailed geographic datasets have been used. These are either at the ward or Office of National Statistics (ONS) Output Area or Super Output Area levels. No data at the individual settlement level was available.

28. There is a lack of established guidance for assessing community and (to a lesser extent) socio-economic effects. Evidence from literature has been used throughout to inform the assessment of the likely effects in the context of the community and socio-economic baseline. Where this is used, references are made in the text.

9.6 Baseline

9.6.1 Geography

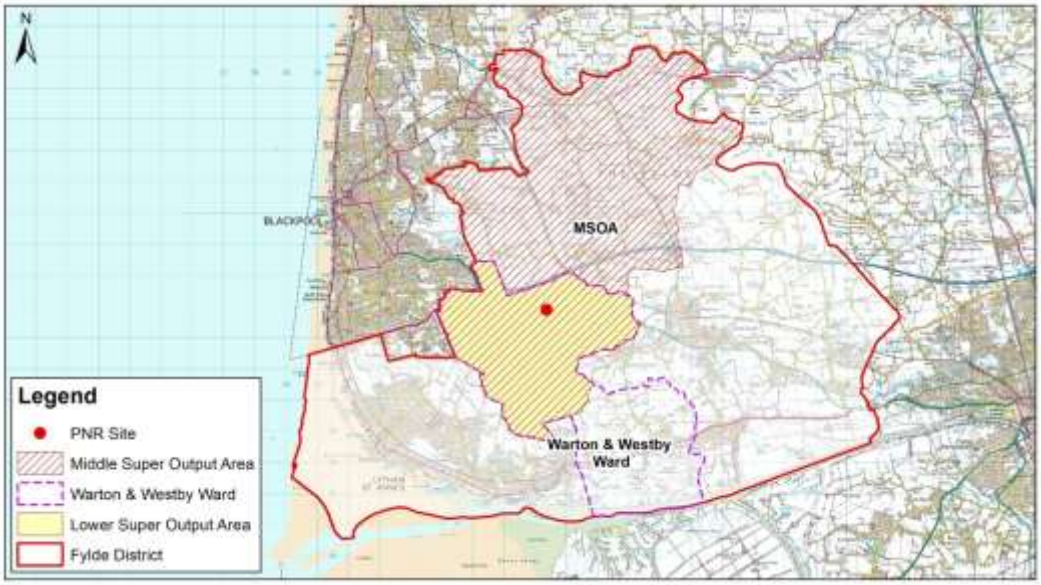
29. The Site is within the borough of Fylde (Lancashire), which contains 21 wards and 51 lower super output areas (LSOA). The Site is situated within:

    - Warton and Westby ward;
    - LSOA 001E; and
    - middle super output area (MSOA) 001.

[98] Note that due to the wide coverage of this assessment, "receptor" is a broad term encompassing many different aspects of the receiving environment. In the context of this assessment, it may include a local industrial sector, a specific residential receptor or amenity resource (as examples).

30. The figure below shows the Fylde borough (wider red line), the MSOA (the red line and shaded area) and the LSOA (yellow area). Also shown is the Warton and Westby ward (purple). The Site sits within the Westby-with-Plumptons Parish (not mapped).

Figure 9.1: Showing the *Lower Super Output Area* Fylde 001E (yellow area), *Middle Super Output Area* Fylde 001 (shaded area) and the Borough of Fylde (thick red line)



(Contains Ordnance Survey data © Crown copyright and database right 2014)

31. The Fylde District Profile[99] defines the Warton and Westby ward as one of Fylde's nine rural wards. One third of the Fylde population live in the rural wards. Warton and Westby accounts for approximately 6% of the population[100].

9.6.2 Current Site use and the surroundings

Current land use

32. The current land use is described in Chapter 3 of this Environmental Statement. The Site is currently an undeveloped greenfield site, used for agriculture.

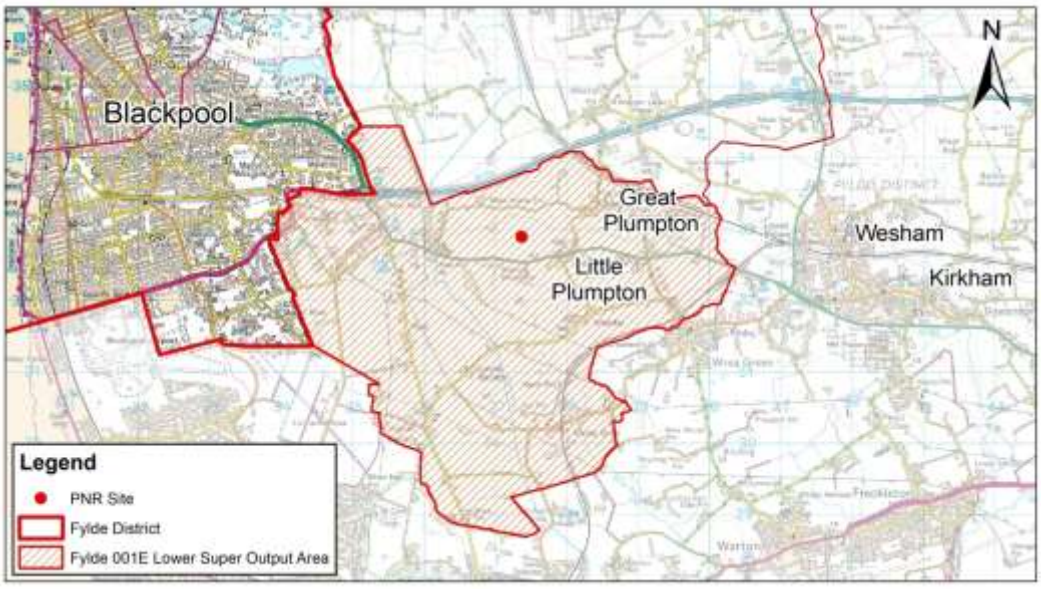
Surrounding area

33. The area of the proposed works is situated in the west of the borough of Fylde. This area is mainly rural in character with various different types of farming activity, including intensive market gardening and extensive arable and dairy farming.

34. Small settlement areas are scattered across the Fylde coastal plain, with the more densely populated areas to the west and south. Communities situated in the surrounding area of the proposed works are illustrated in Figure 9.2 below.

[99] Fylde District Council; Fylde District Profile; 2012.
[100] Fylde District Profile 2012, Fylde Borough Council

Figure 9.2: Communities in the surrounding area (*Contains Ordnance Survey data © Crown copyright and database right 2014*)

35. 

36. The Site is approximately equidistant from the centre of Blackpool (west) and Kirkham (east). Aside from the extensive agricultural land, other businesses exist in the surrounding area. These include, within 1km of the Site:

- A dog grooming business to the south;
- An aquatic superstore, pet centre and cafe (*World of Water*) to the west;
- A garden centre to the west;
- A nursery garden to the north west;
- A cattery to the west (Westby Cattery) and North West (Meadowgreen Cattery); and
- A large caravan park (including static caravans) to the east.

9.6.3 Population

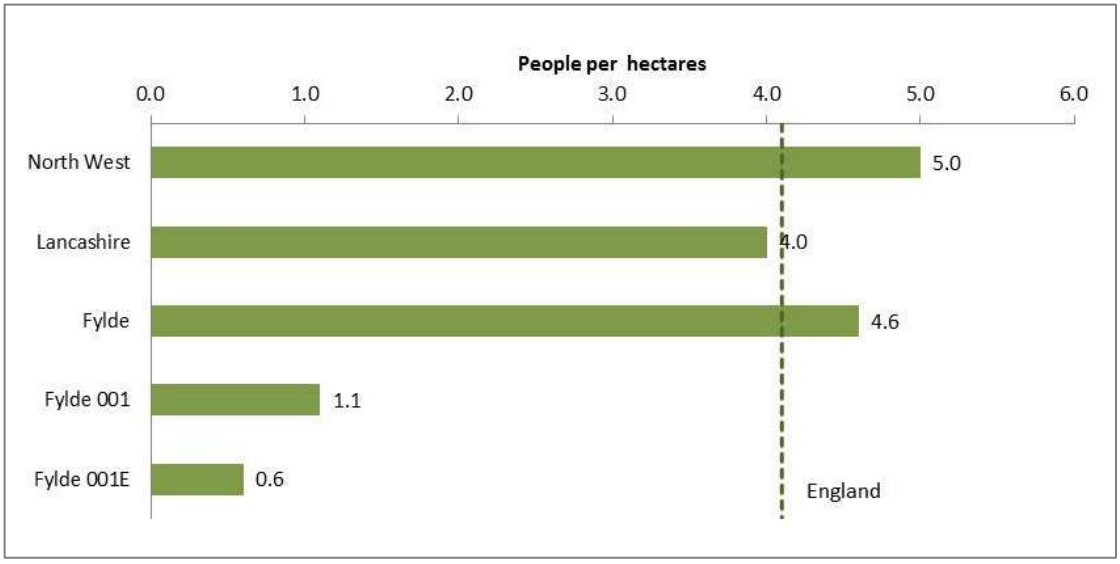
37. The nearest large nearby settlements of Kirkham and Blackpool have approximate populations of just over 7,000[101] and 142,000[450] respectively.

Population density

38. Figure 9.3 below shows the population density for different comparator areas. The LSOA and MOSOA both have significantly lower population density compared with Fylde, Lancashire, the wider North West region and England. The LSOA which the Site sits in has a particularly low population density, with a population density of 0.6 people per hectare.

[101] Office for National Statistics: Census 2011.

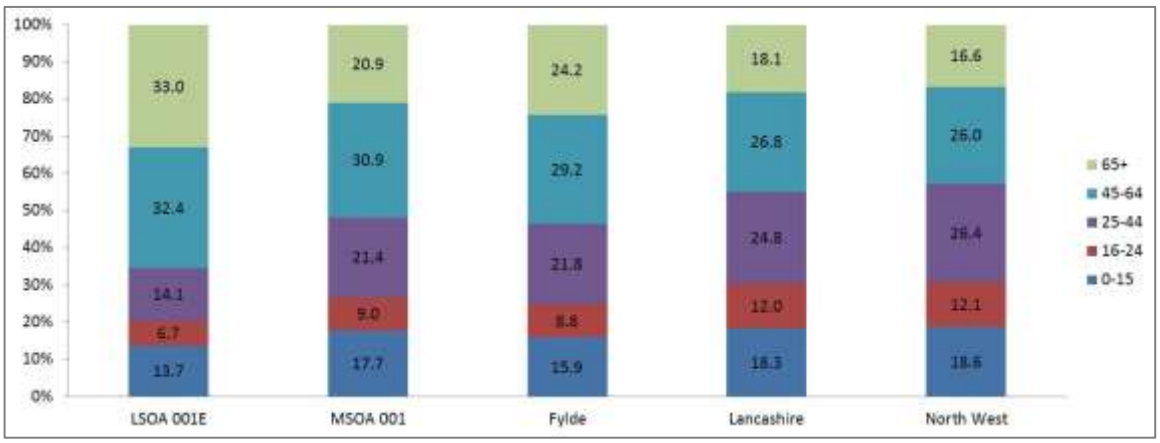
Figure 9.3: Population density for comparator areas (source: ONS) (data from 2011 census)



Population age

39. The age makeup of the population based on figures from the 2011 census is shown in Figure 9.4 below.

Figure 9.4: Age profile for selected geographic comparator areas (Source: ONS, 2011 census)



40. The LSOA contains the highest proportion (33%) of residents over 65 out of all the comparator areas. This is 12% higher than the MSOA, 9% higher than Fylde, 15% higher than Lancashire and 16% higher than the NW. Similarly the LSOA contains the highest proportion of 45-64 year olds, approximately 2-6% higher than the other areas.

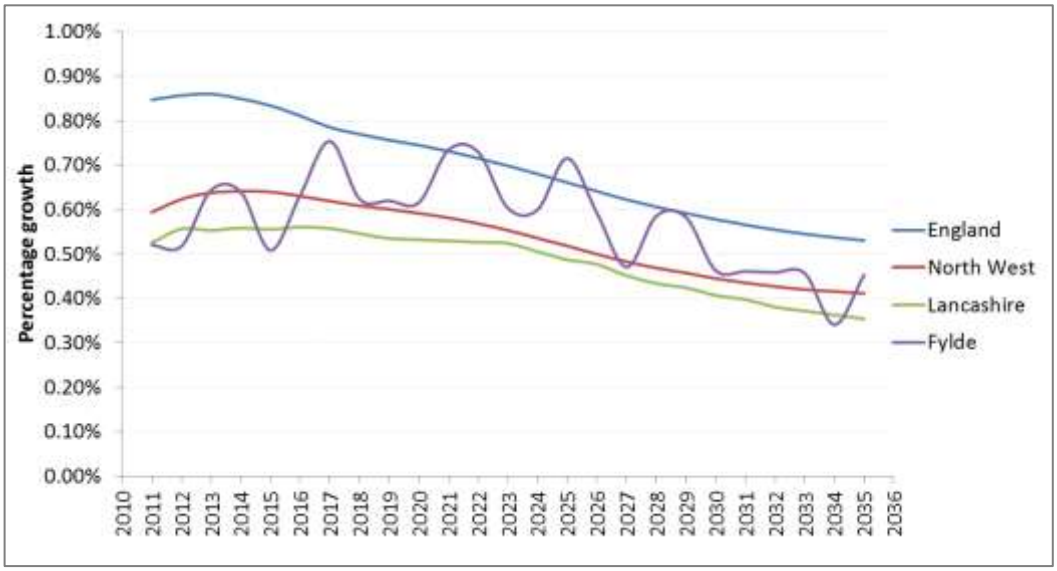
41. This higher concentration of older people, means that there are notably lower proportions of younger people in the area. The LSOA has a lower proportion of the population who are younger than 25, compared with the MSOA.

42. The total working age population (aged 16-64, with no distinction made for males and female retirement ages) ranges from 53% in the LSOA, to 65% in the NW. Fylde has the second lowest amount (after the LSOA) at 60%.

Population projection

43. Projected population growth rates for the local and surrounding areas are shown on the graph below. The population of Fylde is projected to continue to grow into the 2030s, much in line with the growth projection for Lancashire, the North West and England (no data was available at LSOA/MSOA level).

Figure 9.5: Population growth projection for selected geographic areas (Source: Lancashire County Council)



44. The rates of growth for all four comparator areas are projected to fall steadily over the next 25 years but remain positive throughout. The projected population growth for Fylde is more erratic, with steep increases and decreases over the years shown compared with the rates for Lancashire, North West and England. Overall, Fylde is projected to see an increase in the rate of population growth to around 2025, followed by a slowing overall rate in the following years.

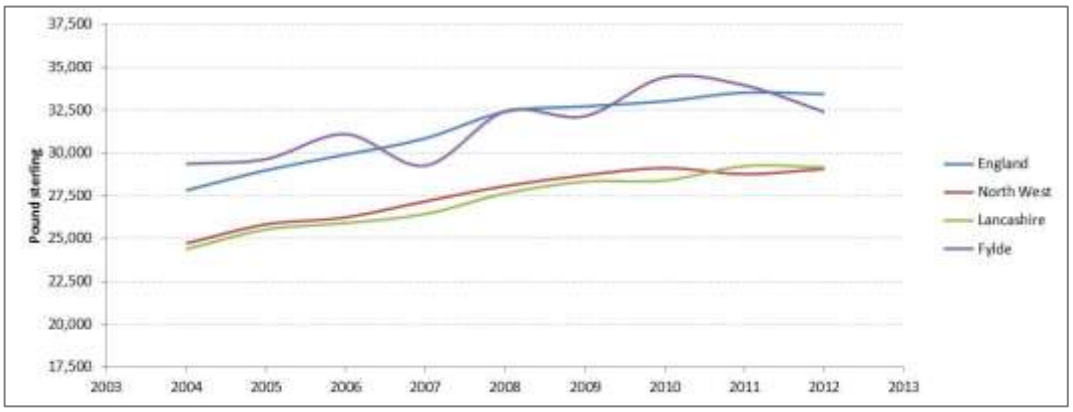
9.6.4 Earnings, employment, unemployment and deprivation

Income

45. The mean gross annual income per full time worker in Fylde has seen an increase from an average of £29,000 in 2004 to £32,000 in 2012[102]. Although higher fluctuation in mean income has been experienced in the borough, the rate of increase is much in line with that of the other comparator areas. The mean income level in the borough is similar to that in England, approximately £3,000 to £4,000 higher than that in Lancashire and the North West (Figure 9.6).

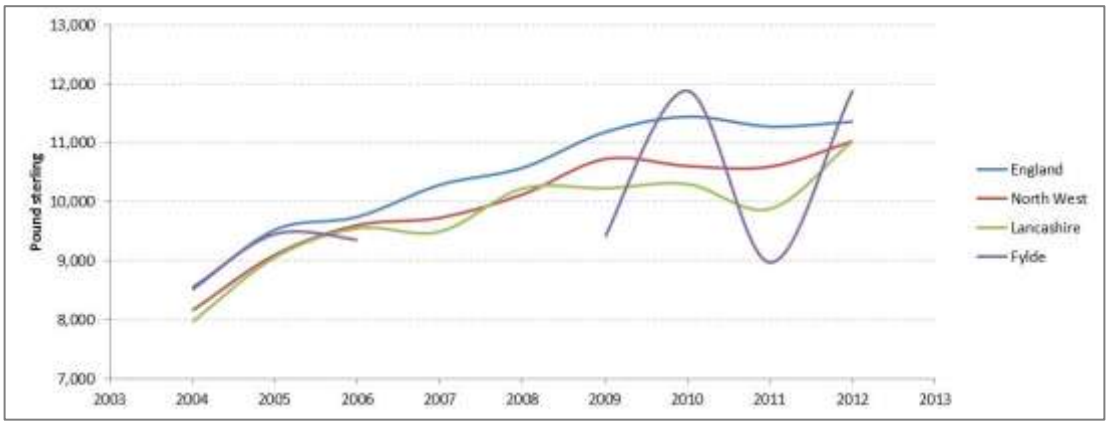
[102] NOMIS ONS data website.

Figure 9.6: Mean gross annual income per full time worker (source: NOMIS).



46. For part time workers, average wages have grown significantly in recent years in Fylde, when comparing point to point (i.e. 2009 to 2012). However, as the chart shows, the level has fluctuated significantly compared with three other comparator areas shown (Figure 9.7). Data downloaded from the ONS for Fylde contained gaps from 2006-2009, as shown in the figure.

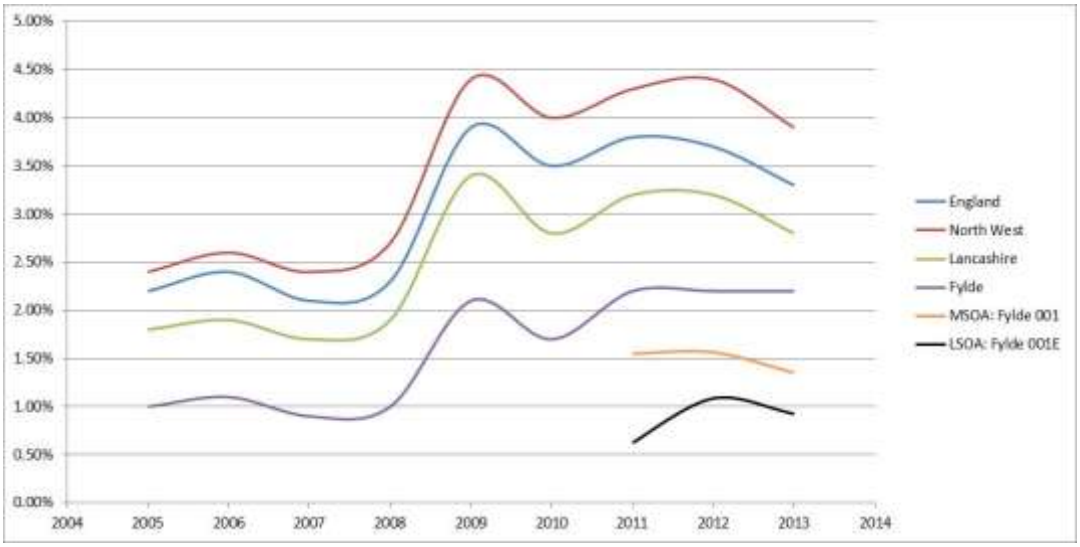
Figure 9.7: Mean gross annual income per part time worker (source: NOMIS).



Benefit claimants

47. The figure below shows the Claimant Count since 2004 for five comparator areas with only recent (2011 onwards) data shown for the LSOA and MSOA. A significant increase in claimant numbers can be observed between 2008 and 2009 with a slight flattening out of the rate from 2010. In 2011 data for the LSOA and MSOA are available. Both have lower rates than the other areas shown. The MSOA is higher than the LSOA, with the gap closing over the time period shown due to an initial sharp (but small) rise in the LSOA 2011-2012, and similar decreasing rates from 2012-2013.

Figure 9.8: Percentage of population claiming Job Seekers Allowance (Source: claimant count, mid-year estimates, ONS).



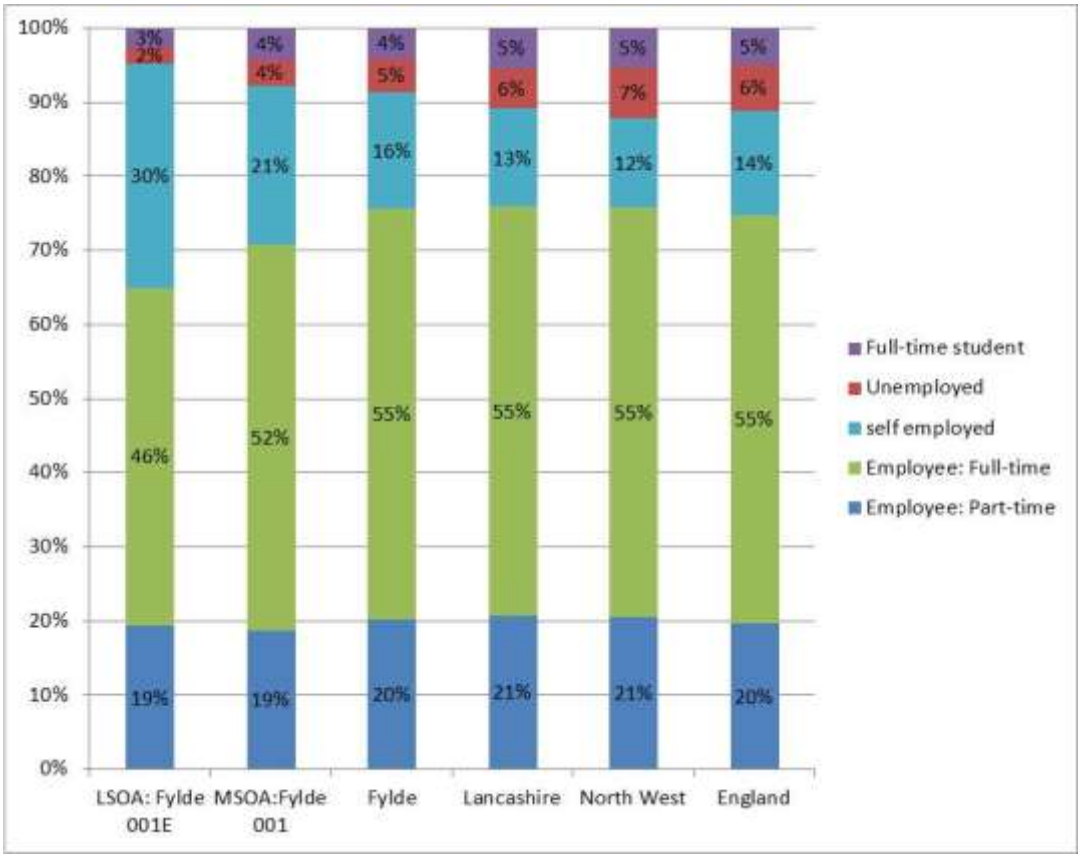
Economic activity

48. Figure 9.9 below shows the economic activity rates and the employment rate for six comparator areas. The LSOA has the highest proportion of self-employed people at 30%, 9% higher than the next highest (MSOA, 21%). This significantly higher percentage of self-employed people brings down the relative proportions of economically active people in the LSOA in every other category, to the lowest levels observed. The LSOA has the lowest observed level of unemployment (2%).

49. The MSOA has a higher than average level of self-employed people and a resulting low amount of people classed as full and part time workers.

50. The proportions of full and part time economically active people are similar across Lancashire, Fylde, the NW and England with unemployment also following similar amounts (5-7%). The North West has the highest proportion of unemployed people (7%).

Figure 9.9: Economic activity and employment rates (Source: ONS)



Employment by industry

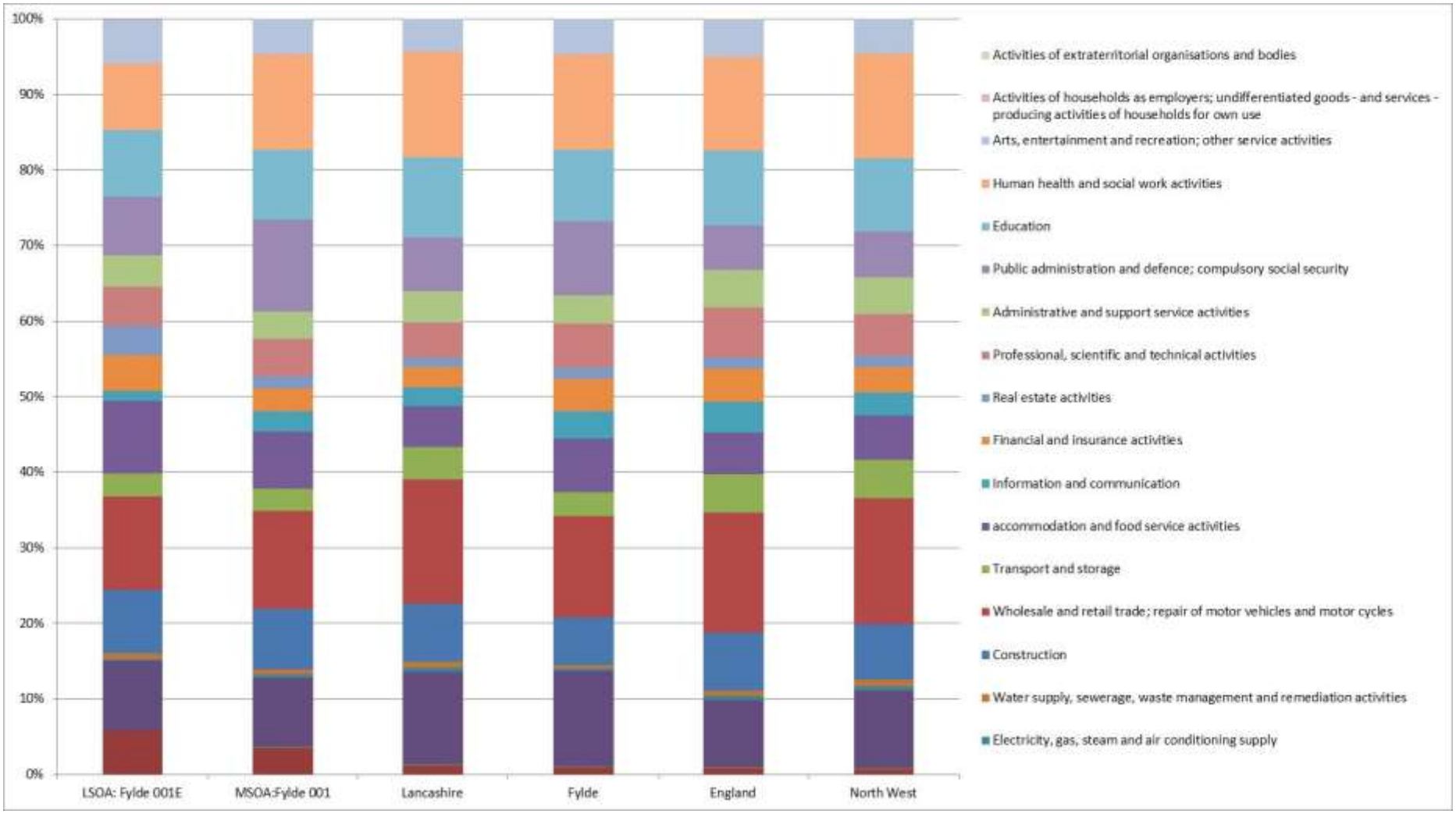
51. The figure below shows the employment profile by industry for six comparator areas. Of the six areas shown, the majority of sectors show similar levels of employment, as a proportion of all industries, with some exceptions.

52. The LSOA has relatively higher proportions in *accommodation and food activities, agriculture, forestry and fishing* and *construction* where the LSOA shows the highest proportions observed.

53. The MSOA has relatively high rates of employment in *Public administration and defence; compulsory social security* with just over 12% of the areas working MSOA population being employed in this sector. Fylde has 10% employment in this area. This type of employment makes up 6-7% in the other comparator areas. Employment levels in *construction* are also slightly higher than most other areas shown.

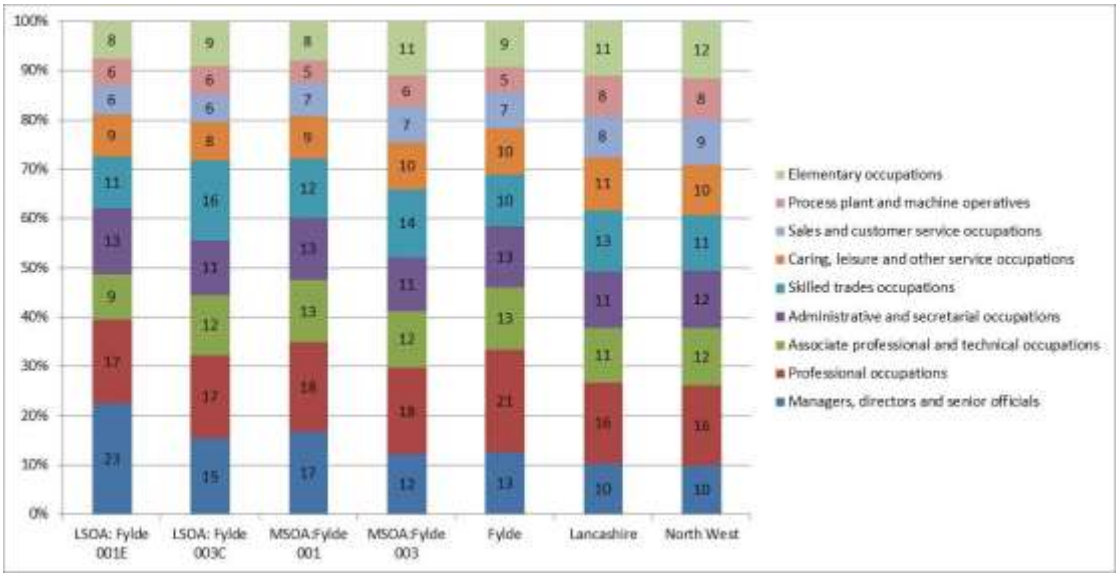
54. The LSOA, MSOA and Fylde have slightly lower levels of *Wholesale and retail trade; repair of motor vehicles and motor cycles* employment, compared with Lancashire, the NW and England (13%, compared with as high as 16-17% in some wider geographic areas).

Figure 9.10: Relative proportions of employment by industry type (Source: ONS)



55. The figure below shows the types of jobs people do for the same comparator areas. The main difference is the LSOA and MSOA have relatively higher proportions of people employed as *managers, directors and senior officials*, where 23% and 17% are employed in these roles respectively, compared with 10-11% for Lancashire, England and North West.

Figure 9.11: Occupation by job type for the comparator areas (source: ONS)



Deprivation

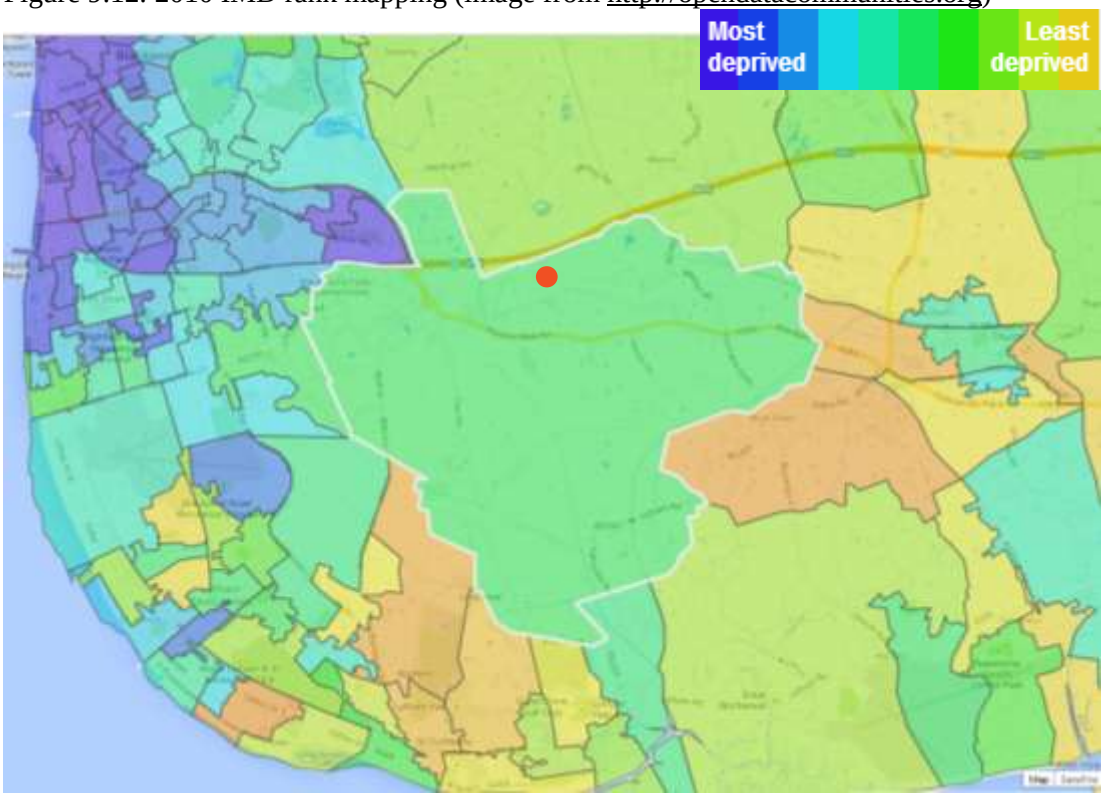
56. The Indices of Multiple Deprivation (IMD) is a multivariate indicator set produced by government to aid and inform awareness of deprivation and approaches to improving the conditions in deprived areas. The Office for National Statistics holds data on this index. It states the following about LSOA areas (what it terms a *Neighbourhood*)

> *All 32,482 neighbourhoods in England have been ranked on a range of deprivation topics. The most deprived neighbourhood in England has a rank of 1. These markers show the overall deprivation and the environment deprivation ranking for your area.*

57. The Figure below shows IMD mapping across Fylde and the neighbouring areas. At local authority level, Fylde's overall rank is 235 out of 326 districts, placing it in the top third least deprived areas. Fylde is also at the top end of the scale in Lancashire, with the least amount of deprivation of any kind and the fewest amount of deprivation hotspots. Compared with the region and national average, Fylde is 102 places higher than the North West average and 36 places higher than the national average.

58. The mapping overleaf shows that the LSOA where the Site sits is in the mid to low region of overall deprivation (official grade in 2010 was 17,130 out of 32,482, where 1 is most deprived).

Figure 9.12: 2010 IMD rank mapping (image from http://opendatacommunities.org)



9.6.5 Industrial structure

General

59. Fylde forms an important part of the central Lancashire economy. It contains regionally significant business sectors, including the military aircraft industry (BAE Systems at Warton) and the nuclear industry (Westinghouse nuclear processing plant at Springfields). The presence of these sectors means that the borough has significant amounts of *high value manufacturing*.

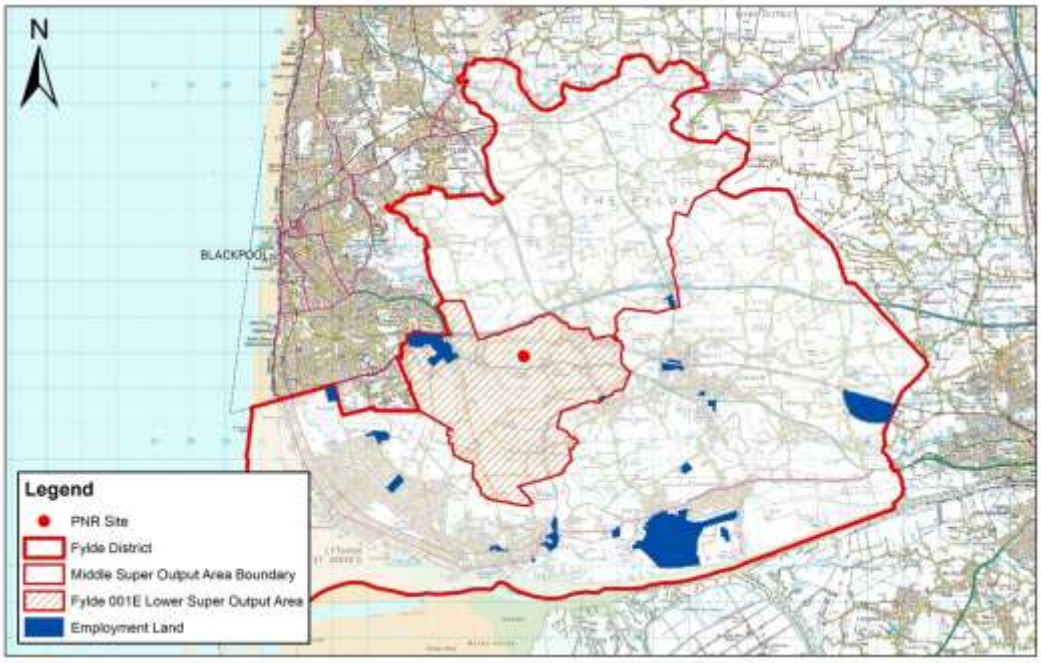
60. The figure below shows the existing and designated employment land in the borough[103]. In addition to existing employment land, Fylde Borough Council has designated four areas in the region for business and industrial development. These are:

- Blackpool Fylde Industrial Estate;
- Whitehills Park (Phase 2);
- Naze Lane, Freckleton; and
- Queensway, St. Annes.

[103] Source: Fylde Borough Local Plan (as altered: October 2005)

Figure 9.13: Existing and designated employment land in the borough *(contains Ordnance Survey data © Crown copyright and database right 2013)*

61.



62. Most of the existing and designated employment land areas in the borough are located outside of the LSOA and MSOA where the proposed Site lies. One site (Blackpool and Fylde Industrial Estate) sits within the LSOA, but this is deemed too far from the Site to require further study.

9.6.6 Community infrastructure

63. Community infrastructure in the vicinity of the Site is scarce due to the immediate area being so dominated by agricultural land. No schools, community centres, places of worship or medical centres (including doctors, dentists etc.) were identified within 1km of the Site. This decreases the sensitivity of the Site in terms of any potential impact on community infrastructure.

9.6.7 Housing

64. The low population density and OS mapping confirm that there is comparatively little housing in the immediate surroundings. There are just over 35,000 houses across Fylde. Compared with the national average, Fylde has a much higher proportion of owner occupied dwellings (80%, compared with 71%). The private rented stock is also at a higher level of 14% compared to 11% for England (see Table 9.3). Consequently, social housing is found at a much lower level than is the case nationally.

Table 9.3: Tenure profile of Fylde (Source: Fylde Borough Council).

Tenure	Fylde (dwellings)	Fylde (percentage)	England (percentage)
Owner occupied	28,490	80%	71%
Privately rented	4,910	14%	11%
Private sector stock	33,400	94%	82%

Tenure	Fylde (dwellings)	Fylde (percentage)	England (percentage)
Housing association (RSL)	2,300	6%	-
Local authority	0	0%	-
Social housing	2,300	6%	18%

65. The Five Year Housing Supply Statement[104] produced by Fylde Borough Council in March 2013 states that, taking into consideration shortfalls since 2003; the adjusted housing requirement for the next five years would be 489 dwellings per annum. To meet this requirement, the council has identified an existing supply of 1,514 dwellings and a potential supply of 200 dwellings. The existing supply includes:

- Existing commitments;
- Planning applications approved subject to a signed Section 106 (if applicable) and planning applications minded to approve; and
- A deduction for planning applications that are no longer considered deliverable in accordance with NPPF paragraph 47.

66. The potential supply includes the five year phased allowance for an area in St Annes for 200 dwellings (former Pontins site). None of the existing or potential supply identified in the statement is located in close proximity to the Site. As such, increased housing supply in close proximity to the Site is not deemed likely.

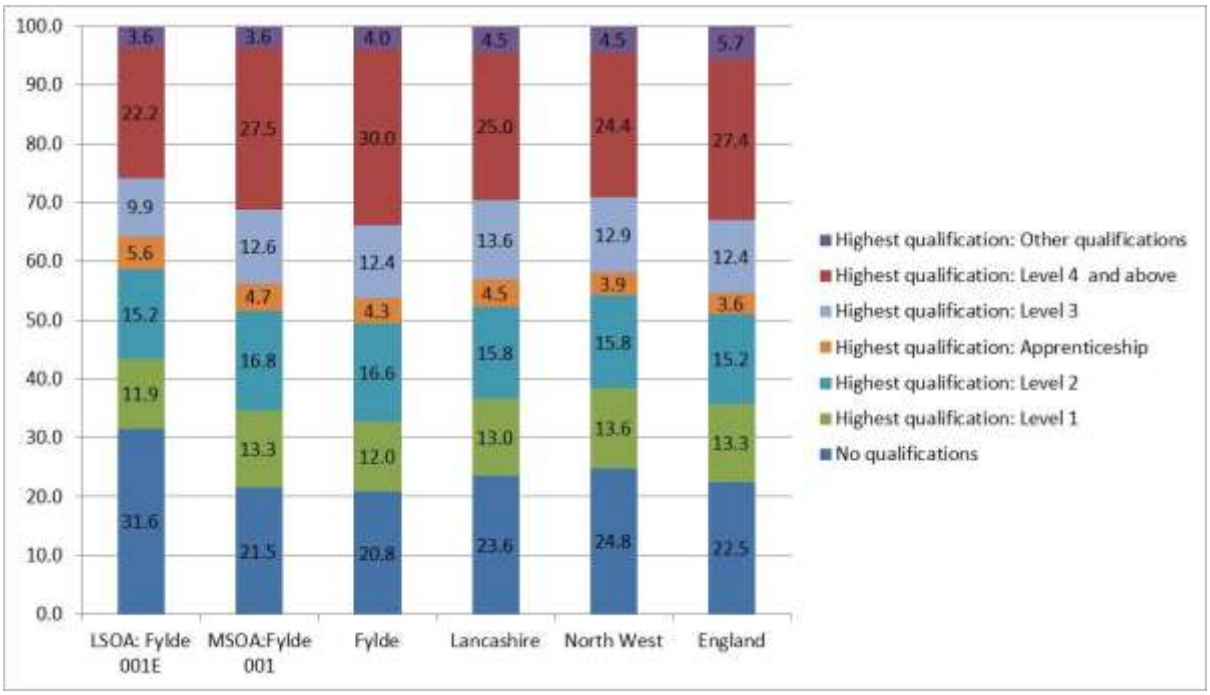
9.6.8 Education and skills

67. Data for education and skills is shown in the figure below (source ONS). The definition for each category is explained below:

- **No qualification:** No academic or professional qualifications;
- **Level 1 qualifications:** 1-4 O Levels/CSE/GCSEs (any grades), Entry Level, Foundation Diploma, NVQ level 1, Foundation GNVQ, Basic/Essential Skills;
- **Level 2 qualifications:** 5+ O Level (Passes)/CSEs (Grade 1)/GCSEs (Grades A*-C), School Certificate, 1 A Level/ 2-3 AS Levels/VCEs, Intermediate/Higher Diploma, Welsh Baccalaureate Intermediate Diploma, NVQ level 2, Intermediate GNVQ, City and Guilds Craft, BTEC First/General Diploma, RSA Diploma;
- **Level 3 qualifications:** 2+ A Levels/VCEs, 4+ AS Levels, Higher School Certificate, Progression/Advanced Diploma, Welsh Baccalaureate Advanced Diploma, NVQ Level 3; Advanced GNVQ, City and Guilds Advanced Craft, ONC, OND, BTEC National, RSA Advanced Diploma;
- **Level 4+ qualifications:** Degree (for example BA, BSc), Higher Degree (for example MA, PhD, PGCE), NVQ Level 4-5, HNC, HND, RSA Higher Diploma, BTEC Higher level, Foundation degree (NI), Professional qualifications (for example teaching, nursing, accountancy); and
- **Other qualifications:** Vocational/Work-related Qualifications, Foreign Qualifications (Not stated/ level unknown).

[104] Fylde Borough Council: Five Year Housing Supply Statement, base dated 31st March 2013

Figure 9.14: Highest level of qualification for five comparator areas, 2011 (Source: ONS)



68. Figure 9.14 illustrates that the LSOA has high levels of the population with *no qualifications*. This is in contrast to the MSOA and Fylde on the whole that contain relatively low or average levels of the population with *no qualifications*. The LSOA has a marginally higher amount of people trained as apprentices.

9.6.9 Crime and public safety

69. Crime levels for the Fylde borough are compared on the police website[105] with other *Most Similar Groups* (MSGs – defined by socio-economic characteristics) and other regions in the Lancashire force area. The results of the search showed the following:

- In the year ending 31 March 2013, the crime rate in Fylde was lower than the average crime rate across similar areas;
- In the year ending 31 March 2013, the crime rate in Fylde was lower than average for the Lancashire force area; and
- In the quarter ending 31 March 2013, crime rates were down in Fylde and in the Lancashire force area compared with the corresponding quarter in 2012.

70. In terms of crime occurrence close to the Site, the police website shows a total of 24 crimes occurring within a mile radius of the Site in the year September 2012-September 2013. The most prevalent types of crime in this area include anti-social behaviour. No crime has been recorded on the Site itself for this period.

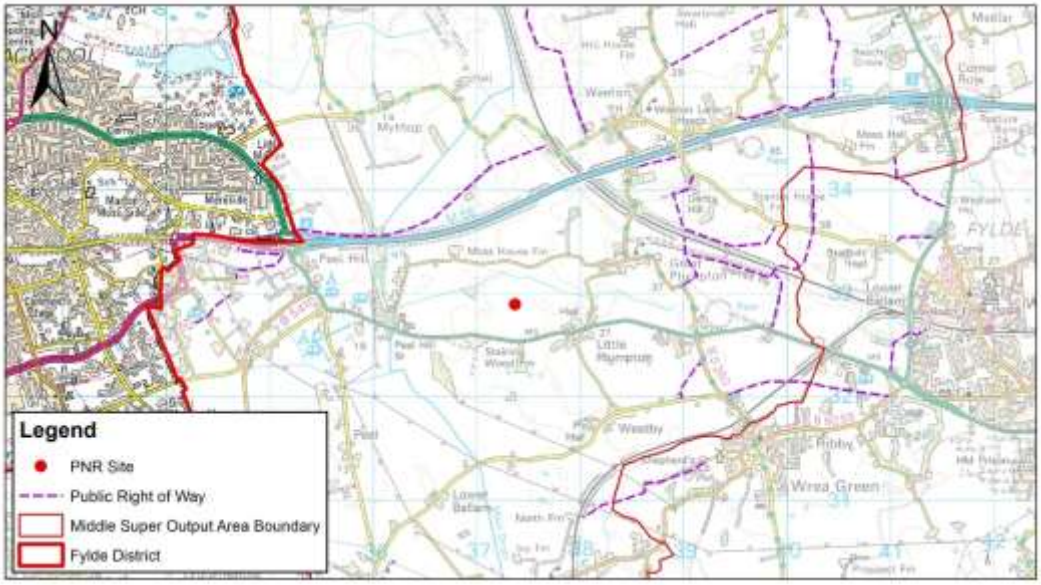
71. The nearest police stations are Kirkham, Blackpool and Lytham, with the closest, Kirkham being approximately 5km to the east of the Site.

[105] Accessible at: http://www.police.uk/

9.6.10 Public rights of way

72. The figure below shows the public rights of way (PROW) in close proximity to the Site. There are no PROW running through the Site and no PROW in close proximity to the Site.

Figure 9.15: Public rights of way (Contains Ordnance Survey data © Crown copyright and database right 2013)



9.6.11 Summary of key baseline findings

73. In summary the baseline assessment has shown:

- The Site is in a rural area of Fylde, surrounded by open farm land and a number of small businesses within 1km of the Site including a garden centre, catteries and a caravan park.
- The area is relatively affluent with high levels of average earnings (mean gross annual earnings) for full time workers, and medium levels of deprivation (IMD).
- The Site is in a low population density area. However the growing population will necessitate employment opportunities into the future, particularly in the context of increasing levels of employment benefit claimants.
- The area has a highly skilled workforce with a high percentage of people working in *managers, directors and senior officials* positions.
- The major existing and potential employment land areas in the borough are located away from the Site.
- The ward has limited provision of community infrastructure due to the small size of the population and the agricultural nature of the area. It is assumed that communities in the area gain access to a wider range of facilities in the nearby towns of Kirkham, Poulton-le-Fylde and/or Blackpool.
- Crime levels are comparatively low in the area near to the site, but the police records do show that there is a degree of anti-social behaviour recorded in the area.

- The local area does not contain any of the existing or potential housing supply identified in the Five Year Housing Supply Statement.

74. The above findings relating to the local community and socio-economic context have been used to inform the results of the following section on the assessment of community and socio-economic effects. For the purposes of the assessment section, the following receptors (shown in the below table) have been identified, and their sensitivity (based on the baseline assessment) given.

Table 9.4: Receptors for assessment and their sensitivity

Assessment area	Receptor	Sensitivity	Justification / comment
Employment	The local labour market	Low	Labour market is established with a number of strong sectors. Healthy local labour market with high wages, based on skilled workforce. Slight changes in demand/supply will not affect the market. Major employers (compared to other areas) are Public administration and defence; compulsory social security; manufacturing and agriculture (relatively). These are robust sectors and unlikely to be sensitive to change. The growing population will require job creation, but population growth is starting from low baseline.
Wider economic effects	Local economy	Medium	A number of local businesses are located in the vicinity of the Site. Low population density.
Public access and recreational amenity	Local public rights of way (no other local receptors identified)	Low	No PROW or other recreational land use identified in close proximity as such, low sensitivity assumed.
Crime and public safety	Site and the immediate surroundings	Medium	Low levels of Crime mean that a slight increase in crime could notably increase crime rates.

9.7 Assessment

9.7.1 Employment generation: gross

75. The table below (the *worker days* estimate) shows the estimated full time employment generation over the course of the exploration works. This will be referred back to in the individual assessments in this section. The FTE calculation is explained further in methodology section of this chapter (Section 9.4 Table 9.2).

Table 9.5: maximum numbers of staff (by stage) over the course of the exploration works

	Days	**Shifts per 24 hours**	**FTE (gross)**	**Leakage factor**	**Why?**	**leaves**	**Net direct**	**Multiplier**	**Why?**	**Gives… (net additional)**	**Total (net all)**
Construction / site prep	56.0	36.0	0.9	0.2	Low leakage factor at this stage. Mainly locally sourced contractors required along with security, cleaning staff etc. It has been assumed however that some amount of specialist labour will be drawn from outside the Lancashire area	0.7	0.7	1.7	Medium links due to nature of work (construction), which can be drawn from the local area.	0.5	1.2
Surface array	No assumptions available at this stage										
Buried array											
Drill Well l 1	154.0	43.0	3.0	0.7	Assumed at this stage the employment requirements are more specialist, with a lower proportion of local labour drawn on for more traditional site work, security, cleaning services and so forth.	0.9	0.9	1.3	Low links due to nature of the work i.e. specialist drilling and flow testing work	0.3	1.2
Drill Well 2	104.0	43.0	2.0	0.7		0.6	0.6	1.3		0.2	0.8
Drill Well 3	104.0	43.0	2.0	0.7		0.6	0.6	1.3		0.2	0.8
Drill Well 4	104.0	43.0	2.0	0.7		0.6	0.6	1.3		0.2	0.8
Hydraulic fracturing mobilisation	32.0	30.0	0.4	0.7		0.1	0.1	1.3		0.0	0.2
Hydraulic fracturing Well 1	45.0	45.0	0.8	0.7		0.2	0.2	1.3		0.1	0.3
Hydraulic	45.0	45.0	0.8	0.7		0.2	0.2	1.3		0.1	0.3

	Days	Shifts per 24 hours	FTE (gross)	Leakage factor	Why?	leaves	Net direct	Multiplier	Why?	Gives… (net additional)	Total (net all)
fracturing Well 2											
Hydraulic fracturing Well 3	45.0	45.0	1.0	0.7		0.3	0.3	1.3		0.1	0.4
Hydraulic fracturing Well 4	45.0	45.0	1.0	0.7		0.3	0.3	1.3		0.1	0.4
Flow testing Well 1	100.0	10.0	0.5	0.7		0.1	0.1	1.3		0.0	0.2
Flow testing #Well 2	100.0	10.0	0.5	0.7		0.1	0.1	1.3		0.0	0.2
Flow testing #Well 3	100.0	10.0	0.5	0.7		0.1	0.1	1.3		0.0	0.2
Flow testing #Well 4	100.0	10.0	0.5	0.7		0.1	0.1	1.3		0.0	0.2
EFT - all	1231.0	4.0	2.2	0.0	Locally sourced security guards and lower skilled staff only.	2.2	2.2	1.7	Medium links as employment and demands on supply chain are limited	1.6	3.8
Assumed that all EFT works carried out in tandem over the 2 year period (i.e. for each of the remaining wells), therefore employment generation for EFT stage for all wells is considered in the above row.											
Decommissioning and restoration	90.0	10.0	0.4	0.2	Employment demand considered likely to draw on local (Lancashire) contractors for decommissioning and site restoration	0.3	0.3	1.7	Medium links due to nature of work (site restoration)	0.2	0.6

	Days	Shifts per 24 hours	FTE (gross)	Leakage factor	Why?	leaves	Net direct	Multiplier	Why?	Gives… (net additional)	Total (net all)
					works. Some specialist input drawn from further afield to deal with well restoration.						

Table 9.6: summary totals, gross and net employment (after rounding)

Summary totals	Quantity
Gross employment levels	19
Total after leakage	8
Total additional	4
Total net employment	11

76. Taking the project as a whole, one can see that the employment on Site goes through spikes of activity at different phases. Converting the employment data into worker days shows the cumulative number of daily shifts, over the lifetime of the identified stage. This can then be converted to worker years and then full time equivalent (FTE, assuming a full time job is 10 years) jobs created. This is the estimated *gross* amount of jobs created, 19 FTE.

77. These calculations do not include the employment generated by the installation of the arrays, which could be for an additional team of up to four people working on each of the 80 sites for up to three days.

9.7.2 Employment generation: net

78. Additionality factors to attempt to understand the net employment generation in the local area have been used (thought to represent the Lancashire scale impact). These are explained further in methodology section of this chapter (Section 9.4 Table 9.2).

79. The calculations show in Table 9.5 attempt to quantify employment relating to on-Site activities, the indirect supply chain effects and the induced effects associated with increased spending by workers (the latter two areas being what the composite multiplier accounts for) at the Lancashire level. The net FTE estimation is estimated to be 11 FTE positions[106].

80. It should be noted that throughout the project there will be other employment impacts through demand in areas such as consultancy (e.g. environmental, and other technical and legal support), which will be necessary throughout the process. It is reasonable, therefore, to state that the overall employment impacts of this exploration phase will be larger than the purely local (Lancashire scale) effects described. Firstly, there will be the additional (non-Site based) jobs described above, and at the stages for which estimates do not yet exist (i.e. where gaps exist in Table 9.5). Furthermore, there will be direct, indirect and induced employment generation at the wider scales. Pertinent examples include the North West and Yorkshire regions where specialist water treatment centres exist, and the further afield in UK such as the midlands, where specialist exploration equipment will be ordered from.

9.7.3 Construction of well pad and access

81. The construction phase is explained in detail in Chapter 4 of this Environmental Statement. For the purposes of this assessment, construction represents the first stage in the exploration process at Preston New Road (PNR). This initial stage has therefore also

[106] Note: As the project is expected to last six years, the net FTE generation was estimated over this period and presented alongside the 10 year FTE estimate. Using the six year FTE conversion factor (with all other factors being constant), gives and estimated net employment figure of 19 FTE positions.

been considered as the *decision to proceed* stage in this assessment. As such the costs and benefits explored at the construction stage will include those associated with the decision to use the land for exploration works (for example, *opportunity costs* of alternative lost land uses).

Table 9.7: Outline of costs and benefits associated with construction (including those flowing from the *decision to proceed*)

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	There is a risk that construction of well pad and access will draw employment away from other projects, where identical roles are required. The extent of this is unlikely to significantly displace any other projects completely; at worse it will cause minor delays where specialist staff are unavailable. The number of staff required for this stage is unknown due to the likely low levels of employment required, it is assumed that the local labour market can accommodate any demand where it appears, and that the wider (national) labour market for this specialist employment, can also accommodate the demand.	Specialist labour will be drawn in to help construct the pad and the access infrastructure. This aspect of the operation represents an increase in labour demand which would not be present without investment at PNR. It is likely that staff will be drawn from outside the local area, due to the specialist requirements on Site. Less skilled jobs including security and cleaning will also be needed at this stage. There will also be some local induced effects through increased income being spent in the local area. This has been factored into the employment generation figures at the start of this section.	The fall in labour supply will only be for the short duration of the construction stage (unless deployed personnel are also required for the future stages). This is not considered to be a significant cost, due to its short term nature and the likely low impact on other projects. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	One opportunity cost at this stage will be equivalent to the loss of potential alternative land-uses. Alternative options might include; mixed farming, housing (unlikely), ecological or recreational uses. The land is currently agricultural, with no alternative uses or allocations proposed. Therefore the most realistic future use will be continued use as agriculture with housing and recreational not deemed realistic future uses	There will also be some local induced effects through increased income being spent in the local area. This has been factored into the employment generation figures at the start of this section.	The outlined opportunity costs of the change in land use will not represent significant loss of value locally, or elsewhere in the economy. Development of the Site for agriculture would mean approximately one additional hectare of land, equal to an increase of 0.01% for Fylde107. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Public access and recreational amenity	Figure 9.15 shows where the closest PRoW is in relation to the Site. None of the identified routes run in close proximity to the Site. No re-routing of any local PRoW is deemed necessary during construction. As such, no significant effects on public access are anticipated.	No benefits are deemed likely in this area.	No significant local, regional or national costs or benefits are deemed likely. The receiving receptor is deemed to be of low sensitivity. Overall, the effect against the objective is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

[107] The Aecom Employment Land and Premises Study for Fylde Borough Council states the following regarding agriculture in the borough; *Agriculture, forestry and fishing employ only 0.03 per cent of the Borough's population … the Department of Environment, Food and Rural Affairs June 2010 Survey of Agriculture and Horticulture…indicates that in that year there were 170 agricultural holdings in Fylde, farming 10,881 ha of land*. This is used as an approximation of the baseline agricultural land supply in the borough.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Crime and public safety	Recent experience has shown that drill Sites can attract public attention and a degree of protest. This is considered at this stage (as the decision to proceed stage) of the exploration works only. The risk of criminal activity is thought to be minimal, although arrests have been noted at other protest sites. Should this occur, it is assumed that public order and people management will be maintained by the local police force, with full cooperation and engagement from Cuadrilla, reducing the impact on the crime and public safety in the area.	No benefits to crime or safety are expected from this stage of the exploration.	Overall, a low adverse effect is deemed likely. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

9.7.4 Installation of Surface and Buried Arrays

Surface array

82. The installation of the surface network array points will be installed outside the Site. As such, the associated works have been dealt with separately. The likely costs and benefits are outlined in Table 9.8.

Buried array

83. The installation of the buried arrays will occur outside the pad Site. As such, the associated works have been dealt with separately. The likely costs and benefits are outlined in Table 9.9.

Table 9.8: Outline of costs and benefits associated with installation of surface network arrays.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	The labour market will not bear any costs from this stage of the exploration works.	Employment generation from the installation of these arrays is deemed to be minimal.	Overall, the effect is deemed to be negligible in all areas assessed. Based on the above, and the sensitivity analysis in Table 9.4, the overall effects are not deemed significant.
Wider economic effects	No significant costs on the economy are deemed likely from this stage of the exploration works.	No significant wider economic benefits are deemed likely from this stage of the exploration works.	
Public access and recreational amenity	No receptors have been identified, as such no significant costs are deemed likely from this stage of the exploration works.	No benefits are deemed likely in this area.	
Crime and public safety	There is a risk that arrays are open to vandalism. Good design and appropriate locations for arrays will ensure that the array housing is robust, and cannot be open to vandalism, or damaged through accident. No costs are considered likely in this area.	No benefits are deemed likely in this area.	

Table 9.9: Outline of costs and benefits associated with installation of buried arrays.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	The labour market will not bear any costs from this stage of the exploration works.	Installation works will require a small team of installation specialists to carry out works. This will require direct expenditure on installation services and will have minor employment generation benefits over time.	A low beneficial effect is anticipated from the employment generation associated with the installation and servicing of the buried arrays. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	No significant costs on the economy are deemed likely from this stage of the exploration works.	No significant wider economic benefits are deemed likely from this stage of the exploration works.	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Public access and recreational amenity	No costs are considered likely in this area.	No benefits are deemed likely in this area	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Crime and public safety	There is a risk that arrays are open to vandalism. Good design will ensure that the array housing is robust, and cannot be open to vandalism, or damaged through accident. No costs are considered likely in this area.	No benefits are deemed likely in this area	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

9.7.5 Drilling

84. This section covers the mobilisation and drilling stages. No distinction is drawn between the four separate wells.

Mobilisation

85. The mobilisation stage will involve deployment of specialist staff to the Site. It is likely that specialist staff will be drawn from beyond the North West due to the specialist nature of the required roles. This will also have direct and indirect effects on the supply chain (again, likely to be predominantly from outside the region, due to specialist requirements). Likely benefits and costs are assessed alongside the drilling activity itself in Table 9.10.

86. Cuadrilla has a commitment to use local labour and suppliers where possible. In addition to this, it is acknowledged that some staff will move in and live in local area on a more permanent basis, whereas some will live in hotels for shorter periods.

Drilling

87. The drilling phase is assessed with the drilling mobilisation stage in Table 9.10. The socio-economic effects will be more sustained than mobilisation. The drilling stage will trigger a contribution payment from Cuadrilla to the local community for works at the Site. This will be administered by the Community Foundation for Lancashire.

Table 9.10: Outline of costs and benefits associated with mobilisation/drilling

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	The local labour market will not bear any costs from mobilisation and drilling. At the national scale (and potentially beyond); deploying specialist staff for mobilisation and drilling of exploration works at Preston New Road will mean a marginal fall in supply of trained staff elsewhere in the country for the two years of the drilling stage.	Specialist labour will be drawn in at mobilisation. This aspect of the operation represents an increase in labour demand which would not be present without investment at the PNR Site. It is likely that staff will be drawn from outside the local area, due to the specialist requirements. Less skilled service jobs will also be required at this stage. Less skilled jobs may be created at the mobilisation stage in the form of Site staff not involved in the more technical, specialist aspects of the mobilisation stage. Expenditure in the local area will marginally contribute to the creation of new jobs or safeguarding existing jobs through indirect (business to business interactions) and induced (local employee spending) effects.	The fall in labour supply is not considered to be a significant effect, due to its short term and temporary nature. The national costs will be secondary to the local benefits. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	No significant costs on the economy are deemed likely from this stage of the exploration works.	Direct local benefits will come in the form of a community benefit payment of £100,000 per drilled well i.e., up to £400,000 for four wells) paid to local communities, where the exploration Site is located. This community money is allocated for direct expenditure on community benefits via consultation with an independent organisations There are likely to be supply chain benefits felt further afield, through induced and indirect economic effects of spending this endowment. Local landowners are likely to benefit from increased income. Assuming this money is spent in the local area, this will have positive supply chain impacts. There will also be the business to business indirect multiplier effect at the construction stage.	The payment of the endowment will be a benefit at the local level, with potential benefits to be felt further afield at the local level through the supply chain. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Public access and recreational	No significant effects on public access are anticipated from mobilization/drilling. Further information is contained in the transport assessment, and the	No benefits are considered likely in this area at the mobilisation and drilling stage.	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
amenity	landscape and visual impact assessment within this ES.		
Crime and public safety	Recent experience has shown that drill Sites can attract public attention and a degree of protest. This is considered likely to remain throughout this stage of the exploration works only. Risk of criminal activity is thought to be minimal, although arrests have been noted at other protest sites. Should this occur, it is assumed that public order and people management will be maintained by the local police force, with full cooperation and engagement from Cuadrilla, reducing the impact on the crime and public safety in the area.	No benefits to crime or public safety are expected from this stage of the exploration.	Overall, a low adverse effect is deemed likely. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

9.7.6 Hydraulic Fracturing

88. After drilling, hydraulic fracturing and flow testing covers the bulk of the works that make up the Preston New Road exploration. Hydraulic fracturing across four wells will mean consumption of resources, deployment of specialist staff, supply chain effects across a number of sectors (and to varying degrees) and effects on local amenity.

89. Less skilled employment opportunities will also be created in the form service staff, for example. Other local economic effects will be in the form of spending in the local area on goods and services such as hotels, local logistics services, restaurants/cafes and local shops (for the avoidance of double-counting; these effects are captured in the employment generation number through use of a composite multiplier).

90. For the purposes of the assessment, the community and socio-economic effects associated with hydraulic fracturing is assessed alongside flow testing (the next stage) in Table 9.11.

9.7.7 Flow Testing

91. Flow testing is assessed in combination with hydraulic fracturing in Table 9.11 overleaf.

Table 9.11: Outline of costs and benefits associated with onsite exploration works post drilling; hydraulic fracturing and flow testing.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	There will be no direct costs to the local employment base from this stage. At the national scale (and potentially beyond) deploying specialist staff for exploration works at Preston New Road will mean a marginal fall in supply of trained staff elsewhere in the country. This will be a temporary effect.	Specialist labour will be drawn in to help with hydraulic fracturing and flow testing. This represents an increase in labour demand. It is likely that staff will be drawn from outside the local area, due to the specialist requirements. Table 9.5 at the start of this section shows the number of employees (worker days) over this stage. Less skilled service jobs will also be required at this stage. Expenditure in the local area will marginally contribute to the creation of new jobs or safeguarding existing jobs through indirect (business to business interactions) and induced (local employee spending) effects.	Costs are deemed to be short term and not of significant concern at any of the geographic scales under consideration. Benefits, whilst also short term, will be felt at the local and national levels. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	Deployment of specialist apparatus may result in an inability to support exploration elsewhere in the country. This will be a temporary effect.	Expenditure in the local area will marginally contribute to the creation of new jobs or safeguarding existing jobs through indirect (business to business interactions) and induced (local employee spending) effects.	Costs are not considered to be significant at this stage, whereas benefits represent sizeable short term investment for certain sectors. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Public access and recreational amenity	There will no direct effects on PROW. There may effects on local amenity through local disturbance and views into the Site from public areas. This loss of amenity will primarily be during the hydraulic fracturing stage, where extensive on-Site apparatus will be visible from outside the Site. This will be temporary (up to 45 days) and reversible. After this point, the flow testing will not have effect local amenity.	No direct or indirect benefits are expected on public access or recreational amenity from this stage of works.	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Crime and public safety	The Site will be a self-contained operation. As such, public safety risks will be minimal. Safety risks off Site are likely to be limited to those associated with changes in frequency and type of traffic. This will be managed according to the assumptions set out in the transport assessment section of this ES.	No benefits to crime or safety are expected from this stage of the exploration.	Overall, a low adverse effect is deemed likely. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
	Recent experience has shown that drill Sites can attract public attention and a degree of protest. This is considered likely to remain throughout this stage of the exploration works only. Risk of criminal activity is thought to be minimal, although arrests have been noted at other protest sites. Should this occur, it is assumed that public order and people management will be maintained by the local police force, with full cooperation and engagement from Cuadrilla, reducing the impact on the crime and public safety in the area.		

9.7.8 Extended flow testing

Construction

92. The extended flow testing phase is described in detail in Chapter 4 of this ES. The construction will involve grid connection works and mobilisation of workers and specialist equipment on the existing well pad Site.

Operation

93. The operation of the EFT phase will be up to two years per well. Once operational, the level of staffing required for this element of the Project is negligible. This is because activity on Site will be negligible, with minimal vehicle movements or intrusive Site activities.

Table 9.12: Outline of costs and benefits associated with extended flow testing infrastructure construction

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	There is a small risk that construction of EFT infrastructure will draw employment (National Grid staff) away from other projects. The exact number of staff required for this stage is unknown. Due to the likely low levels required, it is assumed that the local labour market can accommodate this demand where it appears.	Benefits of short term employment generation for this type of work may be felt locally, compared with the more technical aspects, which may demand labour from further afield. Less skilled service jobs will also be required at this stage.	The fall in labour supply will only be for the short duration of the construction stage (unless deployed personnel are also required for the future stages). This is not considered to be a significant effect, due to its short term nature. Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	There may be some disturbance to infrastructure from installation of the gas connection. It is expected that any resulting economic costs associated with this (such as congestion impacts) will be minimal as works will be managed according to best practice.	There will be some associated spending increases in the local area. Any increase is expected to be minimal.	Overall, the effect is deemed to be negligible in this area. Based on the above, and the sensitivity analysis in Table 9.4, the overall effects are not deemed significant.
Public access and recreational amenity	No costs are considered likely in this area	No benefits are deemed likely in this area	Overall, a negligible effect is deemed likely. Based on the above, and the sensitivity analysis in Table 9.4, the overall effects are not deemed significant.
Crime and public safety	No costs are considered likely in this area	No benefits are deemed likely in this area	Overall, a negligible effect is deemed likely. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant

Table 9.13: Outline of costs and benefits associated with EFT operation

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	The labour market will not bear any costs from this stage of the exploration works.	Employment generation from the installation of these five arrays is deemed to be minimal. Less skilled jobs including security and cleaning will also be required at this stage.	Overall, the effect is deemed to be negligible in all areas assessed. Based on the above, and the sensitivity analysis in Table 9.4, the overall effects are not deemed significant.
Wider economic effects	No significant costs on the economy are deemed likely from this stage of the exploration works.	No significant wider economic benefits are deemed likely from this stage of the exploration works.	

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Public access and recreational amenity	Minimal disturbance is expected to the local area from the Site, from the operational EFT.	No benefits are deemed likely in this area.	
Crime and public safety	No costs are considered likely in this area	No benefits are deemed likely in this area	

9.7.9 Decommissioning and Restoration

Extended Flow Testing (EFT) Infrastructure

94. It is assumed that the Site will be restored to agricultural use. The likely costs and benefits from decommissioning and restoration of EFT infrastructure are outlined in Table 9.14 alongside the decommissioning and restoration of the well, pad and access track.

Exploration well, pad and access track

95. It is assumed that the Site will be restored to agricultural use. The likely costs and benefits are outlined in Table 9.14.

Table 9.14: Outline of costs and benefits associated with decommissioning and restoration

Assessment area	Likely costs	Likely benefits	Assessment of significance and against objective
Employment	Site restoration will stimulate demand for labour. It is assumed that the local and national labour markets will be able to accommodate the rise in demand (assuming that no highly skilled or technical employment is required) and as such there will be no costs from this stage.	Decommissioning/restoration will result in expenditure on employment to restore the Site the agricultural use. Less skilled jobs including security and cleaning will also be required at this stage.	Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Wider economic effects	Decommissioning/restoration will not result in any significant economic costs.	Decommissioning/restoration will not result in any significant economic benefits, beyond the investment in land restoration.	Overall, the effect is deemed to be low beneficial. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Public access and recreational amenity	Decommissioning/restoration will not result in any costs to public access or recreational amenity.	Decommissioning/restoration will not result in any benefits to public access or recreational amenity.	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.
Crime and public safety	No costs are considered likely in this area.	No benefits are deemed likely in this area.	Overall, the effect is deemed to be negligible. Based on the above, and the sensitivity analysis in Table 9.4, the overall effect is not deemed significant.

9.8 Cumulative and Interactive Effects

96. Cumulative and interactive effects have been considered here. The following is considered:

- The in combination effects of hydraulic fracturing and initial flow testing occurring simultaneously on the same well pad.
- In combination effects of initial flow testing and drilling occurring at the same time.
- Preston New Road (PNR) exploration works occurring at the same time as the exploration works at Roseacre Wood (RW).
- The committed or reasonably foreseeable developments identified in Chapter 21 of this Environmental Statement.

97. A qualitative assessment is given below relating to each, for the defined community and socio-economic assessment areas.

Employment

98. The in combination effects of hydraulic fracturing and initial flow testing occurring simultaneously on the same well pad will have no significant (beneficial or adverse) effects on employment. Similarly, no significant (beneficial or adverse) in combination effects are expected on employment from initial flow testing and drilling occurring at the same time.

99. Due to the specialist requirements of the exploration works at PNR and RW, it may be that at certain points in the exploration works programme, demand/supply of labour is such that works may be have to be delayed/reprogrammed (substitution effect). This will be mitigated through detailed planning of the exploration works at both Sites, with Cuadrilla staff working alongside chosen contractors to ensure maximum efficiency on Site through detailed planning and allocation of labour.

100. Induced multiplier effects resulting from increased income of existing workers (and those currently seeking work) will have marginal employment generating effects on the wider economy. Furthermore, business-to-business transactions for building materials and other supplies will also help towards (indirect) job creation and safeguarding.

101. The combined potential employment generation of the PNR and RW exploration Sites along with the construction and operation of the other reasonably foreseeable developments identified in Chapter 21 of this Environmental Statement represent a potential beneficial effect on the labour market. Net demand for construction workers will increase with all the varied projects outlined, creating new jobs in this area and the potential for apprenticeships and training for young entrants into the labour market.

Wider economic effects

102. The in combination effects of hydraulic fracturing and initial flow testing occurring simultaneously on the same well pad will have no significant (beneficial or adverse) effects on the local economy. Similarly, no significant (beneficial or adverse) in combination effects are expected on employment from initial flow testing and drilling occurring at the same time.

103. No significant economic costs have been identified for both PNR and RW. All exploration works at PNR and RW in combination with the investment in the other reasonably foreseeable projects in Fylde and Lancashire represent a positive investment in the local economy.

Public access and recreational amenity

104. No additional impacts, or significant effects, are deemed likely in combination with other identified developments (including RW), or with the on-Site in combination effects.

Crime and public safety

105. No additional impacts, or significant effects, are deemed likely in combination with other identified developments (including RW), or with the on-Site in combination effects.

9.9 Mitigation Measures

9.9.1 Construction of well pad and access

Employment

106. In order to try and maximise positive local employment impacts, Cuadrilla will endeavour to source staff from the local employment base, where practicable. This should be carried through at all appropriate stages of the exploration works. As vacancies become available over the exploration phase, Cuadrilla will advertise locally to ensure people in Lancashire have the best chance of filling the jobs (this policy will be carried throughout the project at all stages, where appropriate).

Crime and public safety

107. Due to the low levels of crime in the area, the area is deemed to have a medium sensitivity to change in crime levels. The potential for public disorder due to protest at the Site has been considered here. Should protest at the Site occur, it is assumed that public order and people management will be maintained by the local police force, with full cooperation of the Site operator. Mitigation will take the form of continued engagement with the relevant local police contacts and the protest groups (where possible), to ensure any disturbance is minimalized.

9.9.2 Installation of surface and buried arrays

108. No mitigation measures are deemed necessary for this stage.

9.9.3 Drilling

Employment

109. In order to try and maximise positive local economic impacts, Cuadrilla will consider sourcing staff from the local employment base, where practicable. No further mitigation measures are deemed necessary.

Crime and public safety

110. Should protest at the Site occur at this stage, it is assumed that public order and people management will be maintained by the local police force, with full cooperation with Cuadrilla. Mitigation will take the form of continued engagement with the relevant local police contacts and the protest groups (where possible), to ensure any disturbance is minimalized.

9.9.4 Hydraulic fracturing

Employment

111. In order to try and maximise positive local economic impacts, Cuadrilla will consider sourcing staff from the local employment base, where practicable.

Crime and public safety

112. Should protest at the Site occur at this stage, it is assumed that public order and people management will be maintained by the local police force, with full cooperation of the Site operator. Mitigation is recommended in the form of continued engagement with the relevant local police contacts and the protest groups (where possible), to ensure any disturbance is minimalized.

9.9.5 Flow testing

113. No mitigation measures are deemed necessary for this stage.

9.9.6 Extended flow testing

Wider economic effects

114. Ensure all best practice measures are employed to minimise disturbance and as such minimise economic impact when installing EFT infrastructure. This will relate to any impact on transport infrastructure which could result in congestion and delays on the local transport network.

115. No further mitigation measures are deemed necessary for this stage.

9.9.7 Decommissioning and restoration

116. No mitigation measures are deemed necessary for this stage.

9.10 Residual Effects

117. No other significant residual effects have been identified, after consideration of the original likely effects and the proposed mitigation measures.

9.11 Assessment Summary Matrix

Table 9.15. Community and socio-economic assessment summary matrix

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad and Access			
Employment	No significant effects	Cuadrilla will source labour from local labour market to attempt to fairly maximise the local job creation (this policy will be carried throughout the project at all stages, where appropriate).	No significant effects identified
Wider economic effects	No significant effects	None proposed	No significant effects identified
Public access and recreational amenity	No significant effects	None proposed	No significant residual effects identified
Crime and public safety	No significant effects	Forward planning and consultation with local police force	No significant residual effects identified
Installation of the Surface and Buried arrays			
Employment	No significant effects	None proposed	No significant residual effects identified
Wider economic effects			
Public access and recreational amenity			
Crime and public safety			
Mobilisation/Drilling			
Employment	No significant effects	None proposed	No significant residual effects identified
Wider economic effects			
Public access and recreational amenity			
Crime and public safety	No significant effects	Forward planning and consultation with local police force.	No significant residual effects identified
Hydraulic fracturing and flow testing			
Employment	No significant effects	None proposed	No significant residual effects identified
Wider economic effects			
Public access and recreational amenity			

Description of effect	Significance	Mitigation	Residual effect
Crime and public safety	No significant effects	Forward planning and consultation with local police force.	No significant residual effects identified
Extended Flow Testing			
Employment	No significant effects	None proposed	No significant residual effects identified
Wider economic effects	No significant effects	Ensure that impacts on local networks is minimised when associated infrastructure is developed	No significant residual effects identified
Public access and recreational amenity	No significant effects	None proposed	No significant residual effects identified
Crime and public safety	No significant effects	Forward planning and consultation with local police force.	No significant residual effects identified
Decommissioning and Restoration			
Employment	No significant effects	None proposed	No significant residual effects identified
Wider economic effects			
Public access and recreational amenity			
Crime and public safety	No significant effects	Forward planning and consultation with local police force.	No significant residual effects identified

10 Ecology

Chapter Summary - Ecology

This chapter assesses the potential for the Project to effect sensitive habitats and species of wildlife value. It does this by firstly establishing which habitats and species of value are present within the zone of influence of the Project. An assessment is then undertaken to determine whether there are any pathways of impact upon the valued habitats and species.

The site is located within an intensively managed landscape adjacent to Preston New Road. This affects the quality of habitats present on site and influences the species that the site may support. In addition, the site is not located within close proximity to any protected nature conservation sites. However, the wider agricultural landscape is of value to wintering birds.

The ecological receptors, of nature conservation value, identified within the zone of influence of the main Site included; hedgerows, bats, breeding birds, wintering birds and brown hare. The ecological receptors, of nature conservation value, identified within the zone of influence of the array sites included; wintering birds connected to Lytham Moss BHS and Morecambe Bay SPA and the Ribble and Alt Estuary SPA and ground nesting breeding birds.

The routes of potential impact identified included;

Loss of habitat.

Disturbance due to increased noise levels, vehicle and personnel movements (visual) and increased light levels.

Alteration of bat behaviour due to heat emitted by the flare stack.

Accidental injury or killing of brown hare

A range of mitigation measures and compensation measures are to be adopted to either reduce the level of impact so that it is no longer significant or provide alternative habitat to ensure that the local population is not significantly impacted by the Project. These measures will be presented within a Biodiversity Mitigation Strategy (BMS).

10.1 Introduction

1. This section of the ES reports the findings of the assessment of predicted impacts on ecology and nature conservation. It is based on detailed technical information provided in Appendix J Part 1-9.

2. The ecology section consists of an Ecological Impact Assessment (EcIA) that assesses the potential impact of the proposed development on the ecology and nature conservation interest of the Site (referred to hereafter as ‘Site’) and surrounding area. The assessment covers the potential for impact on habitats and species, with particular reference to any species that are protected under national and international legislation.

10.2 Key Development Issues

3. The footprint of the works is relevant to the EcIA as it dictates the area of direct and indirect disturbance to habitats and species. It is considered that these impacts would occur during the construction phase which includes the construction of the well pad, access tracks, pipeline connection to grid gas and seismic monitoring array points (e.g. surface array and buried arrays) and the operational lifecycle of up to four wells from the pad well sites (refer to Chapter 4 or Appendix A for main Site boundary and Appendix J: Part 7 for the array sites).

4. Operational features of the proposed development that have the potential to impact upon features of ecological value are drilling, hydraulic fracturing, initial flow testing, extended flow testing, decommissioning and restoration.

5. Mitigation, compensation and enhancement measures for habitats and protected species as part of the proposed development are relevant in the role that they can play in reducing / offsetting adverse impacts and potentially enhancing the current situation (i.e. the environmental conditions).

10.3 Scoping and Consultation

6. An Environmental Scoping Report (Appendix C1) was prepared for the proposed development and submitted to Lancashire County Council (LCC) as part of the statutory consultation process. In addition, discussions have been held with Natural England (via their Discretionary Advice Service (DAS)), LCC and the Environment Agency (EA) during the EIA process in order to agree the need for and scope of surveys and key issues to be addressed within the EcIA process.

7. Table 10.1 summarises the Scoping Opinion comments relevant to the EcIA and outlines how they have been addressed.

Table 10.1: Ecology scoping and consultation overview.

Consultee	Comment	Response
Natural England (NE)	*NE advises that the potential impact of the proposal upon features of nature conservation interest and opportunities for habitat creation/enhancement should be included within this assessment in accordance with appropriate guidance on such matters.*	Potential impacts of the proposal upon features of nature conservation interest have been undertaken in accordance with IEEM guidance.[108] Appropriate habitat creation and enhancement measures have been included as part of the mitigation measures (Section 10.9).
NE	*The ES should thoroughly assess the potential for the proposals to affect internationally and nationally designated sites.*	An assessment of internationally and nationally designated sites has been undertaken as part of the EcIA and with a shadow Habitats Regulation Assessment (HRA) Appendix J: Part 9.
NE	*The EIA will need to consider any impacts upon local wildlife and geological sites.*	An assessment of locally designated sites relating to nature conservation has been undertaken within the EcIA.
NE	*The ES should assess the impact of all phases of the proposals on protected species (including, for example great crested newts, reptiles, birds, water voles, badgers and bats).*	An assessment of impacts as a result of all phases of the proposal on protected and notable species has been undertaken within the EcIA.
NE	*Records of protected species should be sought from appropriate local biological record centres, nature conservation organisations, groups and individuals.*	Biological records have been requested from the following organisations to inform the baseline detailed within the EcIA: Lancashire Environment Record

[108] IEEM (2006) *'Guidelines for Ecological Impact Assessment in the UK.'*

Consultee	Comment	Response
		Network (LERN), Fylde Bird Club, Lancashire Badger Group, Merseyside and West Lancashire *Bat Group, Lancashire Wildlife Trust and the Amphibian and Reptile Group of South Lancashire (via the* Lancashire Amphibian and Reptile Atlas).
NE	*The area likely to be affected by the proposals should be thoroughly surveyed by competent ecologists at appropriate times of year for relevant species and the survey results, impact assessment and appropriate accompanying mitigation strategies included as part of the ES*	An extended Phase 1 Habitat Survey has been undertaken and subsequent surveys in relation to amphibians, bats, birds, badgers and water vole have been undertaken to inform the baseline prepared as part of the ES. The survey results are summarised within the baseline (Section 10.6) and individual survey reports have been provided within Appendix J. Appropriate mitigation has also been included within the EcIA (Section 10.9).
NE	*The ES should thoroughly assess the impact of the proposals on habitats and / or species listed as 'Habitats and Species of Principal Importance' published under Section 40 if the Natural Environment and Rural Communities (NERC) Act 2006.*	An assessment of impacts on NERC Act (2006) Section 41 'Habitats and Species of Principal Importance' has been undertaken within the EcIA.
Environment Agency (EA)	*We have considered the proposals in relation to the Water Framework Directive (WFD) and the need for a WFD compliance assessment. Where there is no discharge of surface water run-off from the Site to a watercourse and there are no works to a watercourse, it is our opinion that a WFD compliance assessment for fluvial water bodies will not be required. Where there is a discharge of surface water run-off that could result in adverse impacts to fluvial water bodies or the proposal involves works to a watercourse, the need for a WFD compliance assessment will need to be reviewed.*	This is noted. There is no discharge of surface water run-off that could result in adverse impacts to fluvial water bodies; nor do the proposals involve works to a watercourse. We are therefore in agreement that a WFD compliance assessment for fluvial waterbodies is not required.
LCC	*There is one non-statutory site within 2km.*	This is noted. Since the Scoping Report was written an updated data request has been undertaken to cover a larger search radius surrounding the Site which identified the presence of presence of seven Biological Heritage Sites (BHS) within the search radius and one within 2km of the Site, namely Great Plumpton Sidings (Section

Consultee	Comment	Response
		10.6). An assessment of potential impacts on all BHS sites located within proximity to the Project has been undertaken within the EcIA.
LCC	*Section 5.5.2.3 Biological records indicates that a records search has been carried out within a 2km radius of the Site. Since the maximum extent of seismometer arrays appears to be larger than this, the biological records search should be extended to include the maximum extent of development.* *In addition to consultation with LERN, consideration should be given to consulting with other potential data holders (e.g. local ornithology, bat, badger, amphibian groups, local wildlife trust) in order that all relevant records are collected.* *The results of the desk study/ data search should be used to inform the need for ecological surveys as well as the design of the development and any mitigation/ compensation/ enhancement measures.* *The results of the desk study should be included within the Environmental Statement (ES).*	Since the Scoping Report was completed biological records have since been requested covering an approximate 1km buffer surrounding the maximum array stations sites. This has included consultation with the following organisations: LERN, Fylde Bird Club, Lancashire Badger Group, Merseyside and West Lancashire *Bat Group, Lancashire Wildlife Trust and the* Amphibian and Reptile Group of South Lancashire (*via the* Lancashire Amphibian and Reptile Atlas).*The results of the desk study has been included within the EcIA and has been used to inform the scope of ecological surveys undertaken and subsequent mitigation measures (Sections 10.4, 10.6 and 10.9).*
LCC	*Full results of great crested newt surveys should be included within the ES.*	Full results of all ecological survey work undertaken to inform the EcIA have been provided within Appendix J.
LCC	*Given that the zone of influence of proposals may be considerably larger than the site (i.e. extent of seismometer arrays) the extent of the survey may need to be increased.*	Ecological baseline appraisals, ornithological site assessments and wintering bird surveys, where required, have been undertaken covering the array station sites (Section 10.6).
LCC	*Full results of the Phase 1 Habitat survey should be included within the ES. If any semi-natural habitats or habitats with the potential to support ecologically significant species would be affected, then more detailed vegetation surveys should be carried out to enable an assessment of impacts and inform mitigation proposals.* *Any hedgerows affected by the proposals should be assessed according to the criteria specified in the Hedgerow Regulations 1997 (and UK BAP).*	Full results of the Extended Phase 1 Habitat Survey is provided in Appendix J. This includes details of hedgerow surveys are accordance with the Hedgerow Regulations 1997. Waterbodies located within a 250 m radius of the Site have been surveyed in accordance with Predictive SYstem for Multimetrics (PSYM). Full results are provided in Appendix J and detailed within the EcIA (Section 10.6).

Consultee	Comment	Response
	If any ponds may be directly or indirectly affected by the proposals then they should be surveyed according to the Lancashire Pond Biodiversity Survey Methodology (or similar) in order to inform the need for mitigation/compensation.	
LCC	*The ES needs to include assessments of habitat suitability, and the results of surveys, for all protected species potentially affected by the proposals. Surveys should be carried out in accordance with recognised guidelines (including those endorsed by Natural England's standing advice for protected species).*	The EcIA includes an assessment of habitat suitability and subsequent protected species potentially affected by the proposals. All survey work has been undertaken in accordance with current guidance.
LCC	*The ES should include the results of surveys for other species, habitats and features of nature conservation value, an assessment of likely impacts on these and mitigation/compensation for unavoidable impacts. This should include Species and Habitats of Principal Importance (NERC Act 2006), priority species and habitats of the UK and Lancashire Biodiversity Action Plans, red list species and any nationally or locally rare or scarce species.*	The EcIA includes an assessment of potential impacts on NERC Act (2006) Section 41 'Habitats and Species of Principal Importance', priority species and habitats of the UK and Lancashire Biodiversity Actions Plans, red list species and any nationally or locally rare or scare species.
LCC	*The ES should demonstrate that the spread of any invasive species will be avoided during the proposed development works.*	The extended Phase 1 Habitat survey included a search for listed invasive species under Schedule 9 Wildlife and Countryside Act, 1981 (as amended).
LCC	*The ES should consider the impacts of lighting on biodiversity and propose mitigation measures where appropriate.*	Potential impacts of lighting on biodiversity have been undertaken within the EcIA (Section 10.7). Subsequent mitigation has been proposed where appropriate (Section 10.9).
LCC	*Any restoration/ enhancement proposals should ideally deliver beneficial biodiversity and should aim to contribute to targets specified in the UK and Lancashire Biodiversity Action Plans. Landscaping proposals should comprise native plant communities appropriate to the locality.*	Mitigation measures proposed aim to deliver biodiversity gains as part of the proposals (Section 10.9).

10.4 Methodology

10.4.1 Introduction

11. The EcIA for the proposed development follows the published guidance by the Institute of Ecology and Environmental Management which has recently received its chartered status (CIEEM).[109]

12. The assessment has involved the following key stages:

- Scoping and consultation;
- Identification of the likely zone of influence of the proposed development (study area);
- Identification and evaluation of ecological resources and features likely to be affected (the baseline environment);
- Identification of the biophysical changes likely to affect valued ecological resources and features and an assessment of whether these biophysical changes are likely to give rise to a significant ecological impact;
- Refinement of the proposed development to incorporate ecological mitigation and enhancement measures to avoid, reduce or compensate for any significant adverse impacts; and
- Assessment of the predicted residual impacts taking mitigation and enhancement measures into account and evaluation of the significance of the consequent residual effects.

13. The likely zones of influence identified comprise:

- An immediate zone of influence within the Site; and
- A wider zone of influence extending to all areas / receptors that could be affected by the proposed development (wider zones of influence utilised in relation to specific ecological receptors have been defined within Section 10.4.2).

14. Establishment of the baseline environment has involved a combination of desk based study, data collation and site survey.

15. Planning guidelines, international commitments, legislation and planning policies relevant to the protection, conservation and enhancement of nature conservation interests associated with the Site are relevant to driving the baseline and assessment methodologies. These documents are listed below (Further details are provided in Appendix J, Part 1):

- Wildlife and Countryside Act, 1981 (as amended).
- Countryside and Rights of Way Act, 2000.
- The Natural Environment and Rural Communities Act, 2006.
- The Protection of Badgers Act, 1992.
- Council Directive (92/43/EEC) on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive).

[109] IEEM (2006) *Guidelines for Ecological Impact Assessment in the UK*

- Council Directive (2009/147/EC) on the Conservation of Wild Birds (Birds Directive).
- Conservation of Habitats and Species Regulations, 2010 (Habitat Regulations).
- The Hedgerow Regulations 1997.
- The Protection of Badgers Act, 1992.
- National Planning Policy Framework (NPPF) 2012.
- Government Circular: Biodiversity and Geological Conservation – Statutory Obligations and their impact within the Planning System (Defra 01/2005, ODPM 06/2005).
- The 'UK Post-2010 Biodiversity Framework' (2012)
- UK Biodiversity Action Plan (UKBAP).
- Lancashire Biodiversity Action Plan (Lancashire BAP).[110]
- Fylde Local Plan as altered 2005.[111]

Within the Fylde Local Plan following key policies are relevant to this assessment:

- *Policy SP2: Countryside Areas;*
- *Policy SP3: Green Belt;*
- *Policy TREC13: Public Open Space;*
- *Policy TREC14: Recreational Area;*
- *Policy EP2: Open Spaces within Towns and Villages;*
- *Policy EP3: Conservation Areas;*
- *Policy EP15: European Nature Conservation Sites;*
- *Policy EP16: National Nature Reserves;*
- *Policy EP17: Biological Heritage Sites; and*
- *Policy EP20: Areas of Open Coastline.*

- Joint Lancashire Structure Plan Supplementary Planning Guidance - Landscape and Heritage (2001-2016).[112]
- Joint Lancashire Mineral and Waste Development Framework Core Strategy Development Plan Document (2009).[113]

Within the Core Strategy the following key policies are relevant to this assessment:

- *Policy CS5 (i): our natural resources including water, air, soil and biodiversity are protected from harm and opportunities are taken to enhance them; and*
- *Policy CS9(i): Natural resources including water, air, soil and biodiversity are protected from contamination in the vicinity of waste facilities and opportunities are taken to enhance them.*

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[110] *'Lancashire Biodiversity Partnership – Lancashire Biodiversity Action Plans'* – Lancashire County Council http://www.lancspartners.org/lbap/biodiversity_action_plans.asp (Accessed August 2013).
[111] Fylde Borough Council '*Fylde Local Plan as altered 2005'* http://www2.fylde.gov.uk/media/LocalPlan/index.html (Accessed August 2013).
[112] Lancashire County Council (2006) *'Joint Lancashire Structure Plan (2001 – 2016) Supplementary Planning Guidance – Landscape and Heritage.'*
[113] Lancashire County Council (2009) *'Joint Lancashire Minerals and Waste Development Framework Core Strategy Development Plan Document.'*

10.4.2 Baseline methodology

10.4.2.1 Desk-based data collation

16. Protected species and designated site records were requested from the following organisations:

- Lancashire Environment Record Network (LERN) within a 4km (approximate) radius surrounding the Site (this includes a 1km buffer surrounding the maximum extent of the array stations).
- Fylde Bird Group within a 5km radius surrounding the Site (this includes a 2km buffer surrounding the maximum extent of the array stations).
- West Lancashire Badger Group within a 4km (approximate) radius surrounding the Site (this includes a 1km buffer surrounding the maximum extent of the array stations).
- Merseyside and West Lancashire Bat Group within a 3km radius surrounding the Site (this includes the maximum extent of the array stations).
- Lancashire Wildlife Trust within a 4km radius (approximate) radius surrounding the Site (this includes a 1km buffer surrounding the maximum extent of the array stations) *(N.B. The Lancashire Wildlife Trust responded to a request for ecological data records within the search radius surrounding the Site stating that they had no further records to add in addition to the records provided by LERN).*
- Amphibian and Reptile Group of South Lancashire (*via the* Lancashire Amphibian and Reptile Atlas (LARA)) within a 4km radius (approximate) radius surrounding the Site (this includes a 1km buffer surrounding the maximum extent of the array stations).

17. Data was also gathered, where appropriate, through a review of internet based relevant nature conservation information at:

- Multi-Agency Geographic Information for the Countryside (MAGIC) website - http://www.magic.gov.uk/MagicMap.aspx.
- National Biodiversity Network website - http://data.nbn.org.uk/ (Review only).
- Biodiversity Action Reporting System (BARS) http://ukbars.defra.gov.uk/.

18. The data searches identified designated sites (statutory and, where available, non-statutory) within a 5km search radius surrounding the Site. Internationally designated sites, including Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Ramsar sites, were searched for within a 10km radius surrounding the Site.

19. Ordnance Survey maps (1:10,000 scale) were examined for the presence of known waterbodies within 250m of the Site.

10.4.2.2 Field surveys – Site at Preston New Road

20. Field survey areas were defined for individual receptors based on their:

- predicted / likely ecology and behaviour locally,
- accessibility,
- radius of likely significant impacts, and

- the availability of biological records.

21. Full survey methodologies are detailed in the individual species report in Appendix J Part 1-9 and are briefly summarised below.

Extended Phase 1 Habitat survey

22. An Extended Phase 1 Habitat survey was undertaken of land within the Site boundary and surrounding habitats in July 2013 by Arup. The Phase 1 Habitat survey followed standard guidance[114] and involved identifying and mapping areas of homogenous vegetation. For each homogenous habitat area and type a species list was made noting the constant species within each habitat along with detail of their relative abundance using the DAFOR scale (Dominant, Abundant, Frequent, Occasional and Rare).

23. The faunal species scoping comprised a review of the habitats present and their potential to support protected or otherwise notable faunal species. Detailed faunal surveys were not undertaken during the Phase 1 Habitat survey; rather the potential for the Site to support each species or species group was assessed based on the known likely range of each species or species group and the suitability of the habitats within the Site. Field signs or sightings of such species were recorded as observed.

24. Any waterbodies present within 250m of the study area were assessed for their potential to support breeding populations of great crested newts. This assessment was undertaken using the Habitat Suitability Index (HSI) developed by Oldham *et al*. (2000)[115], which considers several ecological parameters such as location, desiccation, water quality and pond area. A value is recorded for each parameter and combined to determine an index of breeding suitability for great crested newts. The HSI is represented by a value from 0 to 1, the higher the value the more likely the pond is to support breeding great crested newts.

25. Hedgerows were also surveyed during the Phase 1 Habitat walkover survey against the wildlife and landscape criteria for 'importance' as defined by the Hedgerow Regulations 1997 and UK priority BAP habitat criteria.

Badger survey

26. A badger survey was undertaken within the proposed Site and areas of suitable habitat located within a 250m radius in October and December 2013 by Arup. The survey methodology was adapted from Harris *et al*., (1989). [116] The 250m survey area is deliberately extensive to ensure potential impacts including noise (e.g. from drilling) and visual disturbance impacts (e.g. site lighting) are assessed. This is supported by Statutory guidance (Scottish Natural Heritage (SNH)) which indicates that activities including quarry blasting and piling (i.e. activities more intrusive than drilling in terms of noise impacts) can cause disturbance to a badger sett within a 100m radius. [117]

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[114] Joint Nature Conservation Committee (JNCC) (2007) *Handbook for Phase 1 Habitat Survey. A technique for environmental audit.* Revised re-print 2003, reprinted 2007. JNCC: Peterborough.

115 Oldham, R.S., Keeble, J., Swan, M.J., and Jeffcote, M., (2000) 'Evaluating the suitability of habitats for great crested newt (*Triturus cristatus*)' Herpetological Journal 10: 143-15.

116 Harris, S., Cresswell, P. & Jefferies, D. (1989) *'Surveying for badgers'* Occasional Publication of the Mammal Society No. 9. Mammal Society, Bristol.

117 SNH (2012) *'Best Practices – Minimising Disturbance to Badgers'.* http://www.snh.gov.uk/about-scotlands-nature/wildlife-and-you/badgers/best-practice/ (Accessed November 2013).

Water vole survey

27. Surveys for water vole were undertaken within areas of suitable habitat located within a 100m radius of the Site, in accordance with methodology described by Strachan and Moorhouse (2006). [118] Water vole surveys were undertaken in early October 2013 by Arup. The 100m survey area ensures any impacts relating to noise (e.g. from drilling) and visual disturbance impacts (e.g. site lighting) are given sufficient consideration. This is supported by guidance provided by Natural England which indicates an optimum buffer zone of 10m (5m minimum) should be retained adjacent to suitable water vole habitat to avoid disturbance impacts. The guidance also states that water voles are able to tolerate small scale disturbances, conditional to no habitat loss or degradation. [119]

Bat activity surveys

28. A series of bat activity surveys were undertaken in accordance with current guidance in order to identify actual and potential bat commuting, foraging and roosting features at the Site. [120] This also included an assessment of the likely importance of the survey area for bats and bat conservation. [121] Surveys were undertaken by Ecology Services UK Ltd.

29. Surveys included an initial daytime appraisal site visit to assess the proposed development Site and its immediate surroundings for bat roosting and bat activity potential in August 2013. Two bat activity surveys were subsequently undertaken in August and September 2013 under suitable weather conditions (Table 10.2). This entailed following a pre-determined transect route which included listening points Figure 10.1.

Table 10.2: Bat activity survey dates and weather.

Date (2013)	Temp / ^{o}C	Humidity	Cloud cover %	Rain	Wind mph
24 Aug	Start: 14.6 End: 14.1	Start: 68.0 End: 68.6	Start: 75 End: 30	None	Start: 3.2 End: 0.0
10 Sept	Start: 14.1 End: 13.9	Start: 73.6 End: 77.2	Start: 10 End: 10	None	Start: 4.7 End: 5.6

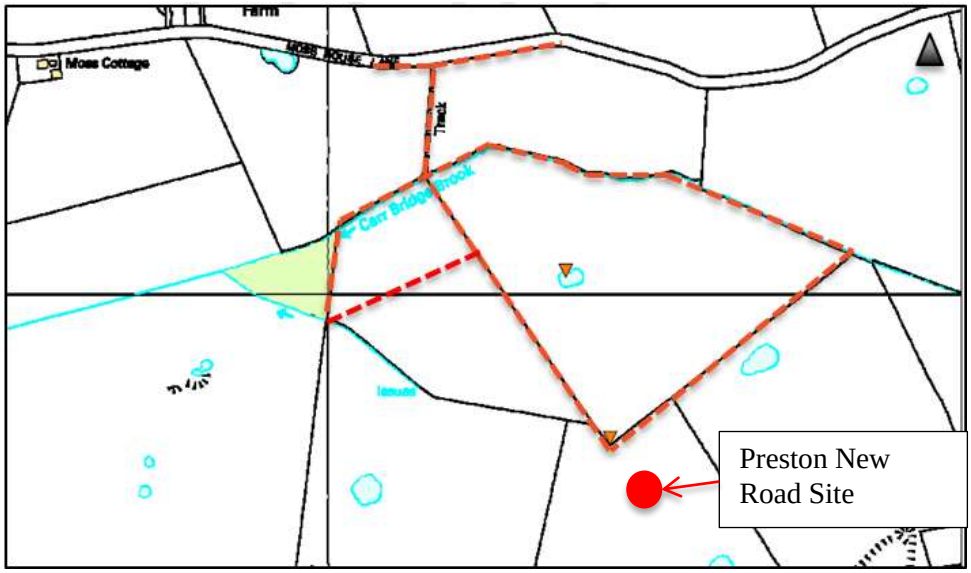
118 Strachan, R., Moorhouse, T., (2006) *'Water Vole Conservation Handbook'* Wildlife Conservation Research Unit, University of Oxford.

119 English Nature (Natural England) (2001) *'Water vole mitigation techniques – A questionnaire research'*.

120 Bat Conservation Trust (BCT) (2012) *'Bat Surveys: Good Practice Guidelines, 2nd Edition'*. Bat Conservation Trust, London.

121 Hundt, L. (2012) *'Bat Surveys – Good Practice Guidelines'* Bat Conservation Trust.

Figure 10.1: Bat survey area boundary (red dashed line) and location of Anabats (orange triangles) deployed at the Site. Figure not to scale.



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30. Two unmanned Anabat SD1 detectors were also continuously deployed from 24 to 26 August 2013. The two detector deployment points utilised at the Site include Figure 10.1:

    1. A field corner close to the Site SD 3373 3280.
    2. Beside a waterbody (Waterbody 3) to the north of the Site at SD 3730 3302.

31. The Anabats were positioned as high as possible above ground level at both deployment points and angled so as to maximise the zone of detectability. Anabats were set to function from 30 minutes before sunset to 30 minutes after sunrise the following morning.

Amphibian surveys

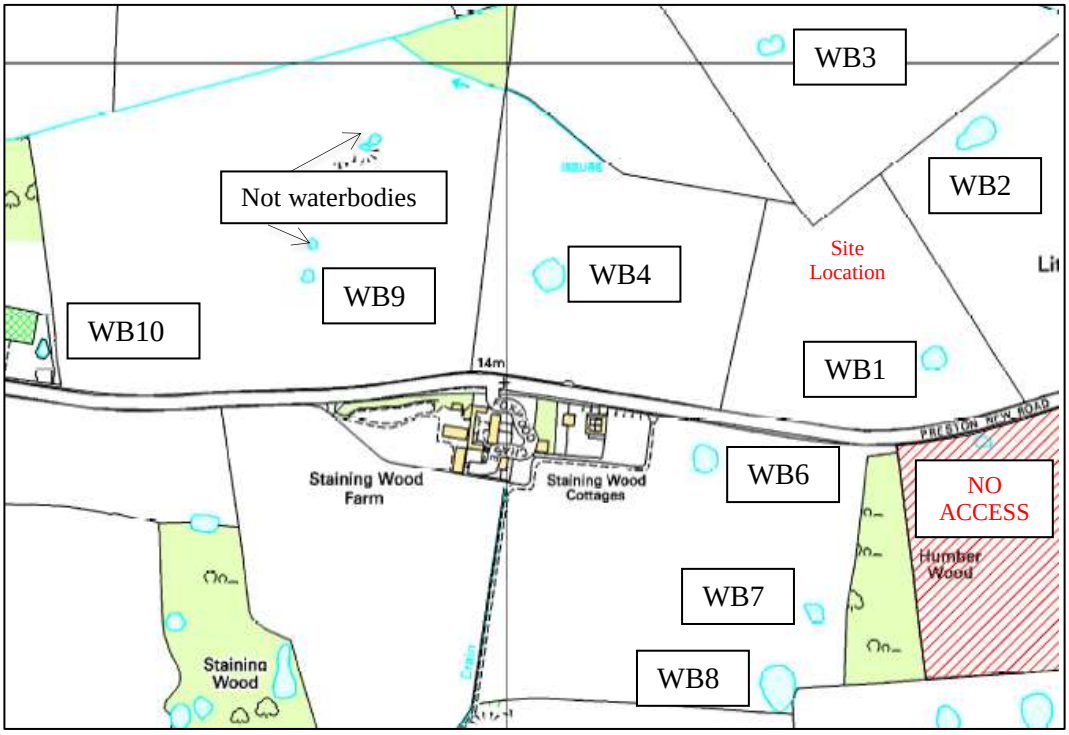
32. Amphibian surveys were undertaken of waterbodies located within a 250m radius surrounding the Site, where access was permitted (red hatching indicates where access was prohibited Figure 10.2), in accordance with guidance (Figure 10.2). [122] The purpose of the surveys was to determine the presence / likely absence of great crested newts within the surveyed waterbodies and hence the importance of the survey area in relation to amphibians, specifically great crested newts.

33. A 250m survey area was selected in accordance with English Nature (now Natural England) Technical Report 576 which concluded 'The most comprehensive mitigation, in relation to avoiding disturbance, killing or injury is appropriate within 50m of a breeding pond. It will also almost always be necessary to actively capture newts 50-100m away. However, at distances greater than 100m, there should be careful consideration as to whether attempts to capture newts are necessary or the most effective option to avoid

[122] English Nature, (2001) '*Great Crested Newt Mitigation Guidelines*'. English Nature, Peterborough (Natural England).

incidental mortality. At distances greater than 200-250m, capture operations will hardly ever be appropriate[123],

Figure 10.2: Waterbodies included within the amphibian survey undertaken at the Site. (Contains Ordnance Survey data © Crown copyright and database right 2013). Not to scale.



34. Surveys of waterbody 1, 2 and 3 were undertaken between April and May 2013 by Ecology Services UK Ltd and surveys of waterbody 4, 5, 6, 7 and 8 were undertaken during April and May 2014 by Ove Arup (See Appendix J: Part 6). During each survey, at least three survey methods were employed including torchlight survey, bottle-trapping, egg-searching, refugia search or netting, in accordance with the Great Crested Newt Mitigation Guidelines. Waterbody 10 will be surveyed using the new eDNA methodology in accordance with the technique prescribed within the guidance note titled 'Analytical and methodological development for improved surveillance of the Great Crested Newt. Technical advice note for field and laboratory sampling of great crested newt (*Triturus cristatus*) environmental DNA' [124].

Table 10.3: Amphibian survey undertaken in 2013 Preston New Road.

Visit number	Date	Weather conditions
1	25/04/2013 – 26/04/2013	Minimum Evening air temperature: 8°C Precipitation: dry

[123] English Nature (2004) '*An assessment of the efficiency of capture techniques and the value of different habitats for the great crested newt Triturus cristatus English Nature Research Reports*. English Nature, Peterborough (Natural England).
[124] Biggs J, Ewald N, Valentini A, Gaboriaud C, Griffiths RA, Foster J, Wilkinson J, Arnett A, Williams P and Dunn F 2014. Analytical and methodological development for improved surveillance of the Great Crested Newt. Appendix 5. Technical advice note for field and laboratory sampling of great crested newt (Triturus cristatus) environmental DNA. Freshwater Habitats Trust, Oxford.

Visit number	Date	Weather conditions
		Wind speed: Beaufort 0
2	02/05/2013 – 03/05/2013	Minimum Evening air temperature: 10°C Precipitation: dry Wind speed: Beaufort 0
3	14/05/2013 – 15/05/2013	Minimum Evening air temperature: 10°C Precipitation: dry Wind speed: Beaufort 0
4	20/05/2013 – 21/05/2013	Minimum Evening air temperature: 13°C Precipitation: dry Wind speed: Beaufort 0

Table 10.4: Amphibian survey undertaken in 2014 Preston New Road.

Visit number	Date	Weather conditions
1	29/04/2014 – 30/04/2014	Minimum Evening air temperature: 11.5°C Precipitation: dry Wind speed: Beaufort 0
2	06/05/2014 – 07/05/2014	Minimum Evening air temperature: 8.9°C Precipitation: light drizzle on and off Wind speed: Beaufort 1
3	08/05/2014 - 09/05/2014	Minimum Evening air temperature: 8.3°C Precipitation: dry (survey completed after a lot of rain) Wind speed: Beaufort 1
4	13/05/2014 – 14/05/2014	Minimum Evening air temperature: 7.1°C Precipitation: dry Wind speed: Beaufort 1

Predictive SYstem for Multimetrics (PSYM) Pond Surveys

35. Surveys of Waterbodies 1,2,3,4,6,7 and 8 were undertaken in accordance with Predictive SYstem for Multimetrics (PSYM) which provides a recognised method for assessing the biological quality of still waters in England and Wales[125]. Refer to Figure 10.2 for the location of waterbodies.

36. Predictive environmental data required for the model was either collected in the field on the 10th April, 2014 or via a 1:25 000 OS map. Field data was collected by a suitably qualified ecologist (Full member of the Chartered Institute of Ecology and Environmental Management and holding a doctorate in a related aquatic science discipline). At the time of survey, weather conditions were suitable with scattered high cloud, no rain and no wind other than occasional gusts.

37. The macrophyte survey was completed through the direct collection of macrophytes along the outer edge of the pond or through grapnel survey of the centre of the pond. A full list of plant species present was produced.

[125]Environment Agency & Ponds Conservation Trust (now Freshwater Habitats Trust) (2002). A guide to monitoring the ecological quality of ponds and canals using PSYM.

38. The invertebrate survey follows a standard RIVPACS three minute hand net sampling approach (using a standard Freshwater Biological Association (FBA) pond net). However, rather than the standard approach apportioning sample time by habitat dominance, the PSYM survey method ensures that samples are collected in habitats around the entirety of the waterbody. Further detail can be found in the published PSYM method.

39. Post identification, survey results and measured indices were sent to the Freshwater Habitats Trust who use the raw data to process the PSYM scores. These produce a measure of biotic integrity from a scale of 0 (bad) to 100 (good) which evaluates the ecosystem of the pond against its expected pristine environment. To aid interpretation, the PSYM method categorises the biotic integrity index into:

- >75% integrity is **Good**
- 51-75% is **Moderate**
- 25-50% is **Poor**
- <25% is **Very Poor**

Ornithological site assessment

40. An ornithological assessment of the Site and surrounding area was undertaken by Ecology Services UK Ltd. The purpose of the assessment was to investigate and assess the likelihood of the area supporting wintering estuary birds and / or breeding birds. The survey entailed a daytime appraisal visit which was undertaken in August 2013. An assessment of potential for breeding birds and wintering birds was undertaken based on the following three aspects:

- Presence or absence of key attributes which are recognised as being essential for a number of bird species, as outlined in Kirby et al., (2000).[126] Scoring systems were devised based on key attributes and factors.
- Information and data from the desk based study.
- Information and data from previous comprehensive surveys of wintering bird sites in West Lancashire and Fylde.

41. The extent of the survey area was based on a potential impact zone for birds of 250m around the Site. The 250m radius is considered appropriate for the proposed development as:

- It relates to potential impacts including artificial lighting, noise and visual intrusion and is supported by extensive observation on other sites associated with shale gas operations on the Fylde and West Lancashire (See Appendix J: Part 2.1).
- Although published data suggests that disturbance distances can, on occasion, be as much as 600m, recent comprehensive observations from other sites in the wider landscape (including at Lytham Moss Biological Heritage Site (BHS) and Marsh Farm Fields BHS) have shown that disturbance distances are nearer 100-250m (See Appendix J: Part 2.1).

Wintering bird surveys

[126] Kirby. J. et al (2000) *'Key Habitat Attributes for Birds and Bird Assemblages in England'*, England Nature Research Report no. 359.

42. Winter bird vantage point surveys (incorporating field counts) were based on methodology and guidance described in 'Survey Methods for use in Assessing the Impacts of Proposed Onshore Wind Farms on Bird Communities' (SNH 2006). Winter vantage point surveys were undertaken approximately every week from October 2013 until the end of March 2014 (25 surveys in total). The following locations were used for observations during each winter vantage point survey; field gate entrance to farmland off Preston New Road (SD 3717 3259) and roadside verge off Moss House Lane (SD 3708 3331). The vantage points were selected as they offered visibility all around the survey area, as well as part of the fields in the near vicinity. All observations were made from a vehicle or partially obscured by cover, to reduce disturbance as much as possible. An even amount of time was spent at each vantage point.

43. During the wintering bird surveys, observers kept a close watch of the proposed development Site and its immediate surroundings, whilst frequently scanning the wider area; this enabled observations to be made of all bird species at the proposed development Site location, as well as birds associated with the surrounding landscape and birds flying over.

44. All birds within the target area during wintering bird surveys were recorded, including bird species, bird behaviour and numbers of birds.

45. Distances (e.g. bird distances from roads) were measured with Zeiss Victory 8x26 *T PRF digital laser rangefinders. Published data suggests that disturbance distances for wintering estuary bird species can, on occasion, be as much as 600 metres. On the Fylde and in West Lancashire, numerous observations in winter 2012-2013 and 2013-2014 have shown that disturbance distances are much more likely to amount to no more than 100-150 metres for a range of wintering estuary birds, including all species observed during the surveys at Preston New Road. 150 metres was therefore used as a standard measure for the purposes of assessing potential impacts on wintering estuary birds.

46. For each wintering bird survey visit, a minimum of three hours of data was collected from a combination of the vantage points.

47. Nocturnal bird surveys were undertaken throughout the wintering bird survey period, approximately twice per calendar month. Surveyors made all observations from a vehicle and field boundaries to minimise disturbance to wintering estuary birds in open fields. All accessible parts of the survey area were initially scanned with the image intensifier from a series of vantage points, whilst observing and listening for bird activity, before the spotting lamp was employed.

Breeding bird survey

Walked transect surveys

48. Breeding bird surveys were based on methodology and guidance described in the BTO/JNCC/RSPB Breeding Bird Survey documents, available at: http://www.bto.org/volunteer-surveys/bbs

49. The breeding bird surveys were undertaken on 12th April and 6th May 2014 (a total of 2 surveys). During each survey, a predetermined transect (selected during a daytime scoping visit) was walked at a slow, methodical pace along field boundaries, scanning in front to check for bird presence prior to disturbance, then scanning behind to check for birds returning following disturbance. Observations along field boundaries were made whilst stood off from hedges and fencelines by approximately 25 metres to reduce disturbance, whilst still enabling clear views of bird species to be gained.

Table 11.5 Weather conditions at the time of survey.

Date (2014)	Temperature (min)	Cloud cover	Rain	Wind (max)	Visibility
2th April 2014	9.2^{0}C	00%	None	6.7mph	5km
6th May 2014	0.6^{0}C	5%	None	4.6mph	5km

50. During the breeding bird surveys, the surveyor kept a close watch of the transect and its immediate surrounding area, whilst frequently scanning the wider area; this enabled observations to be made of all bird species along the transect, as well as birds associated with the surrounding landscape and birds flying over.

51. All birds within the target area during breeding bird surveys were recorded on a base map and accompanying record sheet; records included bird species, bird behaviour and numbers of birds.

52. For each breeding bird survey visit, a minimum of two hours of data was collected from the transect.

53. Surveyors used the following equipment to aid with observations: Swarovski EL 8.5x42 binoculars

54. At the start and end of each survey, a range of environmental readings, including temperature, cloud cover and wind speed, were taken using visual observation and a Kestrel 4000 NV Weather Meter.

Determination of breeding status

55. The breeding status of birds encountered within the survey area were classified in three categories; confirmed, probable and possible breeders.

56. The survey evidence required to allow the assignment of these categories is explained below:

<u>Confirmed breeding:</u>

- Distraction display or injury feigning;
- Used nests or eggshells found (occupied or laid within the survey period); Recently fledged young or downy young;
- Adults entering or leaving a nest site in circumstances indicating occupied nest or an adult sitting on nest;
- Adults carrying food for young or faecal sacs; Nest containing eggs;
- Nest with young seen or heard.
- <u>Probable breeding:</u>
- Pairs observed in suitable nesting habitat in breeding season;
- Permanent territory presumed through registration or territorial behaviour (song etc.) on at least two different days, a week apart, at the same place;
- Display and courtship; Visiting probable nest site;
- Agitated behaviour or anxiety calls from adults;
- Building nest or excavating nest hole.

<u>Possible breeding</u>:

- Species observed in breeding season in possible nesting habitat. Singing male(s) present or breeding calls heard in breeding season.

Value of breeding bird assemblage

57. To assess the overall breeding bird assemblage, Fuller (1980)[127] describes a method for assessing the ornithological interest of sites, whereby the importance is defined by the number of breeding species present. This approach was adopted for valuing the survey area at Preston New Road.

10.4.2.3 Field surveys – Array Stations

Ecological baseline appraisals

58. An ecological appraisal was undertaken at each array station (i.e. all surface and buried array stations) by Arup (Appendix J Part 7). This entailed an ecological walkover survey, consisting of an ecological baseline appraisal for each array station. This was undertaken using predetermined criteria which ensured key features were consistently captured at each station. The surveys recorded key ecological constraints at each site. Walkover surveys were undertaken between October 2013 and March 2014.

59. An assessment relating to the potential for wintering birds was also undertaken at each site. The assessment methodology was based on the presence or absence of key attributes recognised as being essential for a number of bird species (as outline in Kirby et al., 2000[126] and provided within the Ornithological Assessment report by Ecology Services UK Ltd, 2013 Appendix J: Part 2.1. A scoring system was utilised to quantify and evaluate the results of the wintering bird assessment undertaken (Appendix J: Part 7).

60. Wintering bird surveys were undertaken at all array station sites deemed to be of moderate or high potential for wintering birds. This entailed weekly surveys in February 2014. Surveys were undertaken by Ecology Services UK Ltd. Each visit comprised a point count made from a vantage point as close to the array station as possible, either on foot or from a vehicle. Notes were also made of the site condition and presence / absence of wintering birds, including a count of all bird species present.

10.4.3 Ecological impact assessment methodology

61. The prediction of impacts and residual effects has involved an assessment of the value of each ecological receptor and an evaluation of the significance of impacts (both direct and indirect) in ecological terms.

62. The EcIA for the proposed development follows the published guidance by the CIEEM.[128] Firstly, the value of ecological resources potentially affected by the proposed development is assessed. The ecological resources and features present on the Site / array stations are assigned values within this section using a geographical scale of reference, according principally to their biodiversity value, plus any social, community or economic value that can be attributed to them, as well as their legal protection status.

63. Evaluation is based upon both the baseline data established by survey and consultation, and the context of the records against the established criteria, appropriate policies and guidance. Furthermore, professional judgement is used, based upon available information

[127] Fuller, R.J., (I980) A method for assessing the ornithological interest of sites for conservation. Biological Conservation I7: 229-239.
[128] IEEM (2006) *'Guidelines for Ecological Impact Assessment in the UK'*.

on that resource or feature, such as local distribution and status, wider population trends and expert advice. Reference has also been made to UK and local Biodiversity Action Plans as appropriate. Evaluation criteria are given in Table 10.6.

Table 10.6: Ecological evaluation criteria based on potential geographic significance.

Importance for ecology and nature conservation	Description
International	Statutory internationally designated sites identified through international conventions and European directives such as Special Protection Area (SPA), Special Area for Conservation (SAC), and Ramsar Sites. Site supporting an internationally important population of a species or species assemblage.
National	Statutory nationally designated site such as Sites of Special Scientific Interest (SSSI) and National Nature Reserves (NNR). Sites supporting a nationally important population of a species or species assemblage.
County	Non-statutory designated sites identified in local plans such Biological Heritage Sites (BHS). Statutory designated LNRs. Sites supporting a population of a species or species assemblage importance in a county context.
District	Non-statutory designated sites given lower than county importance for nature conservation. Sites supporting a population of a species or species assemblage importance in a district context.
Local	Sites that have no formal designation but contain species or habitats that are important to the ecological integrity of the local area.
The Site (redline boundary) Importance	An ecological resource that would not fulfil the above criteria and is common within the local area and is of low intrinsic value.

10.4.3.1 Ecological significance

64. An ecologically significant impact is defined as an impact (negative or positive) on the integrity of a defined site or ecosystem and / or the conservation status of habitats or species within a given geographical area. The ecological significance of an impact is not dependent on the value of the feature in question; rather the value of the feature is used to determine the geographic scale at which the impact is significant. For example, an ecologically significant impact on a feature assessed as being of value at the District level is regarded as a significant impact at a District level.

10.4.3.2 Significance of impacts

65. In accordance with the CIEEM guidance, detailed assessment of impacts has been limited to ecological receptors considered to be of value at the ‘local’ level or above, other than where receptors of lesser value are subject to some form of legal protection or they act in combination to lead to a cumulative impact.

66. The potential impacts on those resources are then identified and characterised with consideration to the following:

10.4.3.3 Beneficial or adverse impact

- Magnitude – quantification where possible, of impact, e.g. area of habitat loss, partial loss of habitat;
- Extent – area over which the impact occurs (when considering habitat loss the magnitude and the extent are the same);
- Duration – given with consideration to the functioning of the ecosystem or species, e.g. five generations of dragonflies;
- Reversibility – an impact is reversible if spontaneous recovery is possible or if mitigation is possible and an enforceable commitment has been made; and
- Timing and frequency – timing of the works in relation to critical life-stages or seasons, and how often an impact will occur.

67. The significance of the effect is then assessed with consideration to the nature of the impact and the value of the ecological resource. An ecologically significant impact is defined in the CIEEM guidance (IEEM, 2006) as: *'an impact (negative or positive) on the integrity of a defined site or ecosystem and / or the conservation status of habitats or species within a given geographical area.'* In addition, *'the integrity of a site is the coherence of its ecological structure and function, across its whole area, that enables it to sustain the habitat, complex of habitats and / or the levels of populations of the species for which it was classified.'*

68. A level of confidence is also ascribed to the assessment based on the level of certainty in the evaluation of the ecological resource and the prediction of the potential impacts. The confidence level is considered to be high within this EcIA, unless otherwise stated.

10.5 Assumptions and limitations

69. Protected species may return to or colonise a site at any future time. However, professional judgement often allows for the likely presence of these species to be predicted with sufficient certainty so as to not significantly limit the validity of these findings.

70. The majority of the bird records provided by Fylde Bird Club were not accompanied by six figure grid references; rather their locations were provided within tetrads (2km^2). Therefore the exact locations of the bird records provided are not available.

10.6 Baseline

71. The objective of a baseline assessment is to identify ecological features of value within the zone of influence of the development which could be impacted by the proposed works during all of the phases including; construction, operation, decommissioning and restoration of the Site.

72. The baseline for the surface and below ground array sites is present in Section 10.6.1 of this report as there zone of influence is different to that of the main Site; including well pad, access track and grid gas connection which is discussed in section 10.6.2.

10.6.1 Regional context

73. The Site and surrounding array stations are located within the Lancashire Plain and Valleys Natural Area.[129] The Natural Area is characterised by intensively managed areas of arable, horticultural and dairy farmland. However, remnant fragments of other habitats still remain (e.g. fragments of mosslands and peat bogs on the Lancashire Plain, a small number of species-rich meadows / fens and areas of ancient woodland).

74. Due to the area's proximity to several internationally important estuaries, large flocks of wintering waders and wildfowl feed and roost on areas of farmland along the coastal plain. Areas of grazing marshes also support notable assemblages of breeding waders during the summer months.

75. Numerous field ponds are scattered across the boulder clay of the Fylde, some of which support populations of great crested newts *Tritusus cristatus*. Populations of water voles *Arvicola amphibius*, are also present within the network of field drains and watercourses which intersect the mosaic of arable habitats.

76. Occasional pockets of arable areas support sporadic population of notable field 'weeds' including corn marigold *Glebionis segetum*, and purple ramping fumitory *Fumaria purpurea*. This also includes notable farmland birds including corn bunting *Emberiza calandra*, and grey partridge *Perdix perdix*.

10.6.2 Baseline - Array Stations

77. The objective of this baseline assessment is to identify ecological features of value within the zone of influence of the surface and below ground arrays (refer to Appendix J: Part 7 for plans illustrating the distribution of the array sites).

10.6.2.1 Statutory designations

78. No statutory designations were identified within the maximum extent of the surface and buried seismometer array stations. The nearest statutory designation relating to nature conservation is Marton Mere, Blackpool SSSI and LNR, which is located approximately 430m north west of site I04T and 985m from site 138309 (Table 10.7). Lytham Coastal Changes SSSI has been designated for its geological interest, consequently this designation has not been considered further within this chapter.

79. In relation to internationally designated sites, the following sites have been identified within a 10km radius surrounding the array stations (Table 10.7 Appendix J: Part 7):

- Ribble and Alt Estuaries SPA and Ramsar site.
- Morecambe Bay SPA and Ramsar site.
- Liverpool Bay SPA.

(N.B. the above distances between statutory designations differs from the proximity between the Site and statutory designation provided in Section 10.6.2 due to the larger area covered by the array station sites).

[129] Natural England (2013) *'Natural Areas – 13. Lancashire Plain and Valleys'* (Natural England website - http://www.naturalareas.naturalengland.org.uk/SCIENCE/NATURAL/NA_DETAILS.ASP?NA_ID=13&S=&R=2) Accessed August 2013.

Figure 10.3 Map Illustrating the Location of Statutory Nature Conservation Sites in Relation to the Proposed Development Site (Map taken from Magic.gov.uk – not to scale).

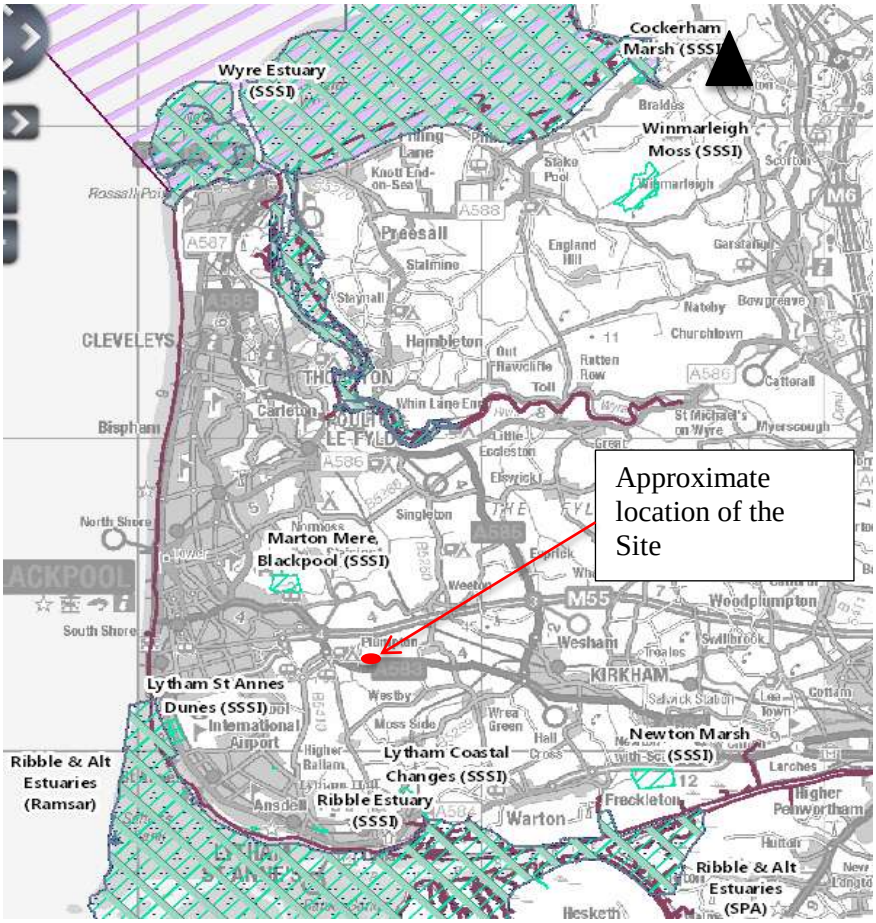


Table 10.7: Statutory designations.

Record	Designation	Distance from Site[130]	Principal citation/designation
Marton Mere, Blackpool	SSSI /LNR	430m north west of site I04T and 985m from Site 138309	Marton Mere supports a wide range of waterfowl and wetland birds. For example, Marton Mere is the most important breeding site in Lancashire for little grebe *Tachybaptus ruficollis*, and is also of county importance for its population of great crested grebe *Podiceps cristatus*, coot *Fulica atra*, mallard *Anas platyrhynchos*, pochard *Aythya farina*, and shoveler *Anas clypeata*. The site is positioned along a major migration route between breeding grounds in the far north and wintering grounds further south. The site is also attractive as a wintering ground for over 65 species of bird and is of county importance for its wintering population of coot, mallard, shoveler and tufted duck *Aythya fuligula*. The site also provides important feeding areas for a variety of waders, including ruff *Philomachus*

[130] *Denotes approximate distance from nearest point to the redline boundary*.

Record	Designation	Distance from Site[130]	Principal citation/designation
			pugnax, redshank, greenshank *Tringa nebularia*, curlew and oystercatcher. [131]
Morecambe Bay	SPA	4.3km north of station Site 138306	The site qualifies under Article 4.1 Qualification (79/409/EEC) as during the breeding season the area regularly supports: -Sandwich tern *Sterna sandvicensis* The site also qualifies under Article 4.2 Qualification (79/409/EEC) as over winter the area regularly supports: -Northern pintail *Anas acuta* -Pink-footed goose *Anser brachyrhynchus* -Ruddy turnstone *Arenaria interpres* -Dunlin *Calidris alpina* -Red knot *Calidris canutus* -Eurasian oystercatcher *Haematopus ostralegus* -Bar-tailed godwit *Limosa lapponica* -Eurasian curlew *Numenius arquata* -Grey plover *Pluvialis squatarola* -Common shelduck *Tadorna tadorna* -Common redshank *Tringa totanus* On passage the area also regularly supports: -Common ringed plover *Charadrius hiaticula* The site also qualifies under Article 4.2 Qualification (79/409/EEC) for supporting an internationally important assemblage of birds. During the breeding season the area regularly supports: -61858 seabirds including sandwich tern Over winter the area also regularly supports: more than 210000 waterfowl including: Pink footed goose; common shelduck; northern pintail; Eurasian oystercatcher; grey plover; red knot; dunlin; bar-tailed godwit; Eurasian curlew; common redshank; and ruddy turnstone.[132]
Ribble and Alt Estuaries	SPA	2km south of station Site AM374	This site qualifies under Article 4.1 of the Directive (79/409/EEC) by supporting populations of European importance of the following species listed on Annex I of the Directive: During the breeding season: -Common Tern *Sterna hirundo* -Ruff *Philomachus pugnax* Over winter: -Bar-tailed godwit *Limosa lapponica* -Bewick's Swan *Cygnus columbianus* -Golden plover *Pluvialis apricaria* -Whooper swan *Cygnus Cygnus* This site also qualifies under Article 4.2 of the Directive (79/409/EEC) by supporting populations of

[131] Natural England (1984) *'Marton Mere, Blackpool SSSI Citation.'*
[132] JNCC (2006) *'Morecambe Bay SPA – UK SPA Data Form.'*

Record	Designation	Distance from Site[130]	Principal citation/designation
			European importance of the following migratory species: During the breeding season: -Lesser black-backed gull *Larus fuscus* On passage: -Ringed plover *Charadrius hiaticula* -Sanderling *Calidris alba* Over winter: -Black-tailed godwit *Limosa limosa* -Dunlin *Calidris alpina* -Grey plover *Pluvialis squatarola* -Knot *Calidris canutus* -Oystercatcher *Haematopus ostralegus* -Pink-footed goose *Anser brachyrhynchus* -Pintail *Anas acuta* -Redshank *Tringa totanus* -Sanderling *Calidris alba* -Shelduck *Tadorna tadorna* -Teal *Anas crecca* -Wigeon *Anas penelope* The area qualifies under Article 4.2 of the Directive (79/409/EEC) by regularly supporting more than 20,000 seabirds: -During the breeding season the area regularly supports 29,236 individual seabirds including: black-headed gull; lesser black-backed gull; common tern *Sterna hirundo*. The area qualifies under Article 4.2 of the Directive (79/409/EEC) by regularly supporting more than 20,000 waterfowl: -Over winter the area regularly supports waterfowl including: grey plover *Pluvialis squatarola*; whooper swan*;* golden plover; bar-tailed godwit; pink-footed goose; shelduck; wigeon; teal; bewick's swan *Cygnus columbianus bewickii*; oystercatcher; curlew; knot; sanderling *Calidris alba*; dunlin *Calidris alpina alpine*; redshank; cormorant *Phalacrocorax carbo*; common scoter *Melanitta nigra*; lapwing *Vanellus vanellus;* and pintail. [133]
Liverpool Bay	SPA	4.9km to the west of station Site 148002	This site qualifies under Article 4.1 of the Directive (79/409/EEC) as over winter the area regularly supports: -Red throated diver *Gavia stellate* This site also qualifies under Article 4.2 of the Directive (79/409/EEC) as over winter the area regularly supports -Common scoter *Melanitta nigra* This site also qualifies under Article 4.2 of the Directive (79/409/EEC) by supporting an

[133] JNCC (2001) *'Ribble and Alt Estuaries SPA description.'*

Record	Designation	Distance from Site[130]	Principal citation/designation
			internationally important assemblage of birds: -In the non-breeding season the area regularly supports: red throated diver and common scoter.[134]

Non-statutory designations

80. Seven Biological Heritage Sites (BHS) were identified within the 4km search radius covering the maximum extent of array stations (Table 10.8). Although no array stations are located within a BHS site the following are located immediately adjacent to Lytham Moss BHS site: 138331 and 138349. In addition, site 148024 is located approximately 200m to the west of Great Plumpton Sidings BHS (See Appendix J: Part 7 for further details).

Table 10.8: BHS Sites located within maximum extent of array stations and a 1km buffer.

Site Name	Distance from Site[135]	Principal citation
Lytham Moss BHS	Adjacent to sites 138331, 138349 and I03B	The site is of ornithological importance for providing winter feeding ground for flocks of pink-footed geese and whooper swans with bird numbers exceeding 0.5% of the British wintering population.
Great Plumpton Sidings BHS	200m (east of site 148024)	The site comprises a section of land associated with the former Blackpool Central Direct Railway Line. The site supports notable invertebrates including green-veined white *Pieris napi*, gatekeeper *Pyronia tithonus*, and common blue *Enallagma cyathigerum*, and two uncommon spiders, namely *Tegenaria agrestis* and *Araneus quadralus*. The embankments provide habitat for a variety of birds including willow warbler *Phylloscopus trochilus*, and lesser whitethroat *Sylvia curruca*.
Westby Clay Pit BHS	240m (west of site AM339)	Botanical interest associated with a mosaic of aquatic (waterbodies and marsh) and terrestrial habitat (e.g. grassland, scrub and hedgerows). Most suitable waterbodies support good populations of great crested newts.
Willowmead Park Swamp (Moss Side) BHS	300m (north of site AM361)	The site comprises a small triangle of low-lying swamp and marshy grassland situated along the north edge of Moss Side Lane. The site is important for regularly supporting a breeding population of harvest mouse *Micromys minutus*. The site also attracts a variety of birds including reed warbler *Acrocephalus scirpaceus*, reed bunting *Emberiza schoeniclus*, sedge warbler *Acrocephalus schoenobaenus*, whitethroat and song thrush *Turdus philomelos*. Barn owl *Tyto alba*, also breeds nearby and hunts over the site.
Herons Reach Golf Course/ Marton Mere Habitat Complex BHS	290m (west of site I04T)	Botanical interest associated with waterbodies and adjacent wetland habitats which supports populations of great crested newt and smooth newt *Lissotriton vulgaris*.
Pond west of Chain Lane BHS	580m (north west of	Botanical and invertebrate interest associated with field pond.

[134] JNCC (2010) *'Liverpool Bay SPA – UK SPA Data Form.'*
[135] *Denotes approximate distance from nearest array station site to BHS site.*

Site Name	Distance from Site[135]	Principal citation
	Site I04T)	
Chapel Road Field BHS	1km (west of Station site 148017)	Botanical interest since the site supports a population of common meadow-rue, a scarce species in Lancashire and the Fylde and the only known extant population within Blackpool.

Biological records

LERN

81. No records of protected or notable species were identified by LERN within a proposed array station or within the immediate vicinity, however a number of protected and notable species have been identified within the search radius surrounding the array stations which have been briefly summarised below (See Appendix J: Part 7 for further details):

- Water vole: A large number of records for water vole are located within the search radius. One array station has a record within 250m: I07T.
- Great crested newts: Records for great crested newts have been identified within a 500m radius of the following array stations: 138349, AM339, 138313, 138305 138310, 148030, 138306 and 148036.
- Otter: Seven records of otter are located approximately 780m north west of I04T and 1km north of site 138309.
- Kingfisher: One record of kingfisher is located approximately 410m south east of site I08T.
- Barn owl: A number of records of barn owl are located within the search radius; the closest to an array station is approximately 300m north-west of array station AM361.
- Bats: A number of records for bats are located scattered throughout the search area including brown long-eared bat, common pipistrelle, Daubenton's and Natterer's bat species. However. no bat records were identified within the footprint of a proposed array station site or immediately adjacent to it.

82. Other notable mammal species identified within the search radius include:

- Two records for harvest mouse located approximately 300m north-west of site AM336.
- Two records for hedgehog located approximately 170m west of station site 148024 and 1.5km north-west of station site 138308.
- A large number of records of brown hare (50+) also exist within the search radius. The majority of these records are located within the southern half of the search radius.

83. The long list BAP bird species recorded within the search radius by LERN are listed below in Table 10.9.

Table 10.9: Lancashire Long List BAP Bird Species identified by LERN.

Bird species	
-Skylark *Alauda arvensis* -Yellowhammer *Emberiza citronella* -Reed bunting *Emberiza schoeniclus* -Curlew *Numenius arquata* -House sparrow *Passer domesticus* -Tree sparrow *Passer montanus* -Grey partridge *Perdix perdix* -Lapwing *Vanellus vanellus* -Linnet *Carduelis cannabina* -House martin *Delichon urbica* -Kestrel *Falco tinnunculus* -Oystercatcher *Haematopus ostralegus* -Swallow *Hirundo rustica* -Corn bunting *Emberiza calandra* -Meadow pipit *Anthus pratensis* -Whooper swan *Cygnus cygnus*	-Willow warbler *Phylloscopus trochilus* -Dunnock *Prunella modularis* -Starling *Sturnus vulgaris* -Shelduck *Tadorna tadorna* -Song thrush *Turdus philomelos* -Cuckoo *Cuculus canorus* -Grasshopper warbler *Locustella naevia* -Spotted flycatcher *Muscicapa striata* -Snipe *Gallinago gallinago* -Swift *Apus apus* -Grey heron *Ardea cinerea* -Teal *Anas crecca* -Black-headed gull *Larus ridibundus* -Berwicks swan *Cygnus columbianus* -Herring gull *Larus argentatus*

84. A number of notable invertebrate species were identified within the search radius (e.g. Nationally Notable B moth species, Lancashire BAP long list and Nationally Notable B beetle species, Lancashire BAP long list butterfly species and S41 and UK BAP butterfly species) (See Appendix J: Part 7 for further details). However, the majority of the moth species records are pre-1970 so are considered to be of limited relevance for an assessment of current value. In addition, the majority of the notable invertebrate records identified are located at Marton Mere SSSI (located approximately 985m from station site 138309) and Great Plumpton Sidings BHS (located approximately 200m east of station site 148024) and not within the immediate proximity to the array station sites.

Fylde Bird Club

85. The bird records provided by Fylde Bird Club identified a large number of records of breeding and wintering estuary bird species within the search radius surrounding the array stations (32,000+). In order to identify relevant records to each array site, notable / relevant bird records (i.e. qualifying SPA bird species and bird species judged to have potential to breed in close proximity to the array stations) within the last five years and within the same tetrad as each array station were analysed (See Appendix J: Part 7 for further details).

86. In summary, of the 20 Morecambe Bay SPA qualifying bird species, a total of 14 species were identified within the same tetrads as the array station sites (e.g. common tern *Sterna hirundo*, curlew *Numenius arquata*, herring gull *Larus argentatus*, lesser black-backed gull *Larus fuscus*, oystercatcher *Haematopus ostralegus*, shelduck *Tadorna tadorna*, pink-footed goose *Anser brachyrhynchus*, bar-tailed godwit *Limosa lapponica*, dunlin *Calidris alpine*, knot *Calidris canutus*, pintail *Anas acuta*, redshank *Tringa totanus*, ringed plover *Charadrius hiaticula*, and golden plover *Pluvialis apricaria*). The highest number of qualifying SPA bird species for Morecambe Bay SPA recorded within one tetrad was 14 out of the 20 species within tetrad 33M, which includes Sites 138308, 138309 and I04T.

87. With respect to Ribble and Alt Estuary SPA, of the 21 qualifying bird species, a total of 17 species were identified within the same tetrads as the array sites (e.g. common tern *Sterna hirundo*, bar-tailed godwit *Limosa lapponica*, dunlin *Calidris alpine*, knot *Calidris canutus*, pintail *Anas acuta*, redshank *Tringa totanus*, ringed plover *Charadrius hiaticula*, ruff *Philomachus pugnax*, and wigeon *Anas penelope*, while the following eight species

were frequently recorded golden plover *Pluvialis apricaria*, Bewick's swan *Cygnus columbianus*, whooper swan *Cygnus cygnus*, teal *Anas crecca*, lesser black-backed gull *Larus fuscus*, shelduck *Tadorna tadorna*, pink-footed goose *Anser brachyrhynchus* and oystercatcher *Haematopus ostralegus*).

88. Regarding Liverpool Bay SPA bird species, no records for red throated diver *Gavia stellate* were identified within the search radius and only a small number of records for common scouter were identified (i.e. only within tetrad 33M).

89. The majority of bird species included within Marton Mere SSSI citation which are not qualifying SPA bird species identified within the search area include little grebe *Tachybaptus ruficollis*, great crested grebe *Podiceps cristatus*, pochard *Aythya farina*, tufted duck *Aythya fuligula* and greenshank *Tringa nebularia*, with coot *Fulica atra*, mallard *Anas platyrhynchos*, and shoveler *Anas clypeata*, being frequently recorded within the search radius.

90. The data search provided by Fylde Bird Club identified records for the majority of bird species judged as having potential for breeding in close proximity to the array sites within the search radius. Most notably, records for yellowhammer *Emberiza citrinella*, song thrush *Turdus philomelos*, linnet *Carduelis cannabina*, skylark *Alauda arvensis*, lapwing *Vanellus vanellus*, dunnock *Prunella modularis*, yellow wagtail *Motacilla flava*, tree sparrow *Passer montanus*, reed bunting *Emberiza schoeniclus*, corn bunting *Emberiza calandra* and bullfinch *Pyrrhula pyrrhula* (all of which are UK and Lancashire BAP species / S41 priority species and red listed Bird of Conservation Concern (BoCC), while reed bunting is an amber listed BoCC and bullfinch and dunnock are amber listed BoCC only) were identified within the majority of the tetrads covering the proposed array sites.

Lancashire Badger Group

91. Six badger setts were identified within the 4.5km search radius by Lancashire Badger Group. These are all located along the rail embankment located within southern-western corner of the search area and were identified in close proximity to the following array sites:

- One sett located approximately 230m west of station site AM343.
- One sett located approximately 200m north-west of station site AM343.
- One sett located approximately 130m west of station site AM353
- One sett located approximately 40m east of station site AM353.
- One sett located approximately 125m north of station site AM353.

West Lancashire Bat Group

92. It is understood that West Lancashire Bat Group did not hold any bat records within the search area covering the array sites.

Amphibian and Reptile Group of South Lancashire

93. Approximately 200 records of amphibians were identified within the 4km search radius by the Amphibian and Reptile Group of South Lancashire (via the Lancashire Amphibian and Reptile Atlas). Records of common toad, common frog, smooth newt and great crested newt were identified within 500m of array sites. Records for great crested newts have been identified within a 500m radius of the following array stations: 138349, AM339, 138313, 138309, 138305 138310, 148030, 138306 and 148036.

Field surveys – ecological baseline appraisals

94. Provided below is a summary of the key results following the ecological walkover survey of the array sites, which included both an ecological baseline assessment and wintering bird assessment, undertaken at each array station (See Appendix J: Part 7 for further details):

Habitats

95. The majority of buried and surface arrays are located within areas of improved grassland, arable fields or within rank grasses / tall ruderal vegetation. Such habitats are considered to be of relatively limited ecological value owing to their low botanical diversity and structural homogeneity. In addition, these habitats were identified as being abundant within the surrounding arable landscape within Lancashire.

96. The majority of the array sites are located adjacent to intact species-poor hedgerows, bands of tall ruderal herbs and patches of scrub.

Bats

97. Trees containing features with bat roost potential were identified in close proximity to five array sites (i.e. Sites 138336, 138337, 148023 and I01T). In all instances array sites were micro-sited a suitable distance away from trees identified to contain features with bat roost potential (at least 10m).

98. Suitable habitat for foraging bats, largely in the form of intact hedgerows, was identified adjacent to the majority of the buried and surface array station sites.

Badgers

99. All six sett sites identified by Lancashire Badger Group are located in close proximity to station sites AM343 and AM353 only; all other array sites were located at least 250m from the identified sett sites. However, suitable habitat for badger setts (e.g. woodland, railway embankments etc.) was identified within 50m of 13 sites including 138335; 138336, 148002; 148006, 148025; 148033; AM332, AM339, AM353; AM354; AM374; I01T, and I06T. In these instances, although no setts were identified within 50m of any array stations, given the transitory nature of badgers, as a precautionary measure pre-start checks / surveys for badgers will be undertaken at these sites prior to works commencing.

Water voles

100. A total of 11 array sites were identified as being in close proximity to field drains with potential to support water vole populations (sites: 138309; 148001; 148002; 148007; 148012; 148014; 148028; 148038; I04T; I07T and I08T). In all instances the sites have been micro-sited / relocated away from field drains (at least 6m) to avoid any potential disturbance impacts on water voles. Potential impacts on water voles regarding the installation of the array stations are therefore not considered further within the chapter.

Otters

101. Seven records for otters were identified approximately 780m north west of site I04T and 1km north of site 138309 at Marton Mere SSSI and LNR. Furthermore, no suitable habitat for otters, in the form of holts (dens) or couches (laying up sites) were identified at any site, or within the immediate proximity. Potential impacts on otters regarding the installation of the array stations are therefore not considered further within the chapter.

Brown hare

102. A large number of records for brown hare were identified within the search radius covering the proposed array stations. In addition, a number of brown hare sightings were made during the ecological walkover and wintering bird surveys undertaken at the array station sites. Although the habitat surrounding the majority of sites (e.g. arable farmland and intact hedgerows) was identified as offering suitable habitat for brown hare, the habitat located within the footprint of the array stations is largely unsuitable to support sheltering brown hare due to the lack of suitable vegetation cover. Given the small footprint of each array station (less than $20m^2$), the station sites and immediate habitat are not regarded as providing a critical resource for brown hare.

Amphibians

103. Records for great crested newts have been identified within a 500m radius of 9 station sites (site: 138305; 138306; 138309; 138310; 138313; 138349; 148036; 148030; and AM339). In addition, a number of proposed array stations were located within close proximity to waterbodies which may support breeding populations of amphibians, most notably great crested newts, this includes sites: 138313; 138324; 138335; 148005; 148018; 148022; and 148033. In all cases the proposed array stations were micro-sited away from waterbodies and located within habitat deemed to be of negligible value with respect to terrestrial great crested newts (e.g. arable fields or grazed improved grassland) to avoid potential adverse impacts on amphibians. Potential impacts on amphibians regarding the installation of the array stations are therefore not considered further within the chapter.

Reptiles

104. Other than at station site AM353, the habitats located within, and contiguous to, the proposed station sites (e.g. areas of improved grassland and arable fields) were identified to provide sub-optimal habitat for reptiles. With respect to station site AM353 where suitable habitat for common reptiles has been identified, the working area will be kept clear of vegetation after a pre-start hand search for reptiles. This will avoid potential adverse impacts on common reptiles. Potential impacts on reptiles regarding the installation of the array stations are therefore not considered further within the chapter.

Breeding birds

105. No suitable habitat to support protected Schedule 1 bird species (e.g. barn owl perches or nesting sites etc.) were identified within close proximity of any array sites. However, suitable nesting bird habitat (e.g. intact hedgerows, tall ruderal herbs and scrub) were identified adjacent to the majority of the proposed sites. Although it is likely that such habitat supports relatively common bird species (e.g. chaffinch, wren, blackbird, robin, goldfinch, etc), records for notable species, including bullfinch, linnet, corn bunting, reed bunting, tree sparrow, yellowhammer, dunnock and song thrush have also been identified within the search radius could also use the hedgerows for nesting.

106. Suitable habitat for ground nesting birds (e.g. skylark, lapwing etc.) was also identified at approximately 6 sites where the habitat is not heavily disturbed / managed (e.g. for livestock grazing, etc) over the nesting bird season. This includes station sites 138321, 138331, 148031, AM332, I05T and I06T.

Wintering birds

107. The data records provided by Fylde Bird Club identified 14 of the 20 qualifying bird species of Morecambe Bay SPA, 17 of the 20 from Ribble and Alt Estuaries SPA and 1

of the 2 from Liverpool Bay SPA within the search radius. A total of 46 (there are three options for one of the array stations) array station sites were identified to be of moderate potential for wintering birds; although no array stations were identified as being of high potential with respect to wintering birds.

White-clawed crayfish

108. There is a remote possibility that some of the larger field drains and watercourses located within the vicinity of some of the proposed array sites may offer suitable habitat for white-clawed crayfish. However, there will be no in-channel works associated with the proposed array stations; nor will there be any increased drainage or sediment / pollution inputs as a result of the array station installation works. Moreover, no records for white-clawed crayfish were identified within the search radius by LERN. Potential impacts on white-clawed crayfish regarding the installation of the array stations are therefore not considered further within the chapter.

Fish

109. No in-channel works are required in relation to the proposed array stations. Potential impacts on fish regarding the installation of the array stations are therefore not considered further within the chapter.

Terrestrial invertebrates

110. A number of notable invertebrate species were identified within the search radius (e.g. Nationally Notable B moth species, Lancashire BAP long list and Nationally Notable B beetle species, Lancashire BAP long list butterfly species and S41 and UK BAP butterfly species). However, the majority of the moth species records are pre-1970 so are considered to be of limited relevance for an assessment of current value. In addition, the majority of the records identified are located at Marton Mere SSSI (located approximately 780m from site I04T and 985m from site 138309) and Great Plumpton Sidings BHS (located approximately 170m west of Site 148024).

111. The habitat located within the all array stations were largely deemed as providing sub-optimal habitat for a diverse assemblage of terrestrial invertebrates (e.g. grazed improved grassland and arable fields). It is possible that the areas of intact species-poor hedgerows which are located adjacent to the majority of array sites offer suitable habitat, albeit relatively limited in extent and of low value, for an assemblage of invertebrate species typical for the surrounding area in Lancashire.

112. Given the temporary and localised nature of the proposed works (e.g. less than one week), the small amount of suitable habitat which may be temporarily affected, it is not envisaged that terrestrial invertebrates will be adversely affected during the construction and operation of the array sites. Potential impacts on terrestrial invertebrates regarding the installation of the array stations are therefore not considered further within the chapter.

Summary of Baseline for Array Sites

113. The baseline eliminates the need for an impact assessment for the following species and habitats; fish, white clawed crayfish, reptiles, terrestrial invertebrates, otter, water vole and habitats including improved grassland, arable and tall ruderal herb.

114. The baseline highlights the need to assess potential impacts upon the following species and habitats:

- Designated sites including SPA’s and Lytham Moss BHS

- Wintering birds
- Breeding birds
- Brown hare

10.6.3 Baseline - Site at Preston New Road

10.6.3.1 Statutory designations

115. No statutory designations were identified within the Site or within the immediate proximity (i.e. within a 3km radius). Two statutory designations exist within the 5km search radius; this includes Marton Mere, Blackpool Site of Special Scientific Interest (SSSI) (and Local Nature Reserve (LNR)) located 3.2km north-west (Figure 10.3 and Table 10.7).

116. In relation to internationally designated sites, the following sites have been identified within a 10km radius surrounding the proposed site (Table 10.7):

- Ribble and Alt Estuaries Special Protection Area (SPA) and Ramsar Site – located approximately 6.7km south.
- Morecambe Bay SPA and Ramsar - located approximately 6.7km to the north.
- Liverpool Bay SPA – located approximately 7.4km to the west.

117. Non-statutory designations

118. Five Biological Heritage Sites (BHS) were identified within the 3km search radius surrounding the Site (Table 10.10) however none were located within the proposed Site boundary or within a 1km radius surrounding it (See Appendix J: Part 1 for further details).

Table 10.10: BHS Sites located within a 3km radius.

Site Name	Distance from site[136]	Principal citation
Great Plumpton Sidings BHS	1.2km (north-east)	The site comprises a section of land associated with the former Blackpool Central Direct Railway Line. The site supports notable invertebrates including green-veined white *Pieris napi*, gatekeeper *Pyronia tithonus*, and common blue *Enallagma cyathigerum*, and two uncommon spiders, namely *Tegenaria agrestis* and *Araneus quadralus*. The embankments provide habitat for a variety of birds including willow warbler *Phylloscopus trochilus*, and lesser whitethroat *Sylvia curruca*.
Lytham Moss	2.1km (south-west)	The site is of ornithological importance for providing winter feeding ground for flocks of pink-footed geese and whooper swans with bird numbers exceeding 0.5% of the British wintering population.
Westby Clay Pit BHS	2.3km (south-west)	Botanical interest associated with a mosaic of aquatic (waterbodies and marsh) and terrestrial habitat (e.g. grassland, scrub and hedgerows). Most suitable waterbodies support good populations of great crested newts.
Willowmead Park Swamp (Moss Side) BHS	2.4km (south)	The site comprises a small triangle of low-lying swamp and marshy grassland situated along the north edge of Moss Side Lane. The site is important for regularly supporting a breeding population of harvest mouse *Micromys minutus*. The site also attracts a variety of birds including reed warbler *Acrocephalus scirpaceus*, reed bunting *Emberiza schoeniclus*, sedge warbler *Acrocephalus schoenobaenus*, whitethroat and song thrush *Turdus philomelos*. Barn owl *Tyto alba*, also breeds nearby and hunts over the site.
Herons Reach Golf Course/ Marton Mere Habitat Complex BHS	2.9km (north-west)	Botanical interest associated with waterbodies and adjacent wetland habitats which supports populations of great crested newt and smooth newt *Lissotriton vulgaris*.

119. In relation to UK BAP habitat, all the woodland copses surrounding the Site have been identified as having the potential to qualify as 'lowland deciduous woodland' UK BAP habitat / NERC Act (2006) Section 41 Habitats of Principal Importance (referred to hereafter as S41 Habitats and / or Species of Principal Importance). This includes the wooded triangle of land located to the north of the proposed development Site. The small wooded area located in front of Moss House Farm has been identified as having the potential to qualify as 'Traditional Orchard' BAP habitat.

10.6.3.2 Habitats and flora

120. Detailed results of the ecological surveys undertaken at the Site are provided in Appendix J: Part 1-9; a summary of the key results are provided below.

Habitats

121. Several habitats are present across the Site and are summarised below. The summary descriptions should be read in conjunction with the Phase 1 Habitat survey report within Appendix J: Part 1 (which includes the Phase 1 Habitat map and full species lists).

[136] *Denotes approximate distance from nearest point to the redline boundary*.

Grassland (Improved)

122. The majority of habitats located within and surrounding the proposed Site area at the Site is comprised of improved grassland either grazed by cattle or recently sown with an improved grassland seed mix. Grass species identified were dominated by perennial rye grass *Lolium perenne*, with occasional rough meadow grass *Poa trivialis*. Occasional ruderal forbs including white clover *Trifolium repens*, broadleaved plantain *Plantago major*, common chickweed *Stellaria media* and scentless mayweed *Tripleurospermum inodorum*, amongst others, were also identified scattered throughout the grazed areas of grassland.

Arable

123. The wider area surrounding the Site is comprised of a mosaic of arable fields and grazed pasture farmland.

Woodland & dense scrub

124. A triangle of woodland and dense scrub exists approximately 400m to the north-west of the Site. The woodland area was dominated by willow tree species (including crack willow *Salix fragilis*, and white willow *Salix alba*) with occasional ash *Fraxinus excelsior.* The understorey comprises dense scrub, tall ruderal herbs and rank grass species dominated by reed canary grass *Phalaris arundinacea*, rosebay willowherb *Chamerion angustifolium*, elder *Sambucus nigra*, bramble *Rubus fruticosus* agg., Yorkshire fog *Holcus lanatus*, common nettle *Urtica dioica* and hedge bindweed *Calystegia sepium.*

Scattered scrub

125. Scattered scrub species were also identified adjacent to some of the waterbodies and field drains located within the survey area. Dominant species identified included hawthorn and elder, with occasional bramble, and goat willow *Salix caprea*.

Tall ruderal herbs

126. Narrow bands of tall ruderal herbs and rank grasses were identified along linear features within the survey area including field boundaries and field drains. Dominant ruderal species recorded included common nettle, false oat grass *Arrhenatherum elatius*, cock's-foot grass *Dactylis glomerata* and reed canary grass, while cleavers *Galium aparine* and creeping thistle *Cirsium arvense* were frequent. Species including redshank *Persicaria maculosa*, ragwort *Senecio jacobaea*, fat hen *Chenopodium album*, shepherd's purse *Capsella bursa-pastoris*, hogweed *Heracleum sphondylium*, hedge bindweed *Calystegia sepium*, bittersweet (woody nightshade) *Solanum dulcamara*, were identified as occasional within bands of tall ruderal herbs located within the survey area.

Hedgerows

127. Large sections of field boundaries located within the survey area were identified to be lacking hedgerows. The majority of the hedgerows identified within the survey area are intact relatively species-poor hedgerows dominated by hawthorn with occasional blackthorn *Prunus spinosa*, elder and wych elm *Ulmus glabra*. Juvenile isolated trees, including ash, sycamore, and field maple *Acer campestre*, were identified infrequently within the section of hedgerow along Preston New Road to the south of the Site. ections of defunct 'gappy' hedgerows and sections of field boundary where the hedge had been completely removed were also identified within the survey area. The majority of

hedgerows identified are aligned by rank grasses and tall ruderal herbs dominated by common nettle, cleavers, creeping thistle, false-oat grass and cock's-foot grass.

128. Using the methodology outlined in The Hedgerow Regulations (1997) (Section 3.2.3), all hedgerows recorded within the survey area did not qualify as 'important' hedgerows as they did not contain enough woody species within a 30m length (predominately hawthorn with occasional blackthorn and elder) or associated features. However, within the UK BAP priority habitat descriptions, all hedgerows consisting predominantly (i.e. 80% or more cover) of at least one woody UK native species are covered by this priority habitat'.[137] Consequently, the majority of the intact hedgerows located within the survey area are likely to qualify as UK BAP priority habitat, despite being relatively species-poor.

Waterbodies

129. A number of waterbodies are scattered within the mosaic of arable and pasture farmland located within the survey area surrounding the proposed Site area (Table 10.11).

Table 10.11: Waterbodies identified at the Site.

Waterbody (WB) No	Grid reference	Waterbody description	PSYM Classification
WB 1	SD 37513 32638	Waterbody 1 is located within an improved grassland field. A narrow fringe of emergent vegetation, dominated by soft rush *Juncus effusus*, with occasional branched bur-reed *Sparganium erectum*, was identified surrounding the edge of the waterbody. Evidence of cattle poaching and fishing (disused pontoons) were identified at this waterbody. The waterbody was identified as being heavily disturbed by waterfowl creating highly turbid water with poor water quality.	Very Poor
WB 2	SD 37572 32912	Waterbody 2 is located within an improved grassland field. Evidence of extensive cattle poaching was identified creating bare and eroding banks. Emergent vegetation was limited to a small area of soft rush located along the western edge of the waterbody. The waterbody was identified as being heavily disturbed by waterfowl creating highly turbid water with poor water quality.	Very Poor
WB 3	SD 37298 33042	Waterbody 3 was identified as heavily vegetated with tall ruderal herbs. The waterbody contained extremely low water levels during the walkover survey.	The northern section is Very Poor, the southern section Poor
WB 4	SD 37049 32748	Waterbody 4 is located within an improved grassland field. The banks were identified as being heavily	Very Poor

[137] UK Biodiversity Action Plan (2008) *'UK Biodiversity Action Plan Priority Habitat Descriptions'* (Updated July 2010).

Waterbody (WB) No	Grid reference	Waterbody description	PSYM Classification
		poached by cattle. The waterbody was also identified as being heavily disturbed by waterfowl. Emergent vegetation was limited to a small patch of great reedmace *Typha latifolia* and soft rush.	
WB 5	SD 36938 33307	Waterbody 5 is located within an area of improved grassland but fenced off from livestock. A marginal area of emergent vegetation exists around the majority of the waterbody. Dominant species identified include great reedmace, branched bur-reed and soft rush. Floating white water-lily *Nymphaea alba*, was also identified within the centre of the waterbody. Tall ruderal herbs and scrub species, including spear thistle *Cirsium vulgare*, creeping buttercup, sweet vernal grass *Anthoxanthum odoratum*, great willowherb, rosebay willowherb, ragwort, willow *Salix sp.*, and alder *Alnus glutinosa*, amongst others, were identified surrounding the waterbody. Evidence that the waterbody is fished, in the form of pontoons, was also identified.	>250 m – therefore, not assessed further within this report
WB 6	SD 37237 32526	Waterbody 6 is located within an arable field and is dominated by willow placing the pond into 100% shade. There is no emergent vegetation and a deep layer of leaf litter. Invertebrates present indicated poor water quality. Water level was very low and the pond is likely to dry out completely frequently.	Very Poor
WB 7	SD 37369 32332	Waterbody 7 is located within an arable field and the pond is dominated by reedmace and yellow flag with emergent water horsetail. Water level is very low and it is considered that the pond will dry out every year.	Very Poor
WB 8	SD 37327 32254	Waterbody 8 is located towards the edge of an improved grassland field. The waterbody was identified as being heavily disturbed by waterfowl creating highly turbid water of poor quality. Evidence of cattle poaching and previous use for fishing was also identified. Scattered pockets of bramble scrub and soft rush were identified within the marginal habitats with areas of tall ruderal herbs dominated by common nettle and Yorkshire fog.	Very Poor

Waterbody (WB) No	Grid reference	Waterbody description	PSYM Classification
WB 9	SD 36759 32742	Waterbody 9 is located within the centre of a field which is to be cut for silage and then grazed by cattle. The margins of the pond are surrounded by common reed *Phragmites australis* and it was observed that the pond supported a range of invertebrates including water scorpion, dragonfly nymph, lesser water boatman, large numbers of ramshorn snail.	Moderate (this is not a PSYM classification)
WB 10	SD 36305 32872	Waterbody 10 is located within an area of amenity grassland located within the grounds of a garden centre. At the time of writing access to this pond was not available and the assessment of its value was taken from adjacent land. It was observed that a significant percentage of the water surface was dominated by water lilies. It is considered that water quality is likely to be good as it will not be affected by agricultural runoff.	Moderate to good (this is not a PSYM classification)

Running water (Carr Bridge Brook & field drains)

130. Carr Bridge Brook flows east to west along the field boundary located approximately 330m north of the proposed Site. The beck is approximately 0.5m in width and was identified as being heavily vegetated by tall ruderal herbs, predominantly comprising reed canary grass, rosebay willowherb and common nettle, for its length. During the walkover survey the beck was identified to contain relatively low flows (0.25m).

131. A small field drain was also identified along a field boundary located approximately 250m north-west of the proposed Site. This field drain flows into Carr Bridge Brook immediately downstream of the triangle of woodland.

Buildings and hardstanding

132. No areas of hard standing are located within the immediate proximity of the proposed Site. However, Preston New Road is located to the south of the main Site. Staining Wood Farm and Plumpton Hall Farm buildings are also located to the south of the proposed Site.

10.6.3.3 Fauna

Badgers

133. No badger records were identified within the 3km search radius surrounding the Site by LERN. The closest badger record by Lancashire Badger Group to the Site is located approximately 1.5km to the south-west of the proposed Site.

134. During the Phase 1 Habitat survey the surrounding woodland copses were identified as providing suitable habitat for badger setts. The intact hedgerows were also identified as

providing suitable foraging habitat for badgers. However, no setts or field signs for badgers (in the form of badger hairs, footprints or mammal paths) were identified during the walkover survey.

135. The badger surveys undertaken within a 250m search radius surrounding the Site did not identify the presence of any active badger setts or badger signs. Consequently badgers are considered to be absent from the Site and are not considered further within the assessment.

Water voles

136. No records for water vole were identified within a 1km radius of the proposed Site by LERN; however they have been recorded within the 3km search radius (Table 10.12).

Table 10.12: Water vole records within a 3km radius surrounding Preston New Road.

Species	Date	Distance from Site[138]	Direction from Site
Water vole	1993 (x3 records)	1km	West (Peel Hill)
	2010	1.5km	West (Whitehill Drain)
	2010	2.6km	South (Branch drain)

137. During the initial Phase 1 Habitat survey undertaken in July 2013, an initial check for water vole signs was undertaken within Carr Bridge Brook, adjoining field drains and accessible waterbodies. During this survey no potential burrows or active field signs for water vole were identified.

138. The detailed water vole survey undertaken within the study area at the Site did not identify the presence of any signs of water vole (e.g. latrines, feeding station, footprints and burrows) within the length of Carr Bridge Book and adjoining field drain or adjacent waterbodies. Moreover, the proposed Site is located over 100m from all suitable habitat for water vole. This includes the reaches of Carr Bridge Brook located approximately 300m to the north and adjoin field drain, located approximately 270m to the north-west. Consequently water voles are considered to be currently absent from the zone of influence surrounding the Site and are not considered further within the assessment.

Bats

139. The data search provided by LERN identified a number of records for bats within the 3km search radius including brown long-eared bat *Plecotus auritus*, pipistrelle *Pipistrellus pipistrellus*, Daubenton's *Myotis daubentonii* and Natterer's *Myotis nattereri* bat species. However, no bat records were identified within the Site or the immediate vicinity. The closest bat record was for a pipistrelle bat approximately 500m south-west.

140. Merseyside and West Lancashire Bat Group did not provide any bat records within the search radius surrounding the Site.

141. During the day time bat roost potential survey it was confirmed that there are no buildings within the study area and no trees were identified with features within which bats could roost.

142. The daytime survey also determined that the survey area includes hedgerows and waterbodies which provide suitable foraging and commuting for bats. Lack of artificial

[138] *Denotes the closest point to redline boundary.*

lighting, discrete sheltering features and the presence of animal dung are likely to be important factors in relation to bat foraging opportunities in the survey area.

143. Table 10.13 lists the bat species recorded during the activity surveys undertaken within the survey area.

Table 10.13: Bat species recorded during the activity surveys.

Date	Species	Location (Site)
24 August 2013	Common pipistrelle	Along Moss House Lane (north boundary of survey area) Access point to field located to the north of the Site. Hedgerow junction along the southern boundary of the survey area. A few records in open areas.
25 August 2013	*Myotis*	Along Moss House Lane (north boundary of survey area).
10 September 2013	Common pipistrelle	Along Moss House Lane (north boundary of survey area). Track along field boundary to north of Site. Wood edge north-west of Site.
10 September 2013	Pipistrelle songpost	Wood edge north-west of Site.
10 September 2013	Noctule	North-west of Site along field boundaries.

144. Based on the activity survey results it is concluded that:

- Most of the foraging and commuting activity was associated with sheltering features along field boundaries.
- Based on all the data gathered, there is no evidence to suggest that bats are roosting in the survey area or in the immediate vicinity due to the timing of the first bat detected after sunset.
- Common pipistrelle was recorded most frequently during the bat transects.
- The survey area provides sufficient resources to support bats for extended periods during the evening.
- Based on the activity surveys, it is reasonable to expect bats to use the survey area (including land in the immediate vicinity of the Site) throughout the active bat season.

145. Results of the bat species recorded during the unmanned detectors surveys are provided in Table 10.14. The key observations provided by the unmanned detector surveys include:

- Bat activity was recorded every night at both Anabat stations.
- Anabat station 1 (Field corner) – The earliest bat recorded was a noctule at 14 minutes after sunset. The earliest time for other species was a common pipistrelle at 52 minutes after sunset.
- Anabat station 2 (Waterbody 3) – The earliest bat recorded was a noctule at 33 minutes after sunset. The earliest time for other species was a common pipistrelle at 57 minutes after sunset.

- Common pipistrelle was recorded most frequently upon the remote recording bat detectors of all species recorded.
- The timing of recordings does not suggest that bats are roosting on, or in the immediate vicinity of, the survey area.

Table 10.14: Unmanned detector survey.

Location of Anabat	Number of nights operational	Bat species	Number of nights when bat species were recorded
Field corner immediately north of the Site	3	Common pipistrelle Brown long eared Noctule *Myotis*	3 3 3 3
Beside Waterbody 3 to the north of the Site	3	Common pipistrelle Brown long eared Noctule *Myotis*	3 3 3 2

146. Following the surveys, the survey area was subject to an evaluation in relation to bats and their supporting features. Although there is currently no adopted national standard for this process, an approach proposed by Wray *et al*., (2010[139]) was utilised. Based upon an evaluation of the data using this approach, the following conclusions have been made (Table 10.15 and Table 10.16):

Table 10.15: Evaluation of the Site and survey area with respect to bat commuting routes.

Species	No. of bats	Roosts/potential roosts nearby	Type and complexity of linear features	Score and geographic frame of reference
Common pipistrelle Common (2)	Individual bats (5)	None (1)	Gappy or flailed hedgerows and moderate field sizes (3)	11 = District, local or parish
Brown long eared bat Common (2)	Individual bats (5)	None (1)	Gappy or flailed hedgerows and moderate field sizes (3)	11 = District, local or parish
Myotis Rarer	Individual bats (5)	None (1)	Gappy or flailed hedgerows and moderate field sizes (3)	14 = District, local or parish
Noctule Rarer (5)	Individual bats (5)	None (1)	Gappy or flailed hedgerows and moderate field sizes (3)	14 = District, local or parish

[139] Wray, S., Wells, D., Long, E., Mitchell-Jones, T., (2010) 'Valuing Bats in Environmental Impact Assessment' *In Practice* (70), CIEEM.

Table 10.16: Evaluation of the Site and survey area with respect to bat foraging areas.

Species	No. of bats	Roosts/potential roosts nearby	Foraging habitat character	Score and geographic frame of reference
Common pipistrelle Common (2)	Individual bats (5)	None (1)	Intensive arable land (2)	10 = not important / Local or parish
Noctule Rarer (5)	Individual bats (5)	None (1)	Intensive arable land (2)	13 = District, local or parish

N.B – only common pipistrelle and noctule bats were recorded as making feeding attempts during surveys.

Amphibians

147. Five species of amphibian were identified within the data search provided by LERN and Lancashire Amphibians and Reptiles Association (LARA), namely great crested newt *Triturus cristatus*, common toad *Bufo bufo*, common frog *Rana temporaria*, smooth newt *Lissotriton vulgaris*, and palmate newt *Lissotriton helveticus* (Table 10.17). The closest amphibian record is for smooth newt located 900m north east. The closest great crested newt record is 2.4km south west of the site.

Table 10.17: Amphibian records from LERN and LARA within 4km of the Site.

Species	Date	No. of records	Distance from Site (km)*	Direction from Site
Great crested newt	1988 - 2003	21	2.4	South-west
	2005	35	2.4	South-west
Common frog	1988-1997	12	2.6	South-east
	2007	1	2.3	North-west
	2009	10	2.5	North-west
	2010	13	3.0	South-east
	2011	11	2.2	South
Common toad	1988-1997	11	3.1	North-east
	2006	1	3.0	East
	2009	4	2.5	South-west
	2010	1	3.6	North-west
	2011	2	3.5	North-west
	2012	1	2.9	South-east
Smooth newt	1988	1	3.5	North-west
	2009	15	2.5	South-east
	2011	1	3.5	North
Palmate newt	1988	1	3.8	North
Lissotriton sp.	1997	1	0.9	North-east
	2011	2	3.5	North

(= Denotes approximate distance from nearest point to the Site boundary).*

148. Waterbodies located within a 250m radius surrounding the Site, which were not separated by a significant barrier to newt movement (e.g. roads, rivers etc.), were assessed using the Habitat Suitability Index (HSI) assessment (Oldham *et al.* 2000) to determine their potential to support breeding great crested newts (Table 10.18 and Figure 10.2).

Table 10.18: HSI values for waterbodies located within a 500m radius surrounding the Site.

Waterbody	Grid reference	Suitability for breeding great crested newt
WB 1	SD 37513 32638	Poor
WB 2	SD 37572 32912	Poor
WB 3	SD 37298 33042	Poor
WB 4	SD 37049 32748	Poor
WB 6	SD 37237 32526	Below average
WB 7	SD 37369 32332	Below average
WB 8	SD 37327 32254	Poor
WB 9	SD 36759 32742	Average
WB 10	SD 36305 32872	Average

149. The HSI results demonstrate that the majority of the waterbodies located within the survey area are sub-optimal in relation to breeding great crested newts, with only Waterbody 9 and 10 being considered of average suitability for breeding great crested newts. This was largely due to the heavily disturbed nature of the waterbodies by waterfowl, the sub-optimal nature of the terrestrial habitat for newts, the low water quality and/or the lack of macrophytes / aquatic invertebrates identified. In addition, the proposed Site (including access routes and gas pipeline) is located within short mown or grazed improved grassland fields which were identified as providing habitat of negligible value in relation to terrestrial great crested newts, albeit that short sections of hedgerow will be affected which offer common amphibians with suitable terrestrial habitat.

150. Although HSI assessments provides an indication of the suitability of waterbody in relation to breeding great crested newts, such an assessment does not confirm presence or likely absence. Therefore, as a precautionary measure, to avoid the presence of doubt, the waterbodies located within a 250m radius of the Site were formally surveyed for great crested newts (Figure 10.2). These surveys confirmed the absence of great crested newts (Table 10.19). The surveys confirmed the presence of a small number of small newts, common toad and common frogs within Waterbody 1, 4, 6, 7, 8 and 9.

Table 10.19: Amphibian surveys summary results.

Waterbody	Number of survey sessions	Maximum Adult Count					
		Common frog	Common toad	Great crested newt	Smooth newt	Palmate newt	Small newt species
WB 1	4	2	3	0	0	0	0
WB 2	4	0	0	0	0	0	0
WB 3	4	0	0	0	0	0	0
WB 4	4	2	1	0	0	0	4
WB 6	4	1	0	0	0	0	0
WB 7	4	0	0	0	0	0	1

WB 8	4	0	0	0	1	0	3
WB 9	4	0	0	0	1	0	0
WB 10	Access not available at the time of the great crested newt surveys						

**Numbers represent highest adult count within single survey session. 'Small newt species' refers to female smooth / palmate newts that cannot be reliably identified by torchlight.*

Reptiles

151. No records of reptile species were identified within the 3km search radius surrounding the proposed Site by LERN or LARA.

152. During the Phase 1 Habitat survey the habitats located within, and contiguous to, the proposed Site area (e.g. disturbed areas of grazed / short mown improved grassland and arable) were identified to provide sub-optimal habitat for reptiles. In addition, no areas of suitable hibernacula (e.g. log piles etc.) for reptiles were identified within the survey area. Reptiles are therefore not considered as a constraint to the proposed development and have are not considered further within the chapter.

Ornithological Assessment

153. Data provided by Fylde Bird Club identified 14 of the 20 qualifying bird species of Morecambe Bay SPA, 17 of the 20 from Ribble and Alt Estuaries SPA and 1 of the 2 from Liverpool Bay SPA, within the 5km search radius surrounding the Site within the last 5 years (Table 18). Records included common tern *Sterna hirundo*, curlew *Numenius arquata*, golden plover *Pluvialis apricaria*, lesser black-backed gull *Larus fuscus*, oystercatcher *Haematopus ostralegu*, pink-footed goose *Anser brachyrhynchus*, common redshank *Tringa totanus*, bar-tailed godwit *Limosa lapponica*, dunlin *Calidris alpina*, herring gull *Larus argentatus*, knot *Calidris canutus*, pintail *Anas acuta*, ringed plover *Charadrius hiaticula*, shelduck *Tadorna tadorna*, Bewick's swan *Cygnus columbianus*, whooper swan *Cygnus cygnus* and common scoter *Melanitta nigra*. In particular a large number of records for pink-footed geese have been identified within the search radius.

Table 10.20: Ribble and Alt Estuaries SPA, Morecambe Bay SPA and Liverpool Bay SPA qualifying bird species, and bird species included within Marton Mere SSSI citation, identified within 5km of Preston New Road within last 5 years from Fylde Bird Club.

Species	**No of records**	**Most recent record**	**Approximate location of record closest to Site (to the nearest km)**
Ribble and Alt Estuaries SPA, Morecambe Bay SPA, Liverpool Bay SPA			
Bar-tailed godwit *Limosa lapponica*	2	January 2011	4 km NW
Bewick's swan *Cygnus columbianus*	82	December 2012	2 km NE
Common scoter *Melanitta nigra*	5	November 2012	4 km NW
Common tern *Sterna hirundo*	16	August 2012	2 km SW
Curlew *Numenius arquata*	67	November 2012	2 km SW
Dunlin *Calidris alpina*	13	September 2012	3 km NW
Golden plover *Pluvialis apricaria*	30	August 2012	2 km NE
Herring gull *Larus argentatus*	128	December 2012	2 km W
Knot *Calidris canutus*	3	May 2009	4 km NW

Lesser black-backed gull *Larus fuscus*	81	December 2012	2 km N
Oystercatcher *Haematopus ostralegus*	204	July 2012	2 km E
Pink-footed goose *Anser*	394	December 2012	< 1 km NE
Pintail *Anas acuta*	86	December 2012	2 km N
Common redshank *Tringa totanus*	97	December 2012	2 km SW
Ringed plover *Charadrius hiaticula*	4	August 2012	3 km SW
Ruff *Philomachus pugnax*	31	September 2012	2 km N
Shelduck *Tadorna tadorna*	179	December 2012	2 km NE
Teal *Anas crecca*	676	December 2012	2 km E
Whooper swan *Cygnus cygnus*	412	December 2012	< 1 km NW
Wigeon *Anas penelope*	277	December 2012	2 km W
Marton Mere SSSI			
Little grebe *Tachybaptus ruficoll*	132	October 2012	2 km SW
Great crested grebe *Podiceps cristatus*	404	November 2012	3 km NW
Coot *Fulica atra*	447	December 2012	2 km E
Mallard *Anas platyrhynchos*	324	December 2012	2 km E
Pochard *Aythya ferina*	327	December 2012	2km N
Shoveler *Anas clypeata*	561	December 2012	2 km N
Tufted duck *Aythya fuligula*	461	December 2012	2 km N
Greenshank *Tringa nebularia*	8	September 2012	4 km NW

154. In relation to breeding bird species, a number of bird species were identified within the search radius by LERN. Those judged to have potential to breed at the Site and have been recorded within the last 5 years are listed in Table 10.21. Notable breeding bird species identified include: lapwing, linnet *Carduelis cannabina*, skylark *Alauda arvensis*, song thrush *Turdus philomelos*, and yellowhammer *Emberiza citrinella* (all of which are UK & Lancashire BAP / S41 species & red listed BoCC) (Table 10.21).

Table 10.21: Breeding bird records provided by Fylde Bird Club located within the 4 tetrads surrounding Preston New Road (e.g. 33Q, 33R, 33V and 33W).

Species	**Number of records**	**Most recent record**	**Approximate location of record closest to Site (to the nearest km)**
Blackbird *Turdus merula*	8	June 2010	2 km NE
Blackcap *Sylvia atricapilla*	2	April 2010	2 km SE
Chaffinch *Fringilla coelebs*	8	June 2010	2 km NE
Collared dove *Streptopelia decaocto*	8	June 2010	2 km NE
Corn bunting *Emberiza calandra*	3	July 2012	2 km SW
Dunnock *Prunella modularis*	7	June 2010	2 km NE
Goldfinch *Carduelis cannabina*	8	June 2010	2 km NE
Grey partridge *Perdix perdix*	4	April 2012	2 km E
Lapwing *Vanellus vanellus*	7	April 2010	2 km NE
Lesser whitethroat *Sylvia curruca*	2	May 2012	2 km NE
Linnet *Carduelis cannabina*	8	June 2012	2 km SW

Species	**Number of records**	**Most recent record**	**Approximate location of record closest to Site (to the nearest km)**
Long-tailed tit *Aegithalos caudatus*	7	April 2012	2 km NE
Moorhen *Gallinula chloropus*	6	June 2012	2 km NE
Pheasant *Phasianus colchicus*	6	June 2010	2 km NE
Red-legged partridge *Alectoris rufa*	2	April 2010	2 km S
Reed bunting *Emberiza schoeniclus*	3	June 2010	2 km S
Robin *Erithacus rubecula*	7	June 2010	2 km NE
Skylark *Alauda arvensis*	4	January 2011	2 km NE
Song thrush *Turdus philomelos*	5	January 2010	2 km NE
Tree sparrow *Passer montanus*	7	October 2012	2 km E
Wren *Troglodytes troglodytes*	8	June 2010	2 km NE
Yellowhammer *Emberiza citrinella*	1	May 2011	2 km SE

155. The habitats on and surrounding the proposed development were assessed as to their potential to support wintering SPA qualifying bird species and it was concluded that the habitat was of moderate value to these species, and likely to support them at least occasionally. Therefore, vantage point wintering bird surveys were undertaken to gain a better understanding of the usage of the local area. The results of these surveys are presented below.

156. The habitat assessment also looked at the value of the Site for breeding birds and it was determined to be of low value. However, there are hedgerows surrounding the main development Site which could support breeding birds. Therefore, a breeding bird survey was undertaken and the results of these works are presented below.

Wintering birds

157. In winter 2013-2014, Ecology Services UK Ltd recorded the following wintering estuary bird species.

Table 10.22: Wintering bird species recorded winter 2013 – 2014.

Species	Mean count	Peak count	Frequency (% total surveys recorded)	Frequency of occurrence on the ground (% total surveys recorded)
Whooper swan	6	8	24	0
Pink footed goose	439	2500	36	4
Oystercatcher	2	2	4	4
Lapwing	22	90	24	24

184. The wintering bird survey identified two oystercatcher within field 8 on one occasion. It is within this field that the main Site will be located. Pink footed goose was recorded on one occasion on the ground; in the field to the west of field 7, through which the proposed gas pipeline will be constructed. This was during a period of shooting when they were frequently changing field and only briefly landed within field 7. Lapwing was recorded

on the ground in two fields (fields 5 and 6); immediately to the north and north west of the proposed development Site

Figure 10.4: Survey area with field numbers and vantage points indicated (not to scale as figure has been copied into this report).

185. Bird flightlines over the survey area were identified as follows:

- Whooper swan - north to south and south to north.
- Pink-footed goose - north to south and south to north.
- Oystercatcher - no flightlines observed.
- Lapwing - north to south.

186. Other than the single observation of pink footed geese, there is no evidence of bird usage to suggest that the survey area forms an integral part of a key landscape for wintering birds. However, the fact that whooper swans, pink footed geese and lapwings have been seen flying over the survey area does highlight the potential for these species to occur in the wider survey area.

187. The fact that a limited number of wintering estuary bird species associated with the Ribble Estuary have been seen foraging and loafing within and adjacent to the survey area shows that there is some potential for the wider survey area to have a functional link with the Ribble and Alt Estuaries SPA/Ramsar site; however, the level of use by wintering estuary birds in winter 2013-2014 is not regarded as demonstrating a functional link. There is no evidence to suggest that the proposed development Site has a link with the Ribble and Alt Estuaries SPA/Ramsar site.

Breeding birds

188. In April and May 2014 Ecological Services UK Ltd recorded the bird species listed in Table 10.23 on Site.

Table 10.23: Birds recorded on Site in 2014.

Species	Total number of individuals - April 2014	**Total number of individuals - May 2014**
Herring gull	2	0
Grey heron	2	0
Lapwing	4	2
Oystercatcher	0	3
Mallard	3	3
Shelduck	0	3
Wood pigeon	2	2
Rook	5	2
Swallow	0	5
Swift	0	0
Skylark	0	3
Meadow pipit	2	0
Wheatear	0	0
Blackbird	0	0
Great tit	0	0
Blue tit	0	0
Linnet	3	2
Dunnock	0	0
Chaffinch	2	3
Goldfinch	0	7
Reed bunting	0	0

189. Reed bunting, chaffinch and blackbird were the only species recorded in the immediate vicinity of the proposed development Site; all of these species were recorded within field boundary hedgerows. Meadow pipit, linnet, skylark and dunnock were also recorded within 100 metres of the proposed development Site location. All other species were recorded at greater distances or overflying the survey area.

190. The following behaviours were observed:

Table 10.24: Bird behaviour recorded.

Species	Behaviour recorded
Herring gull	Overflying Site
Grey heron	Overflying Site
Lapwing	Overflying Site and display flights - possible breeding
Oystercatcher	Overflying Site
Mallard	Male and female loafing and overflying Site
Shelduck	Loafing and overflying Site
Wood pigeon	Perching on telegraph posts and overflying Site
Rook	Foraging and overflying Site - confirmed breeding on adjacent land
Swallow	Overflying Site
Swift	Overflying Site
Skylark	Display flights - possible breeding
Meadow pipit	Perching on fence posts
Wheatear	Perching by pond
Blackbird	Male perching on hedge top
Great tit	Foraging within hedgerow
Blue tit	Foraging within hedgerow

Species	Behaviour recorded
Linnet	Perching on hedgerow and telegraph wires - possible breeding
Dunnock	Perching on fence line - possible breeding
Chaffinch	Male singing and male and female perching on hedgerow - probable breeding
Goldfinch	Feeding and overflying Site
Reed bunting	Male perching on hedgerow

191. The birds confirmed to be breeding or demonstrated behaviour to suggest breeding included lapwing, rook, skylark, linnet, dunnock and chaffinch.

192. Using the approach in Fuller (1980) the survey area is regarded as having no more than local importance for breeding birds.

Terrestrial invertebrates

193. The records search provided by LERN did not identify the presence of any notable or protected (e.g. Lancashire BAP species) invertebrate species within the Site. Although a number of Lancashire BAP moth species were identified within a 1km search radius, all records were identified in 1960 with no given grid reference so are considered to be of limited relevance for an assessment of current value. Moreover, the heavily disturbed and intensively managed nature of the mosaic of habitats identified within the survey area (e.g. heavily grazed improved pastureland) is considered to provide sub-optimal habitat for terrestrial invertebrates. Consequently, it is considered that the proposed Site area, including adjacent habitat, is unlikely to support any notable / protected assemblages of terrestrial invertebrates. However, it is possible that the intact hedgerows may offer suitable habitat, albeit relatively limited and of low value, for generic assemblages of invertebrate species typical of the surrounding habitats in Lancashire.

Fish

194. No notable fish records were identified within the search radius by LERN.

195. During the Phase 1 Habitat survey, Carr Bridge Brook and adjoining field drain were assessed as not being suitable to support any notable populations of fish (e.g. brown / sea trout and European eel) owing to their small size and low flows. Moreover, Carr Bridge Brook is located over 300m to the north of the Site and no suitable interconnecting habitat was identified in between (e.g. field drains, etc). Consequently fish have not been considered further within the chapter.

White-clawed crayfish

196. No records for white-clawed crayfish *Austropotamobius pallipes,* were identified within the search radius by LERN.

197. Carr Bridge Brook and adjoining field drain were identified as providing sub-optimal habitat for white-clawed crayfish during the Phase 1 Habitat survey. This is largely owing to the small size and low flows of the watercourses identified. Furthermore, Carr Bridge Brook is located over 300m to the north of the proposed Site and no suitable interconnecting habitat was identified in between (e.g. field drain). Consequently white-clawed crayfish have not been considered further within the chapter.

Brown hare

198. A number of brown hare records have been identified by LERN within the search radius surrounding the Site.

199. During the Phase 1 Habitat survey the habitat mosaic located to the south and west of the proposed Site was identified as offering suitable habitat for brown hare. A number of brown hare sightings have also been identified within the survey area during the suite of ecological survey work undertaken at the Site.

Other species

200. The Site and surrounding habitat located within the survey area was not identified as providing suitable habitat for any other protected or notable species (e.g. red squirrel *Sciurus vulgaris*).

Summary of Baseline

201. The baseline study identifies those ecological receptors that require assessment in relation to the proposed development. Below is a summary of those receptors.

202. There are no designated sites (international/national/local) on or adjacent to the proposed development, however, the baseline identified that there are five designations within the local area which have been designated due to the bird assemblages which they support during the summer breeding season or during the winter. These designations include:

- Ribble and Alt Estuary SPA;
- Morecambe Bay SPA / Ramsar;
- Liverpool Bay SPA;
- Marton Mere SSSI ; and
- Lytham Moss BHS.

203. Due to the mobility of birds, the presence of suitable habitat within the proposed development Site and the potential for a functional link between habitats on Site and the designated sites, an impact assessment upon the designated sites listed above is required.

204. The habitats on Site are typical of an intensively managed landscape, and the proposed development area is dominated by species poor grassland. Field boundaries on Site are lined by intact and defunct species poor hedgerow which are not considered ‘important’ under the Hedgerow Regulations 1997, but are considered to be UK BAP habitat. Therefore, impacts on this habitat type need to be assessed.

205. The baseline eliminated the need for further assessment in relation to badgers, water vole, reptile, white clawed crayfish, fish and terrestrial invertebrates.

206. The baseline did identify a need for further assessment in relation to:

- Bats;
- Breeding birds;
- Wintering birds;
- Common amphibians; and
- Brown hare.

10.6.4 Nature conservation evaluation – Site at Preston New Road and Array Sites

207. This section of the report provides an overview of the geographic importance of nature conservation designations within the vicinity of the main Site at Preston New Road and the array sites, and the geographic importance of habitats and species identified, or considered to be potentially present, at the main Site at Preston New Road and the array sites. This assessment is detailed in Table 10.25, Table 10.26 and Table 10.27. Unless otherwise stated, confidence levels are 'certain/near certain'

10.6.4.1 Designations

208. As detailed within Section 10.6.1, the following statutory designations, relating to nature conservation, were identified within a 10km surrounding the Site and the Array Sites:

- Marton Mere, Blackpool SSSI and LNR located:
- Ribble and Alt Estuaries SPA and Ramsar Site located:
- Morecambe Bay SPA and Ramsar locate:
- Liverpool Bay SPA located

209. With respect to Liverpool Bay SPA, the designated site is located over 4.9km from the arrays and 7km from the Site and no qualifying SPA species off this designation, which include common scouter and red-throated diver, have been identified during the bird surveys undertaken. In addition, no known records for common scouter or red throated diver have been identified in close proximity to the Site (i.e. within a 2km radius) or arrays and no known sites / feeding areas of common scouter or red throated diver exist in close proximity to the Site or arrays. Consequently, it is not envisaged that the proposals will cause any adverse impacts (direct or indirect) that could affect the integrity of Liverpool Bay SPA. This designation has therefore not been considered further within the chapter.

210. As detailed within Section 10.6.2 five BHS were identified within the 3km search radius surrounding the Site with an additional two BHS sites within 1km of the array sites:

- Herons Reach Golf Course/ Marton Mere Habitat Complex
- Westby Clay Pit
- Great Plumpton Sidings
- Willowmead Park Swamp (Moss Side)
- Lytham Moss
- Chapel Road Field
- Pond west of Chain Lane

211. However, due to a combination of the following factors it is envisaged that the proposals at the Site/arrays could not potentially adversely impact upon these BHS sites, excluding Lytham Moss BHS:

- The proximity of the BHS sites from the proposed works.
- The nature of the BHS sites (Largely due to botanical and invertebrate interest) and the lack of complementary habitat and features located at the Site or arrays.

- The lack of any suitable connecting habitat between the BHS sites and the development Site or array sites.
- The temporary, localised and small scale nature of the proposed works associated within the construction and operation of the array stations (See Section 10.7.1).

212. Consequently, only Lytham Moss BHS is considered further as potential impact pathway exist (e.g. birds) Table 10.25.

Table 10.25 Intrinsic evaluation of designated sites for the main Site at Preston New Road and Array Sites, unless stated otherwise.

Designations	Geographic Value	Justification
Ribble and Alt Estuaries SPA and Ramsar Site.	International	Ribble and Alt Estuaries SPA and Ramsar sites are located over 6.7km south of the proposed site. However qualifying SPA and Ramsar bird species, notably whooper swan and pink-foot geese, have been identified to utilise the mosaic of habitat located surrounding the Site and have been recorded flying over the Site. Ribble and Alt Estuaries SPA / Ramsar site is located approximately 2km from the nearest array station. SPAs are areas of special protection for the rare or vulnerable species listed in Annex I (Article 4.1), for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of international importance. [140] Ramsar sites are wetlands of international importance designated under the Ramsar Convention. [141]
Morecambe Bay SPA and Ramsar	International	Morecambe Bay SPA and Ramsar Site are located over 6.7km to the north of the proposed site. However qualifying SPA and Ramsar bird species, notably whooper swan and pink-foot geese, have been identified to utilise the mosaic of habitat located surrounding the Site and have been recorded as flying over the Site. Morecambe Bay SPA / Ramsar site is located approximately 4.7km from the nearest array station. SPAs are areas of special protection for the rare or vulnerable species listed in Annex I (Article 4.1), for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of international importance. [140] Ramsar sites are wetlands of international importance designated under the Ramsar Convention.[141]
Marton Mere SSSI	National	Marton Mere is located approximately 3.2km north-west of the Site. Bird species included within the SSSI citation that utilise the mosaics of habitat surrounding

[140] JNCC (2013) 'SPA selection guidelines' http://jncc.defra.gov.uk/page-1405 (Accessed January 2014).
[141] JNCC (2013) '*Ramsar sites in the UK, its Overseas Territories and Crown Dependencies'* http://jncc.defra.gov.uk/page-161 (Accessed January 2014).

Designations	Geographic Value	Justification
		the Site or flyover the Site; include coot, oystercatcher and mallard. Marton Mere SSSI is located approximately 1km from the nearest array station. SSSIs are a national suite of sites providing statutory protection for the best examples of the UK's flora, fauna, or geological or physiographical features.[142]
Lytham Moss BHS	County	Although Lytham Moss is located over 2km from the Site, birds included within the citation for the BHS site, including whooping swan have been recorded as utilising the adjacent habitat surrounding the Site and flying over the Site. Station sites 148004; 138331; and 138349 are located immediately adjacent to Lytham Moss BHS site. BHS sites are the most important non-statutory wildlife sites in Lancashire and form a major part of the strategy to conserve the biological richness within the County area. The BHS system seeks to *'identify all known sites of substantive nature conservation value in the County'*.[143]

10.6.4.2 Habitats

Table 10.26 Intrinsic evaluation of habitats for the main Site at Preston New Road and array Sites, unless stated otherwise.

Habitat	Geographic Value	Justification
Improved grassland fields and arable fields	Site	Arable farmland Lancashire BAP priority habitat includes *'all cultivated land in agricultural or horticultural production. This includes bare fallow and grassland leys that are regularly ploughed and re-seeded. It also addresses field margins and boundary features such as hedges and ditches in arable fields'*.[144] However, the areas of improved grassland identified within the survey area was identified as being heavily managed, with vegetation cover throughout the majority of the year, which are not regularly ploughed (every 3-5 years) and are dominated by non-native or sown species. Consequently such habitat is considered to be of low value. In addition, the value of arable farmland identified is limited by: • The extent and nature of disturbance.

[142] JNCC (2013) *'Protected sites designations directory'* http://jncc.defra.gov.uk/page-1527 (Accessed January 2014).
[143] Lancashire County Council (1998) *'Biological Heritage Site – Guidelines for Site Selection'*.
[144] Lancashire Biodiversity Partnership (2001) *'Arable Farmland'*.

Habitat	Geographic Value	Justification
		• The presence of vegetation cover throughout the majority of the year dominated by crops/non-native or sown species. • The absence of field margins. Field margins are absent or limited to narrow bands of tall ruderal herbs around the main Site so do not qualify as S41 Habitat of Principal Importance (Arable and Horticultural – Arable field margins) and are considered to be of low value. Furthermore, intensively managed areas of improved grassland fields are not rare for the locality and are locally abundant within the surrounding arable landscape in West Lancashire.
Hedgerows	Local	Large sections of field boundaries within the survey area surrounding the main Site are not accompanied by hedgerows (intact or defunct). The hedgerows which do exist within the survey area do not qualify as 'important' hedgerows under the Hedgerow Regulations 1997. It was also found that the hedgerows within the survey area for the arrays were heavily managed and species-poor. Although the majority of intact hedgerows located qualify as UK BAP priority habitat since the majority were identified to contain over 80% of at least one native woody species. The hedgerows also qualify under arable farmland Lancashire BAP habitat as a boundary feature and as S41 Habitat of Principal Importance (Boundary – Hedgerows).
Broadleaved woodland	District	**Only applicable to the main Site** The woodland copse, located approximately 400m north-west qualify as a moderate example of UK BAP (Low deciduous woodland) / Lancashire BAP (broadleaved and mixed woodland) priority habitat.
Waterbodies	Local	**Only applicable to the main Site** The waterbodies located at the Site do not qualify as UK BAP habitat (Ponds) or S41 Habitat of Principal Importance (Freshwater – Ponds) since they are under 2ha in extent, they do not support: habitat of international importance; species of high conservation importance; or exceptional assemblages of key biotic groups. In addition, Waterbodies 1,2,3,4,6,7 and 8 were assessed as being of low ecological value (using the Predictive System for Multimetrics (PSYM)) owing to a combination of the following factors: the amount of disturbance by waterfowl; the poor water quality; the lack of macrophytes or aquatic invertebrates and the level of poaching from livestock. Waterbodies 9 and 10 were of moderate value (not PYSM assessed).
Running Water - Carr Bridge Brook.	Local	**Only applicable to the main Site** Carr Bridge Brook does not qualify as UK BAP habitat (Rivers), S41 Habitat of Principal Importance (Freshwater – Rivers) or Lancashire BAP habitat (Rivers and streams). This is largely owing to the small size of Carr Bridge Brook and the amount of human alteration which the watercourse has received (e.g. dredging, straightening). Carr Bridge Brook is however likely to support site fauna (e.g. bats) and does support a relatively higher botanical diversity in comparison to the adjacent areas of arable and pasture farmland.
Field Drains	Site	**Only applicable to the main Site**

Habitat	Geographic Value	Justification
		The field drain located at the Site does not qualify as UK BAP habitat (Rivers), S41 Habitat of Principal Importance (Freshwater – Rivers) or Lancashire BAP habitat (Rivers and streams). The field drain also does not qualify as arable farmland Lancashire BAP habitat as a boundary feature. The value of the field drains is limited by: • The low level of flows and poor water quality. • The extent of management / dredging (e.g. regular dredging). • The lack of connectivity to other field drains within the area. • The lack of macrophytes or aquatic invertebrates identified. • The relatively low plant species diversity identified within the riparian corridor.
Tall ruderal herbs, scrub and scattered immature broadleaved trees	Site	The value of isolated scattered rank tall ruderal herbs, juvenile broadleaved trees and scattered scrub is limited by: • The small size and coverage of habitats. • The low botanical species diversity recorded. • The extent of disturbance.

10.6.4.3 Fauna

Table 10.27: Intrinsic evaluation of fauna for the main Site at Preston New Road and Array Sites, unless stated otherwise.

Species	Geographic level of value	Justification
Bats	District (level adopted as a precautionary measure as classification indicates it is district-local-parish value)	The survey area (main Site and Array Sites) do not have any value for roosting bats since no potential bat roosts were identified. The array sites were relocated if a conflict was identified. Common pipistrelle bat species, the principal bat species identified at the main Site, is the UK's most widely distributed bat species, known to be common and widespread within Lancashire. [145] The survey area is considered to be of district, local or parish value in relation to commuting and foraging areas. This is based upon an evaluation of the data collected during surveys in accordance with an approach proposed by Wray et al., (2010). [146] The lengths of intact hedgerow adjacent to the array stations offer suitable resource for foraging and commuting bats
Amphibians	Local	A small population of common toad and frog were identified within Waterbody 1, 4, 6 and 8 and smooth newt were recorded in Waterbody 4, 7, 8 and 9. The majority of terrestrial habitat located at the Site was identified as being sub-optimal in relation to amphibians; although the triangle of broadleaved woodland located approximately 400m to the north, adjoining intact hedgerows and field drain banks may offer suitable habitat for common toad. Common toad is a UK BAP Priority Species and S41 Species of Principal Importance.
Badgers	Local	**Only applicable to Array Sites (no badger setts or signs at the main Site)** Station site AM353 is located within a 50m radius of a sett site identified by the Lancashire Badger Group. Station site AM343 is located within a 200m radius of sett sites identified by the Lancashire Badger Group. The remaining 86 array stations are located at least 500m from the six sett sites identified. Thirteen array sites were identified adjacent to or within close proximity (50m) to habitat identified as being suitable for badger setts such as woodland or railway embankments (Station sites: 138335; 138336, 148002; 148006, 148025; 148033; AM332, AM339, AM353; AM354; AM374; I01T; and I06T).
Breeding birds	Local	Site: The breeding bird surveys confirmed that the Site was not in use by ground nesting birds at the time of the survey. 21 bird species were recorded within the study area of which six species demonstrated behaviour which suggested that the may breed within the hedgerows/trees that surround the site or the surrounding area including lapwing, skylark and linnet. Arrays: The lengths of intact hedgerow, scrub, tall ruderal herbs and broadleaved trees adjacent to the array stations offer a suitable resource for foraging and nesting birds. Areas of arable farmland located adjacent to a small number

[145] The Lancashire Wildlife Trust 'Mammals – Bats' http://www.lancswt.org.uk/discovery-center/mammals/bats (Accessed September 2013).
[146] Wray, S., Wells, D., Long, E., Mitchell-Jones, T., (2010) *'Valuing Bats in Environmental Impact Assessment'* In Practice (70), CIEEM.

Species	Geographic level of value	Justification
		(approx. 6 station sites) of proposed array stations offer suitable habitat for ground nesting birds.
Wintering birds	Local	Site: Ten bird species were noted during the wintering bird surveys. Four species of estuary birds were recorded; oystercatcher, lapwing, whooper swan and pink footed goose. The most abundant estuary bird species (in terms of recorded activity) were pink footed geese and lapwing. However, the peak count for pink footed geese of 2500 birds related to shooting within the local area leading to frequent disturbance of this species. Typically if wintering birds were observed within the study area they occurred in low numbers. Due to the low number of birds on site and an absence of behaviour by SPA qualifying bird species to indicate functional link between the proposed development site and the nearby Ribble & Alt Estuaries SPA/Ramsar site the site is considered to be only of local value to wintering birds. Arrays: 42 out of a total 88 array stations are located within habitat deemed to be of low potential with respect to wintering birds. However, 46 (there are three options for one of the array sites) station sites were deemed to be of moderate potential in relation to wintering bird potential, albeit that all array structures will be located adjacent to a field boundary which are typically avoided by wintering birds while on the ground foraging.
Terrestrial invertebrates	Site	No notable or protected invertebrate species records were identified at the Site or within a 250m radius surrounding the Site. The heavily disturbed and intensively managed nature of the habitats located at the Site were identified as providing sub-optimal habitat for terrestrial invertebrates. It is possible that boundary features (e.g. hedgerows) may support assemblages of invertebrates typical for this area in West Lancashire, albeit of relatively low value owing to the extent of disturbance and the limited botanical diversity identified.
Brown hare	Local	A number of brown hare observations have been recorded within the adjacent fields during survey work undertaken at the main Site. The Site itself and the Array Sites are unlikely to support sheltering brown hare owing to the lack of suitable vegetation cover; however brown hare is a locally abundant species in West Lancashire and the habitat mosaics of agricultural fields with intact hedgerows surrounding the Site offer suitable habitat for brown hare. Brown hare is listed as a Priority Species within both the UK and Lancashire BAP and is a S41 Species of Principal Importance. The north-west in particular has been identified as an area which has suffered a significant decline in brown hare populations.[147]

10.7 Assessment, without Mitigation

213. This section provides an assessment of the predicted impacts of the proposed development on valued habitats and species in an unmitigated scenario. In accordance with the CIEEM guidance, detailed assessment of impacts has been limited to ecological

[147] S. Bolton (GMEU) (2013) *'North-West Brown Hare Project – Final Report January 2013'*.

receptors considered to be of value at the 'local' level or above (refer to Table 10.25, Table 10.26 and Table 10.27).

214. The impacts and effects are described according to whether they will occur during: installation of surface and buried arrays (Section 10.7.1), the construction of the well pad and access (Section 10.7.2); drilling; hydraulic fracturing; initial flow testing (Section 10.7.3); extended flow testing (construction & operation) (Section 10.7.4); and decommissioning and restoration (Section 10.7.5).

215. This assessment considers all potential sources of impact based on the current baseline. If there is a delay between submission of the detailed planning applications, construction and operation of all of the activities being assessed, specific elements of survey work would be repeated prior to works commencing (See Mitigation Measures: Section 10.9).

10.7.1 Installation of Surface and Buried Arrays, without Mitigation

10.7.1.1 Construction

Surface arrays

216. Each array station site will require a maximum construction working footprint of 20m^2 (this applies to both surface and buried array stations). Installation of the surface arrays (i.e. Sites I01T – I08T) will require only small scale plant for minor earthworks required to install a small vault just below ground level. This will include a small excavator and light vehicles for site personnel and equipment. The top of the vault will be accessible from the surface via a manhole cover. The construction period for the surface arrays is very short (i.e. maximum of two days). On completion, a wooden post and rail fence will be installed surrounding the manhole cover.

Buried arrays

217. The buried arrays (station sites 138305 – 138349, 148001 – 148039, AM332, AM339 – AM341, AM343, AM345, AM350 – AM354, AM360 – AM363, AM374) will be buried up to 100m below surface and will be accessible from the surface through manhole covers. Similarly to the surface arrays, the buried arrays will only require small scale plant but will require a site investigation type drilling rig rather than an excavator. The construction period of each buried array will require a maximum of four days (one day to mobilise, two days to install and one day to demobilise). On completion, a wooden post and rail fence will be installed surrounding the manhole cover.

Impacts on designations

218. The following sites have been designated for their value to support breeding or wintering bird species:

- Morecambe Bay SPA & Ramsar.
- Ribble and Alt Estuaries SPA & Ramsar.
- Marton Mere SSSI / LNR
- Lytham Moss BHS

219. The array sites will be located more than 2km from any international or national designated site. However, two of the arrays will be located adjacent to the Lytham Moss

BHS. These are array sites 138331 and 138349. Lytham Moss BHS has been designated as it supports pink footed geese and whooper swans with bird numbers exceeding 0.5% of the British wintering bird population. This site is functionally linked to the SPA sites. Therefore, the installation of the arrays will require a Habitats Regulation Assessment, in the mitigation scenario. The following assessment will be in the unmitigated scenario.

220. As none of the array sites are located in any of the designated sites, impacts will be indirect. Therefore, to determine whether any of these designated sites could be adversely affected we need to considered the indirect loss of:

- Foraging and loafing habitat outside of the designated sites.
- Disturbance of foraging and loafing birds outside of the designated sites and within Lytham Moss BHS, which is functionally linked to the SPA's.

221. The data records provided by Fylde Bird Club identified fourteen out of a possible 20 qualifying SPA bird species within the search radius. However, the ornithological assessment of habitat suitability determined that the habitat surrounding the majority of the proposed array sites were low potential in relation to wintering birds (i.e. 42 sites out of 88 sites). This was based on the scoring system developed by Kirby et al., (2000).[148] and was largely attributed to the small size of fields, limited sightlines and a lack of large, shallow accessible pools at the majority of the proposed array sites.

222. However, 46 array sites were identified to be of moderate potential for wintering birds. No array site was identified as being of high potential with respect to wintering birds.

223. Wintering bird surveys were undertaken at those 46 sites identified to have moderate potential and this identified six sites; 138308, 138326, 148028, 148033, I01, I03 and I04, where lapwing were present within the field that works will be undertaken and IO8 is within a field where lapwing, oystercatcher and curlew were recorded. This site is close to Lytham Moss BHS.

224. At the time of the survey species including pink footed geese, whooper swan and Berwick's swan were not recorded within any of the fields that the array's are to be constructed albeit that they were recorded flying over site. However, historically they have been recorded in the field that 138326, 138331, 138339, 138340, 138349, 148008, I03, IO4 and IO8 would be constructed.

225. Due to the small footprint of each of the arrays and their position adjacent to boundary features (hedgerows and fence lines) it is not considered that the construction of the arrays would lead to the loss of habitat which supports wintering birds and that could indirectly impact upon the function of the four designated sites, as wintering birds will not be located within the immediate vicinity of these areas.

226. It was identified that 42 array sites were of low value to wintering birds and therefore, it is considered that at these sites there will be a low potential of disturbance to wintering birds and therefore no impact upon any of the designated sites.

227. 46 array sites were identified to have moderate wintering bird potential, and of these eight were confirmed to be within a field which supports wintering birds in 2014 while a further nine are known to have done so historically.

228. It is considered that at 15 of the sites there is a high risk that loafing or foraging SPA qualifying bird species could be present and impacted by disturbance through noise and

[148] Kirby. J. et al (2000) *'Key Habitat Attributes for Birds and Bird Assemblages in England'*, England Nature Research Report no. 359.

vehicle movements, the risk of this is considered greatest for the site adjacent to Lytham Moss. This impact could be considered significant in an unmitigated scenario at a district level. The level of impact is not considered to be either international or county as impacts will not be direct and taking account of the small scale of works and the short duration of works.

229. The risk of disturbance impacts upon SPA qualifying bird species at the remaining 31 site originally identified to be of moderate value to these species is considered moderate to low, but taking a precautionary approach impacts at these array sites could be significant at a local level.

230. A shadow Habitats Regulation Assessment was undertaken in a mitigated scenario to determine whether impacts upon the SPA's would be significant (refer to Appendix J: Part 9

Table 10.28: Construction impacts (of arrays) related to designated sites.

Level	Potential Impacts without Mitigation
District	Potentially significant impact upon the four designated sites which have been designated for wintering and breeding birds during installation works over the winter period at 15 of the array sites, including those adjacent to Lytham Moss BHS.

Impacts on habitats

Habitats – Direct loss

231. None of the habitats identified within any of the array stations are of national or international value or are functionally linked to any habitat of national or international value. In addition, none of the habitats identified within the array stations are infrequent or rare for their locality (e.g. areas of improved grassland and arable fields) and all are considered to be locally abundant within the wider agricultural landscape. However the sections of hedgerow located adjacent to a large number of array stations qualify as UK BAP habitat / Lancashire BAP habitat / S41 Habitat of Principal Importance and are considered to be of local value.

232. Construction of the array stations will result in the and loss of the following areas of habitats:

- *Improved grazed grassland, arable farmland and tall ruderal herbs (Site value): Loss of approximately ~0.18ha of improved grassland and arable farmland in total for all 88 stations. This also includes a small amount of rank tall ruderal herbs (e.g. 0.01ha in total).*

233. Impacts to habitats are not considered significant.

Habitats – Summary of impacts

234. In summary, there are judged to be no significant impacts on habitat as a result of the construction of the array station sites.

Impacts on fauna

Bats

Bats – Loss of roost sites

235. Proposed array sites have been micro-sited and relocated away from any features identified to contain potential bat roosts. Consequently, no roosts or potential roosting features are located within the proposed working footprint or within at least a 10m radius surrounding an array station[149]. Consequently, there are no potential impacts (direct or indirect) in relation to roosting bats, at the local level.

Bats – Disturbance to foraging bats

236. Features suitable for foraging and commuting bats were identified adjacent to the majority of array stations in the form of intact hedgerows. However, no suitable bat foraging habitat will be removed to install the array stations. All construction works to install the array stations will be undertaken during daylight hours and will have ceased by the time bats emerge from a roost. In addition, no general site lighting at night will be required during the construction works. In summary, there are no significant adverse impacts on foraging bats during the construction of the arrays, at the local level.

Breeding birds

Breeding birds – Loss of habitat

237. The habitats located within the majority of array station sites were assessed as being of low potential to support ground nesting birds (e.g. heavily grazed and disturbed fields for agricultural). However, it was recorded at a small number of the array stations where the habitat is not heavily disturbed / managed (e.g. for livestock grazing etc.). Due to the small scale of works at each site and due to the position of the arrays adjacent to hedgerows it is considered that this habitat would be sub-optimal for ground nesting birds and therefore its loss would not be significant upon the local population.

Breeding birds – Direct killing / injury

238. It is possible that, in an unmitigated scenario, ground nesting birds utilising areas of suitable habitat identified at a small number of array station sites may be killed or injured during site clearance works required to install the array station sites. This is considered a potentially significant impact at the local level.

Breeding birds – Disturbance impacts

239. Suitable bird nesting habitat was identified adjacent to the majority of the array stations. This was largely in the form of intact hedgerows but also included broadleaved trees and scrub at a small number of stations. It is likely that such habitat supports relatively common bird species (e.g. chaffinch, wren, blackbird, robin, goldfinch), however records for notable species, including tree sparrow, linnet, yellowhammer and song thrush have also been identified within the search radius. Although suitable bird nesting habitat for these species will not be lost as a result of the construction of the array stations, it is possible that birds utilising areas of suitable habitat may be temporarily disturbed during construction, should proposed works be undertaken within the bird breeding season. It is also possible bird species utilising adjacent areas suitable for ground nesting birds (e.g. skylark and lapwing) may also be temporarily disturbed during construction.

240. Potential disturbance impacts on breeding bird species will be highly localised, very small scale (generating low noise levels; Chapter 16: Noise; Section 16.7.2), extremely temporary in nature (i.e. less than one week) and will only impact on a very small amount

[149] Given the temporary nature of the installation work (less than one week) and the low level of noise which will be generated, a standoff zone of at least 10m around a tree with bat roost potential is judged to be large enough to ensure no potential disturbance impacts on potential roost sites.

of suitable breeding bird habitat. Due to the combination of the above factors, most significantly the temporary nature of the construction works (i.e. less than one week), there is only limited potential that the proposed construction works, if undertaken during the bird breeding season, will adversely affect nesting birds with area of adjacent suitable habitat. This is considered to be a potentially significant impact on nesting birds at the local level.

Wintering birds

241. The assessment of impacts upon wintering birds during the construction of array sites is detailed above. In accordance with this assessment the loss of habitat is not considered significant at any of the sites due to the small foot print of the works but disturbance due to increased noise levels and movement could have an impact for the duration of works (2 days).

242. The assessment above concludes that at 15 sites there is a high risk of significant disturbance impacts on wintering bird species albeit for a short duration. In addition, taking a precautionary approach, significant impacts could occur through disturbance at the remaining 31 sites identified to be of moderate value albeit, that wintering birds were not recorded on site in 2014 and have not been recorded there historically. The precautionary approach has been taken as these species are highly mobile and will take advantage of new foraging resources as they occur.

Brown hare

Brown hare – Loss of habitat

243. The habitat located within the working footprint of the array stations is judged to be of low value with respect to brown hare. This is largely owing to the lack of vegetation cover identified and their small size (less than 20m^2). It is therefore judged that the total habitat located within the array station sites (less than ~0.18ha in total) does not offer a critical resource for local populations of brown hare. The loss of such habitat is therefore not considered a significant impact on brown hare at the local level.

Brown hare – Direct killing / injury

244. Owing to the localised, small scale and temporary nature of the proposed installation works the potential for brown hare being killed or harmed by machinery is considered to be highly unlikely. This is therefore not considered a significant impact on brown hare at the local level.

Brown hare – Disturbance impacts

245. Since West Lancashire is a known stronghold for brown hare, it is likely that the areas of arable habitat and intact hedgerows within the surrounding proximity to the proposed array stations support populations of brown hare. However given the small scale, localised and temporary nature of the proposed installation works, potential disturbance impacts on brown hare populations as a result of construction activities are not considered significant at the local level.

246. Potential construction impacts relating to fauna are summarised in Table 10.29.

Table 10.29: Construction impacts (of arrays) related to fauna.

Level	Potential Impacts without Mitigation
Local	Killing / injury of ground nesting birds during installation activities.

Level	Potential Impacts without Mitigation
	Disturbance to breeding birds during installation works through the bird breeding season. Disturbance to wintering birds during installation works over the winter period at a further 31 array sites which were identified to have winter bird potential but no evidence has been obtained to confirm this.

10.7.1.2 Operation

247. Once installed, the array sites will only visited once a week to check for a fault with the equipment and to replace the battery. The information that the monitoring equipment collects will be down loaded remotely. This approach has been taken to avoid impacts on sensitive receptors, particularly birds. Due to the small size of the array structures, there positioning adjacent to hedgerows, absence of noise emissions or artificial light it is considered that when in operation that these structures will not have a significant impact upon any sensitive ecological receptors including designated sites, bats, breeding or wintering birds or brown hare

10.7.2 Construction of Site and Access Road, without Mitigation

248. Construction methods are anticipated to involve site clearance, excavation, the creation of the Site compound, the creation of the access track, the installation of security fencing, the installation of the mains water connection and the introduction of plant species for landscaping (refer to Chapter 4 or Appendix A for red line boundary).

249. Therefore, the potential impacts upon ecological features of value to be assessed in this section include:

- Habitat loss and severance
- Disturbance through noise and light
- Indirect impacts through release of dust and sediment

250. Habitat loss and severance occur as a result of the construction phase of development. Therefore, these impacts will not be considered in relation to the operation phase of the development including drilling; hydraulic fracturing and initial flow testing.

Impacts on designations

251. The following sites have been designated for their value to support breeding or wintering bird species:

- Morecambe Bay SPA & Ramsar.
- Ribble and Alt Estuaries SPA & Ramsar.
- Marton Mere SSSI / LNR
- Lytham Moss BHS

252. Due to the distance of all four designated sites from the proposed development Site there will be no direct impacts upon these sensitive habitats. There is the potential that breeding or wintering birds could be impacted during the construction phase of the

development due to loss of foraging and nesting habitat and through disturbance caused by noise and light.

253. The breeding bird survey identified 21 bird species on Site of which only three species demonstrated behaviour which suggested that they might breed (inc. linnet). The breeding bird report concluded that there is limited evidence to suggest that the survey area and its immediate surroundings have any importance for breeding birds.

254. The winter bird survey identified 10 bird species which included oystercatcher, lapwing, whooper swan and pink footed goose. Pink footed goose were recorded within the local area, albeit not on the main Site, in high numbers (2500 birds) on one visit out of 25 due to shooting occurring in the local area causing the birds to take flight. It was also concluded based on the bird behaviour recorded that there was no evidence to suggest that the proposed development Site has a functional link with the Ribble and Alt Estuaries SPA/Ramsar site. Therefore, it was concluded there is little evidence to suggest that the survey area is of importance for wintering estuary birds. A shadow Habitat Regulation Assessment (HRA) has be3en drafted supporting this conclusion and to aid the local authority with their assessment (Appendix J: Part 9).

255. Therefore, the survey results indicate that the disturbance of the wintering and breeding birds on Site would not have a significant impact on the integrity of the four nature conservation designations, where a potential impact pathway had been identified. Consequently, no further assessment of impacts upon designated sites will be undertaken within this report.

256. Impacts upon breeding birds and wintering birds will be discussed further below.

Impacts on habitats

257. None of the habitats within the Site are of national or international value. In addition, none of the habitats identified within the Site are infrequent or rare for this locality and all are considered to be locally abundant within the wider agricultural landscape. However the sections of hedgerow located within the survey area may qualify as UK BAP habitat / Lancashire BAP habitat / S41 Habitat of Principal Importance and are considered to be of local value.

Habitats – Direct loss

258. Construction of the well pad and associated access will result in the loss of the following areas of habitat:

- Species-poor, intact hedgerows (Local value): Approximately ~30m of hedgerow will be removed and approximately 250m will be lowered along Preston New Road to create the necessary sight lines required at the junction of the new access road.
- *Improved grazed grassland (Site value): Loss of approximately ~2.6ha of improved grassland. This includes the stoned surface well pad from which the drilling, hydraulic fracturing and initial and extended flow testing activities will be undertaken (approximately ~1.5ha in area) , a new 200m access track (approximately ~ 0.12ha in area) and surface water collection ditches, landscaped bunds (from topsoil and subsoil excavated during construction of the well pad) and security fencing.*
- *Tall ruderal herbs (Site value): Loss of a small area (Approximately ~ 0.01 ha) of tall ruderal herbs located along the existing boundary features.*

259. Of this habitats it is only the loss of the hedgerow which could be a significant impact due to the low quality and abundance in the local environment of the other habitat types.

Habitats – Summary of impacts

260. A summary of construction related impacts is presented below Table 10.30: Construction (well pad and access) related impacts on habitats.

Table 10.30: Construction (well pad and access) related impacts on habitats.

Level	Potential Impacts without Mitigation
Local	Loss of ~ 10m of intact species-poor hedgerow.

Impacts on fauna

Bats

Bats – Loss of roost sites / foraging habitat

261. No roosts or potential roosting features were identified within the zone of influence for bats surrounding the Site (e.g. 100m radius); although it is likely that the wider landscape supports features suitable for roosting bats. Therefore no potential impacts (direct or indirect) are envisaged in relation to roosting bats. This includes all stages of the Project and as a consequence potential impacts on roosting bats have not been discussed further within this chapter.

262. The survey area supports features suitable for foraging and commuting bats. This specifically relates to the vegetated boundary features (e.g. intact hedgerows) and, to a lesser extent, areas of open grassland. Vegetation clearance includes removal of species poor grassland and approximately 30m of species poor hedgerow. These habitats are of value to foraging bats. The hedgerow is also of value to commuting bats. Their loss is considered to create a potential significant impact on foraging and commuting bats at the district level.

Bats – Disturbance impacts on foraging bats

263. Although the Site and surrounding area will be subject to increased noise levels and vehicle movements during construction, construction works will be undertaken within daylight hours and will have ceased by the time bats emerge each day. Therefore there are no disturbance impacts from increased construction noise and vehicle movements on foraging and commuting bats at the district level.

264. There will be no general site lighting present during the construction phase of works, but it will be necessary to light critical equipment. As the Site is currently subjected to low light levels (excluding New Preston Road) increased lighting at night could deter light intolerant bat species (e.g. *Myotis* and brown long eared bats) from foraging and commuting through the Site (Appendix J: Part 3) and may increase the chances of bats being preyed upon.[150] Artificial lighting can enhance foraging opportunities for light-tolerant bat species (e.g. common pipistrelle) (Appendix J: Part 3). While it is recognised that artificial lighting may offer some advantages to some species, potential impacts on light intolerant species (e.g. *Myotis* bat species which were recorded at the Site) as a

[150] BCT (2009) *'Bats and Lighting in the UK – Bats and the Built Environment Series'* (Bat Conservation Trust).

result of night lighting, albeit focused solely on equipment, are considered a potentially significant impact at the district level.

Amphibians

265. A small population of common toads and common frog were identified within Waterbody 1, 4, 6 and 8 located more than 65m south of the Site. Smooth newts were recorded in low numbers in Waterbody 4, 7, 8 and 9. No great crested newts were identified in any of the ponds surveyed therefore the following assessment of impacts will relate to common toad, frog and smooth newt only.

Amphibians - Loss / severance of habitat

266. The development will result in the loss of improved grassland and approximately310m of hedgerow. The improved grassland is considered to be sub-optimal habitat but the hedgerow could provide common amphibians with suitable foraging and hibernation habitat. It is not considered that the development will result in the severance of linkages as the improved grassland upon which the development is to be located would not have been an optimal route for migration due to the risk of predation. The loss of hedgerow will not represent significant severance as the access track will be infrequently trafficked. Therefore there are no significant impacts on local populations of amphibians as a result of the habitat to be lost or fragmentation as part of the proposed scheme at Preston New Road.

Amphibians - Disturbance impacts

267. It is possible that a small number of amphibians may be subject to minor disturbance impacts due to increased construction noise, traffic, dust deposition and general night lighting. There is very little published evidence on disturbance to amphibian species[151], although studies have indicated that light pollution has a positive effect on common toads by facilitating foraging.[152] The lack of published data may suggest that *'in general direct disturbance is not considered a major threat'*.[151] It is judged that potential disturbance impacts as a result of construction activities are considered to be minimal and are not considered a significant impact on the common amphibian population at the local level. This is largely due to the proximity of breeding habitat to the Site (more than 65m) and the dominance of low value habitat for amphibians within the zone of influence.

Wintering birds

Wintering birds – Loss of habitat

The surveys identified two oystercatchers in the field that the Site is to be constructed and a flock of pink footed geese were observed to land within the field that the gas pipeline will be constructed, when there was shooting within the local area. However, regular usage was not observed. However, 10 species of wintering birds were recorded in the local area including oystercatcher, lapwing, whooper swan and pink footed goose. It was considered that the habitat on Site could be used by these species for loafing and foraging. Therefore, the loss of 2.6ha of habitat could be important at a local level. The impact is not considered to be of higher value due to an absence of evidence indicating a linkage between the Site and the Ribble and Alt Estuary SPA.

151 Natural England (2007) *'Disturbance and protected species: understanding and applying the law in England and Wales - A view from Natural England and the Countryside Council for Wales ,*

152 Schaijk, M.E (2013) *'The influence of human disturbance on amphibians and small mammals'* Master thesis, Utrecht University.

Wintering birds – Disturbance impacts

The wintering birds during the survey demonstrated that they were disturbed by loud noises (shooting) and movement, suggesting that they would be disturbed by the noise generated by vehicles movements and machines operating on the Site to construct the well pad and access track. Therefore, at a local level disturbance could be significant to wintering birds.

Breeding birds

Breeding birds – Loss of habitat

268. Although the habitats located within the Site itself are assessed as being of low potential to support breeding birds (e.g. heavily grazed and disturbed fields by cattle during spring / summer), boundary features (e.g. intact hedgerows) were identified as being of moderate potential to support a range of nesting bird species. The small loss of hedgerows (30m) and tall ruderal herbs (0.01ha) during construction could impact upon the amount of available habitat located at the Site for nesting birds. This may have a significant impact on nesting birds, in an unmitigated scenario, at the local level.

Breeding birds - Disturbance impacts

269. Other adverse impacts include increased disturbance and resultant displacement impacts on breeding birds as a result of construction noise and traffic within areas of suitable habitat located the zone of influence surrounding the Site.

270. Ambient noise measurements collected at Plumpton Hall Farm (380m east of Site) and Staining Wood Cottages and Farm (270m south of Site) were between 55 and 62 dBL_{Aeq} (Chapter 16: Noise). The nearest ecological receptor will be a hedgerow, and it is known that noise levels of construction vehicles range from 64 (generator) to 90 (dump truck) dBL_{Aeq} at 10m from the noise source (Calculations provided by Arup Acoustics, March 2014). Although not directly comparable to construction activities, evidence when investigating road traffic noise disturbance impacts on breeding birds have indicated threshold values of 47 dBL_{Aeq} (taken as an average over a range of bird species), above which reduced densities of breeding birds were identified.[153] Taking into account that ambient noise levels at Preston New Road are greater than 47 dBL_{Aeq} it is considered that individuals maybe less sensitive to noise. However, construction noise levels will still be greater than ambient.

271. It should also be noted that noise levels will not always be consistent and will include 'impulsive' / sudden noise. This impact on animal populations has not been well researched (Wright et al., 2010)[154].

272. Five species of confirmed, probable or possible breeding birds were recorded within the vicinity of the proposed development Site which are notable; lapwing, skylark and linnet. These are either amber of red listed species and therefore have either been the subject of historical decline or are the subject of current decline. As an intensively grazed pasture by cattle the value of the proposed development Site to ground nesting birds such as skylark and lapwing is low, which is reflected in that these species were not recorded on Site but within the study area.

153 Reijnen, R., Foppen R., Meeuwsen, H (1996) 'The effects of traffic on the densities of breeding birds in Dutch agricultural grasslands' Biological Conservation 75, Issue 3 Pg 255-260.

154 Wright, M.D., Goodman, P., Cameron, T.C., (2010) 'Exploring behavioural response of shorebirds to impulsive noise' Wildfowl 60: 150-167.

273. Linnet and dunnock were recorded on Site, but in low numbers. Therefore, it is judged that the sections of hedgerow located within zone of influence do not support significantly important populations of linnet or dunnock (defined as 0.5% of the county's population and would equate to over 25 pairs of linnet).[155]

274. Therefore, disturbance impacts of suitable habitat located within the zone of influence is unlikely to significantly affect the conservation status of these four species in Lancashire. Although it is possible that noise disturbance impacts, in an unmitigated scenario, has the potential to adversely affect breeding birds at the local level. Therefore, disturbance impacts on breeding birds as a result of increased noise levels during construction activities within the bird breeding season are considered as potentially significant at the local level.

275. There is also potential for disturbance impacts on breeding birds, in an unmitigated scenario, as a result of increased visual disturbances (e.g. from site staff, machinery and construction activities and increased light levels) during construction. This has the potential of causing a significant impact on breeding birds at the local level.

Brown hare

Brown hare – Loss of habitat

276. It is unlikely that the habitat located within the Site boundary supports sheltering brown hare owing to the lack of vegetation cover. However the surrounding area of West Lancashire is a known stronghold for the species and a number brown hare sightings have been made within the zone of influence surrounding the Site. It is therefore judged that the loss of habitat within the Site compound and associated access, covering approximately 2.6ha in size, represents a reduction in the amount of available habitat for brown hare. This is considered to be a potentially significant impact on brown hare at the local level.

Brown hare – Direct killing / injury

277. In an unmitigated scenario, there is a small chance that brown hare will be killed or harmed by machinery during Site clearance works. This particularly relates to leverets that are left alone in the day and may be reluctant to move from their place of refuge. There is also the potential for hares to be killed or harmed by becoming trapped in any pits, pipings, chemical containers or wire mesh associated with Site activities. This is a potentially significant impact on brown hare at the local level.

Brown hare – Disturbance impacts

278. It is also possible that, in an unmitigated scenario, suitable habitat for brown hare located within the zone of influence will be disturbed during construction as a result of increased lighting, noise, vehicle movement and the presence of humans. This has the potential to adversely affect local populations of brown hare, especially breeding females should construction activities be undertaken within the breeding season for brown hare.[156] This is judged to be a potentially significant impact on brown hare at the local level.

279. Potential construction impacts relating to fauna are detailed in Table 10.31.

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[155] Lancashire County Council (2006) *'Revised Guideline for Selection of Biological Heritage Sites'.*

[156] Tapper, S., Hobson, D (2002) *'Conserving the Brown Hare'* Game Conservancy Trust, Fordingbridge.

Table 10.31: Construction impacts related to fauna or fragmentation of associated habitats.

Level	Potential Impacts without Mitigation
District	Loss of bat foraging habitat and impacts on connectivity. Disturbance caused by night lighting on foraging and commuting bats.
Local	Loss of habitat for wintering birds. Disturbance to wintering birds (noise and visual). Loss of habitat for breeding birds. Disturbance to breeding birds (noise and visual). Loss of habitat for brown hare. Killing / injury of brown hare during construction activities. Disturbance to habitat utilised by brown hare.

10.7.3 Operation: Drilling, Hydraulic Fracturing and Initial Flow Testing (excluding Extended Flow Testing), without Mitigation

280. The impacts of the operational phase of the development including drilling, hydraulic fracturing and initial flow testing are to be assessed together within this report for two reasons. Firstly, the impact pathways will be the same for all of the above activities; disturbance to ecological receptors from noise, movement and light, dust/sediment and heat (bats only during initial flow testing) secondly these operations could occur in isolation or in combination.

281. Lighting levels through all three operational activities will remain the same as the Site will be lit for security reasons rather than reflecting the operations which takes place on Site. Lighting will be of a level that will enable works to occur 24 hours a day.

282. Visual disturbance through the day will occur as the result of vehicle movements and vehicles operating on Site. The number of vehicle movements in a day will vary throughout the duration of the project depending on the combination of operations that will occur on Site. Peak periods of activity will occur when equipment is being brought on to Site or during hydraulic fracturing when water is tankered on and off Site.

283. Noise levels at the closest ecological receptor (hedgerow) will vary throughout the development. The predicted noise levels are as follows(Calculations provided by Arup Acoustics, March 2014):

- Drilling – 53 – 59 dBLAeq
- Hydraulic fracturing – 62 – 80 dBLAeq
- Initial flow testing – 74 dBLAeq, which is based on a 29 tonne lorry and crane delivering piping decreasing to 64 dBLAeq (based on a generator being the noisiest equipment on Site), predicted noise levels for a flare stack are 20 dBLAeq.

284. If these operations were to occur in combination noise levels would increase logarithmically. Therefore, the increase in noise would not be predicted to be significantly different (Cumulative Effects - Arup Acoustics, March 2014).

285. In relation to disturbance of fauna it is also important to consider that noise levels will not be consistent when the Site is operating and that sudden loud noises will impact upon species even if they are habituated to a noise.

286. Dust and sediment will be produced during works as a result of the movement of vehicles within the compound. Particulate matter which is deposited within the well pad will remain contained as the Site is bunded within its own drainage system.

287. Heat will only be emitted while the flare stacks are in operation. To reduce impacts two small flare stacks are to be used rather than one large one. The flare itself is also contained inside a structure so that the flare is not visible externally. Therefore, visually the flare will have no impact upon local ecological receptors (See Chapter 14: Landscape and Visual Amenity; Section 14.11). However, the flare stacks will emit heat which could impact upon bats and it therefore assessed below.

288. This assessment of impacts does not include habitat loss and severance as this has been assessed under impacts of construction (Section 10.7.2).

289. Vibration impacts are *'not considered to be perceptible as a result of the project'*, and have consequently been scoped out of the EIA at the initial scoping stage as not requiring further assessment(Arup 2013[157] and Chapter 16: Noise; Section 16.1).

10.7.3.1 Impacts on habitats

290. There is no potential for increased surface water runoff to adjacent waterbodies, field drains and adjacent areas of agricultural farmland during operational activities in a storm event since all water will be collected, retained on-Site and tankered off Site during operational activities (See Chapter 19: Water Resources and Flood Risk; Section 19.7.3). Therefore, there are no significant impacts associated with increased runoff to adjacent field drains, agricultural farmland and waterbodies during these activities, at the local level.

291. In summary, no significant impacts on habitats are envisaged during operational activities.

10.7.3.2 Impacts on fauna

Bats

292. Potential disturbance impacts on bats as a result of increased noise and traffic during Site mobilisation are not considered significant since the majority of the mobilisation works will be undertaken during daylight hours and will have ceased by the time bats emerge from roost sites. However, drilling, hydraulic fracturing and initial flow testing, when in operation, will be undertaken 24 hours a day. Predicted noise level during these activities along the hedgerows that bats are known to forage will range from 53 - 80dBL_{Aeq} (Provided by Arup Acoustics, March 2014), with hydraulic fracturing being the loudest activity. There are limited studies which have been undertaken to understand the degree to which increased background noise levels influence bat foraging behaviour (Schaub *et*

[157] Arup (2013) *'Temporary shale gas exploration at Preston New Road, Lancashire – Scoping Report'*.

al., 2008[158]). However, studies undertaken to date indicate that foraging areas very close to highways or intense broadband noise sources degrade the suitability of foraging areas for `passive listening' bats.[158]

293. It should also be noted that potential disturbance impacts on foraging bats will only occur should drilling activities occur within the active bat season (April to October, weather dependant). Guidance provided by Natural England relating to disturbance on bat species has assessed the relative impact of disturbance on pipistrelle bat species (the bats species predominately recorded at the Site) in relation to their conservation status as being low.[159]

294. While it is recognised that potential adverse impacts on foraging bat species located at the Site as a result of 24 hour works are likely to be minor, as a precautionary measure, and to avoid the presence of doubt, potential disturbance impacts on foraging and commuting bats as a result of increased noise levels during the active bat season have been considered as potentially significant at the district level.

295. General site lighting will be required for the length of the operational activities. As stated above in relation to construction impacts (Section 10.7.2), increased levels of lighting at night could adversely impact foraging and commuting bats. This is considered to be a potentially significant impact on foraging and commuting bats at the district level.

296. Gas will be burned during initial flow testing via an on-site enclosed flare stack. The operation of a flare may adversely affect bats by killing / injuring bats and by creating a heat source (approximately 800-1000°C within the operational flare stack) with the potential to attract insects and subsequently draw in bats. The killing and injuring of bats is however considered to be unlikely as a result of the design of the flare chimney which fully encloses the flare within metal casing. However, potential remains for bats to be drawn to an increased number of insects attracted to the heat source created by the operational flare. This is considered a significant impact on bats at the district level.

297. The flare involves an enclosed design intended to reduce the air quality impacts from this operation (See Chapter 6: Air Quality; Section 6.7.5). Consequently no potential impacts on foraging bats due to emissions from the operational flare stack are therefore envisaged at the district level.

Wintering and Breeding birds

298. Wintering and breeding bird species utilising areas of suitable habitat immediately adjacent to the Site during operational activities may be disturbed by elevated noise levels, increased traffic and increased visual disturbances.

299. Predicted noise level during operational activities at the adjacent boundary features will range from 53 - 80dBL_{Aeq} (Provided by Arup Acoustics, March 2014), with hydraulic fracturing being the loudest activity. It is calculated that noise created by hydraulic fracturing will have dissipated to current ambient noise levels outside an approximate 600m radius surrounding the Site (Calculations provided by Arup Acoustics, March 2014).

[158] Schaub, A., Ostwald, J., Siemers, B.M., (2008) 'Foraging Bats Avoid Noise' *The Journal of Experimental Biology* 211, 3174-3180.
[159] Natural England (2007) *'Disturbance and protected species: understanding and applying the law in England and Wales - A view from Natural England and the Countryside Council for Wales Section 1: The disturbance offence'*.

300. Ambient noise levels recorded at Plumpton Hall Farm (380m east of Site) and Staining Wood Cottages and Farm (270m south of Site) were between 55 and 62 dBLAeq (Chapter 16: Noise). Therefore, locally birds could be habituated to elevated noise levels, but research has shown that at noise levels above 47dBA densities of breeding birds are found to reduce when investigating the impact on road noise adjacent to agricultural farmland (See Section 10.7.2).[160]

301. Therefore, it is possible that breeding birds utilising suitable habitat located within the zone of influence surrounding the Site will be disturbed by increased noise levels during operation activities undertaken.

302. It was also observed during the winter bird survey that species such as pink footed geese and lapwing took flight frequently when a shoot was underway due to sudden noises. This could also be the case in relation to sudden noise emitted from an operational Site. Although the effects of 'impulsive' / sudden noise on animal populations are not well researched (Wright et al., 2010)[161]. It is also known that pink foot geese tend to avoid features such as busy roads so increased activity and movements on Site are likely to displace wintering bird species away from the Site.

303. Potential impacts associated with 'impulsive' / sudden noise levels on wintering and breeding birds utilising areas of suitable habitat within the zone of influence may be potentially significant, at the local level, should operational activities occur during the breeding season (March to August) or wintering period (October – March).

304. As stated above in relation to construction impacts (Section 10.7.2), there is potential for disturbance impacts on wintering and breeding birds utilising suitable habitat within the zone of influence as a result of visual disturbances (e.g. from site staff, machinery, construction activities). This is considered to be a potentially significant impact on breeding and wintering birds at the local level.

305. Due to the design of the flare chimney and the enclosed nature of the exposed flare within the chimney, it is considered highly unlikely that any bird species will be killed or harmed while the flare stack is in operation. Moreover, the flare stack will not be located in close proximity to habitat deemed to be of high potential for nesting birds (i.e. the flare stack will be sited away from intact hedgerows, field drains and waterbodies). Therefore, no significant impacts on breeding birds are envisaged as a result of the operational flare stack during initial flow testing activities.

Amphibians

306. Similarly to construction related disturbance impacts, it is possible that a small number of amphibians may be subject to minor disturbance impacts due to increased construction noise, traffic, dust deposition and general night lighting. However, as concluded in relation to construction impacts (Section 10.7.2), it is judged that potential disturbance impacts as a result of operational activities are considered to be minimal and are not a significant impact on amphibian populations at the local level. This is largely due to the proximity of breeding habitat to the Site (over 65m) and the dominance of low value habitat for amphibians within the zone of influence.

Brown hare

Brown hare – Direct killing / injury

160 Reijnen, R., Foppen R., Meeuwsen, H (1996) 'The effects of traffic on the density of breeding birds in Dutch agricultural grasslands' Biological Conservation 75, Issue 3 Pg 255-260.

161 Wright, M.D., Goodman, P., Cameron, T.C., (2010) 'Exploring behavioural response of shorebirds to impulsive noise' Wildfowl 60: 150-167.

307. There are no potential impacts associated with brown hare being killed or harmed by machinery or vehicle movements during operational activities within the well compound. This is largely as a result of the impenetrable nature of the site security fencing around the Site which will prohibit mammals, including brown hare, from entering inside the Site compound. A low risk exists that a small number of animals could be impacted by vehicle movements along the access track. However, due to the short length of the access track, noise emitted by vehicles and the slow speed of vehicles on the access track impacts are considered unlikely. Consequently, potential impacts relating to direct killing / injury of brown hare associated with these activities is considered to be negligible and not significant at the local level and has not been considered further within the chapter.

Brown hare – Disturbance impacts

308. It is possible that, in an unmitigated scenario, suitable habitat for brown hare located within the zone of influence will be disturbed during operational activities as a result of increased lighting, noise, vehicle movement and the presence of humans. As stated above in relation to construction activities (Section 10.7.2), this has the potential to adversely affect local populations of brown hare and is judged to be a potentially significant impact on brown hare at the local level.

309. Potential construction impacts relating to fauna are detailed in Table 10.32.

Table 10.32: Impacts related to operational activities on fauna.

Level	Potential Impacts without Mitigation
District	Disturbance caused by night lighting and 24 hour works on foraging and commuting bats. In addition, disturbance caused by heat outputs from the operational stack.
Local	Disturbance (noise and visual) on wintering birds Disturbance (noise and visual) on breeding birds. Disturbance to habitat utilised by brown hare.

10.7.4 Extended Flow Testing, without Mitigation

310. Extended flow testing involves many of the same operations that are required during initial flow testing. However, the Site will be connected to grid gas through the construction of pipeline (approximately 1km in length) between the well pad and the existing gas main which is located to the west of the well pad. At the point of connection a box measuring 8m x 8m will need to be constructed. Refer to Chapter 4 or Appendix A for red line boundary.

311. The construction of the pipeline will involve a short term loss of habitat including improved grassland and the permanent loss of approximately 10m of species poor hedgerow (lowering of 100m) to provide a new access point to the field at the connection point to the gas main. The pipeline is to be sited so that it, and its construction area, does not compromise the health of any trees or hedgerow shrubs by affected their root systems.

312. Therefore, short term potential impacts on ecological receptors through the construction of the pipeline could include:

- Permanent loss of hedgerow
- Short term habitat loss of improved grassland.

- Short term severance of connective linkages.
- Disturbance due to noise, visual and dust/sediment. The construction corridor for the pipeline will not be lit at night as there will be no night working.

313. The impacts of construction discussed within this section of the report relate solely to the construction of the pipeline. Impacts of constructing the well pad, including habitat loss and severance are discussed in section 10.7.2 and will not be repeated in this section.

314. The impacts of the operational phase will be the same as those discussed at the start of section 10.7.3. Therefore, ecological receptors could be disturbed due to:

- Lighting – the Site will have 24 general site lighting.
- Noise – personnel, vehicles and machinery operating on Site. The maximum noise level as previously indicated will be from generators on Site at 64 dBLAeq (based on a generator being the noisiest equipment on Site), predicted noise levels for the flare stack are 20 dBLAeq. The potential also remains for sudden loud noises.
- Dust and sediment - will be produced during works as a result of the movement of vehicles within the compound. Particulate matter which is deposited within the well pad will remain contained as the Site is bunded within its own drainage system.
- Heat – small flare stack will be fitted as part of the installation of the extended flow testing in order to enable safe operation of the facility in accordance with standard procedures. This flare would only be used in emergency conditions in order to avoid dangerous pressure build up. The gas well can be shut off to control gas flow should this be required; therefore the flare will be used very infrequently during emergency conditions only. Consequently potential adverse impacts as a result of the operational flare during the extended flow testing on Site fauna are considered to be negligible and not significant and have not been considered further in relation to extended flow testing.

315. As the potential disturbance pathways are the same as those discussed in section 10.7.3 and the sensitive ecological receptors are the same, the assessment of impacts completed within 10.7.3 is considered valid in relation to the operational phase of extended flow testing. Therefore, potentially significant effects in an unmitigated scenario for the process of extended flow testing are presented below in Table 10.33

Table 10.33 Impacts related to operational activities of extended flow testing on fauna.

Level	Potential Impacts without Mitigation
District	Disturbance caused by night lighting and 24 hour drilling on foraging and commuting bats.
Local	Disturbance (noise and visual) on wintering birds Disturbance (noise and visual) on breeding birds. Disturbance to habitat utilised by brown hare.

Construction

Habitats – Direct habitat loss

316. None of the habitats that will be directly impacted during the construction of the gas pipeline and its associated connection box are of national or international value. In addition, none of the habitats identified within the working area are infrequent or rare for this locality and all are considered to be locally abundant within the wider agricultural

landscape. However, the species poor sections of hedgerow to be directly impacted by the proposed works may qualify as UK BAP habitat/Lancashire BAP habitat /S41 Habitat of Principal Importance and are considered to be of local value.

- *Species-poor, intact hedgerows (Local value): Approximately 10m, to create a new point of access to the connection building from New Preston Road. No trees will be removed for these works.*

317. Construction related impacts on habitats are detailed in Table 10.34.. Impacts relating to fauna and their habitats are detailed in Table 10.35.

Table 10.34: Extended flow testing (construction) related impacts on habitats.

Level	Potential Impacts without Mitigation
Local	Loss of approx. 10m of species poor hedgerow.

10.7.4.1 Impacts on fauna

Bats

Bats – Disturbance impacts

318. Excavation of the connection pipeline will be completed within day light hours and will have ceased by the time bats emerge from roosts. Therefore no potential impacts as a result of increased noise and construction traffic on foraging and commuting bats are envisaged at the district level.

319. Species-poor hedgerow will need to be removed to create a new access point where the pipeline from the well pad joins the main gas pipeline. Semi mature trees (including sycamore) are present within the vicinity of the proposed access gate but they do not have cavities or features within which bats could roost. Therefore there will be no significant impacts upon roosting bats.

Wintering birds

320. Impacts upon wintering birds could only occur if construction works take place during the winter bird season which extends from October to March.

Wintering birds – Loss of habitat

321. The pipeline is to be constructed for approximately 800m along the hedgerow which lines Preston New Road before it diverts up a field boundary fence/interrupted hedgerow to the Site compound. The value of this habitat to foraging and loafing winter birds is low as these species will typically avoid busy roads and boundary features. Therefore, the direct loss of habitat is not considered significant to this group of species.

Wintering birds – Disturbance impacts

322. Construction works during the wintering bird period could accentuate the disturbance buffer around Preston New Road. Ambient noise levels recorded at Plumpton Hall Farm (380m east of Site) and Staining Wood Cottages and Farm (270m south of Site) were between 55 and 62 dBLAeq (Chapter 16: Noise), which indicate that noise levels locally are elevated by the presence of Preston New Road. There will be periods where vehicles/machines could be operating in the construction area resulting in higher noise emission such as the running of a generator produces 64 dBLAeq at 10m. In addition, the works could lead to the production of sudden noises. As discussed previously, evidence

collected during the winter bird survey indicated that pink footed geese and lapwing took flight changing fields rapidly while a shoot was underway. Indicating that they are disturbed by sudden noises.

323. It is therefore considered that the impact upon wintering birds without mitigation could be significant at a local level. This impact is not considered to be of an international level as it was concluded during the wintering bird survey that there was no evidence that the birds present on Site were functionally linked to the Ribble and Alt Estuaries SPA.

Breeding birds

Breeding birds – Loss / severance of habitat

324. The habitat being temporarily lost for the installation of the pipeline connection (i.e. a small area of improved grazed grassland) was assessed as providing low potential for ground nesting birds in 2014 as the fields through spring were managed for silage production (low grass) and then heavily grazed by sheep and cattle. This limits the value of this habitat. In addition, the pipeline is proposed to follow field boundaries, typically ground nesting birds nest away from field boundaries to enable surveillance of predators.

325. To enable the construction of an access point it will be necessary to remove 10m of hedgerow. In an unmitigated scenario this may have a significant impact at a local level.

Breeding birds – Disturbance impacts

326. The breeding bird survey identified that linnet, chaffinch and great tit had been recorded within the hedgerow which lines Preston New Road. Behaviour indicated that of these linnet (UK BAP species) and chaffinch demonstrated behaviour which suggested that they might breed. The breeding bird survey report indicated that the abundance of birds was lower than expected when compared to other sites within the local area. This is potentially due to the presence of New Preston Road. It could also be the case that birds present within the hedgerow along New Preston Road would be habituated to higher levels of noise.

327. It is considered that an increase in sudden noises as a result of construction and the movement of vehicles could deter birds from nesting within the hedgerow, if works took place during the breeding period. Therefore, it is considered that at a local level that works could significantly impact upon breeding birds.

Amphibians

Amphibians – Loss / severance of habitat

328. There is no direct loss of suitable habitat for breeding amphibians during construction of the pipeline connection. The habitat located within the proposed pipeline connection is considered to be of low value, excluding hedgerows, with respect to amphibians owing to the lack of vegetation cover and the amount of disturbance it receives by cattle grazing / land management practices. There is also no evidence to suggest that the proposed pipeline connection will cause any fragmentation to any known or potential migration corridors or routes for common amphibians. Therefore there are no significant impacts on local populations as a result of the permenant/temporary habitat loss as part of pipeline installation at Preston New Road.

Amphibians – Disturbance impacts

329. It is possible that a small number of amphibians may be subject to minor disturbance impacts due to increased construction noise, traffic, dust deposition and general night

lighting. Similarly to construction related impacts of the Site (Section 10.7.2), it is judged that potential disturbance impacts as a result of construction activities are considered to be minimal and are not considered a significant impact on the amphibian populations at the local level. This is largely due to the proximity of breeding habitat the proposed pipeline connection, the temporary nature of the works and the dominance of low value habitat for amphibians within the zone of influence.

Brown hare

Brown hare – Loss of habitat

330. As stated above in relation to construction impacts (Section 10.7.2), West Lancashire is a known stronghold for brown hare, a number of brown hare observation have been made within the zone of influence and suitable habitat for brown hare exists within the surrounding areas of arable fields and intact hedgerow. However the value of the Site to brown hare will change through the season as the land is managed for a silage cut and then heavily grazed, making the habitat suboptimal for this species. Furthermore, the habitat will be fully replaced on completion of the pipeline connection. The temporary loss of habitat considered to be of low value for brown hare is therefore considered to be negligible and not a significant impact at the local level.

Brown hare – Direct killing / injury

331. In an unmitigated scenario, there is a small chance that brown hare will be killed or harmed by machinery during excavation works to install the pipeline connection. There is also potential for hares to be killed or harmed by becoming trapped in any pits, pipings, chemical containers or wire mesh associated with Site activities to install the pipeline connection. This is a potentially significant impact on brown hare at the local level.

Brown hare – Disturbance impacts

332. It is also possible that suitable habitat for brown hare located within the zone of influence will be disturbed during installation of the pipeline connection as a result of increased lighting, noise, vehicle movement and the presence of humans. This has the potential to adversely affect local populations of brown hare and is judged to be a potentially significant impact on brown hare at the local level.

333. Potential construction impacts during the extended flow tests relating to fauna are detailed in Table 10.35.

Table 10.35: Impacts related to construction during the extended flow tests on fauna

Level	Potential Impacts without Mitigation
Local	Disturbance impacts (noise and visual) on wintering birds. Disturbance impacts (noise and visual) birds. Loss of nesting bird habitat (hedgerow) Potential killing / injury to brown hare during excavation of the pipeline connection. Disturbance to habitats utilised by brown hare.

10.7.5 Decommissioning and Restoration, without Mitigation

334. On completion of the operation phase of the proposed development the Site and buried and surface arrays will be fully restored to their original condition (i.e. areas of agricultural land). It is not anticipated that the pipeline would be removed.

Decommissioning and restoration of the Site will be relatively short term and temporary in nature.

335. This assessment does not include an assessment of the positive impacts that would result on conclusion of the re-instatement of habitats. This assessment relates to impacts of the restoration works which will occur as a result of operations to return the Site back to its original condition.

10.7.5.1 Impact on habitats

Habitats – Loss of habitat

336. Depending on the timescales of the project when in operation, it is possible that features within the Site may develop and mature (e.g. surface water drainage ditches, vegetated earth bunds, landscaped planting). The loss of such habitat therefore has the potential to be a significant impact during the decommissioning and restoration phase.

337. Significant impacts on habitats during decommissioning are detailed in Table 10.36. Impacts relating to fauna and their habitats are detailed in Table 10.37.

Table 10.36: Decommissioning related impacts on habitats.

Level	Potential Impacts without Mitigation
Local	Loss of habitat within the Site boundary.

10.7.5.2 Impacts on fauna

Bats

338. All decommissioning and restoration works will be undertaken within daylight hours and will cease by the time bats emerge each day. Therefore there are no disturbance impacts from increased noise and vehicle movements on foraging and commuting bats.

339. General night lighting will be removed and will be no longer required at the Site. Once lighting has been removed from the operational Site there will be no further adverse impacts on foraging and commuting bats.

Wintering birds

340. If decommissioning were to occur during the wintering bird period then species such as pink footed geese, oystercatcher and lapwing could be displaced by the increased noise levels (including sudden noises) and personnel and vehicle movements which will be required to decommission the Site. Activities on Site will be similar to those experienced during the construction phase of the well pad, section 10.7.2. This assessment identified that at a local level disturbance could be significant to wintering birds as this could lead to their displacement from fields within the local area for the duration of decommissioning works.

Breeding birds

341. If decommissioning were to occur during the breeding bird period then species such as linnet could be displaced by the increased noise levels (including sudden noises) and personnel and vehicle movements which will be required to decommission the Site. Activities on Site will be similar to those experienced during the construction phase of the well pad, section 10.7.2. This assessment identified that at a local level disturbance could

be significant to a small number of breeding birds as this could lead to their displacement from hedgerows within the local area for the duration of decommissioning works.

Amphibians

342. It is possible that a small number of amphibians may be subject to minor disturbance impacts due to increased construction noise, traffic and dust deposition. However, as concluded in relation to construction and operation phases of the development (Section 10.7.2 and 10.7.3), it is judged that potential disturbance impacts as a result of decommissioning and restoration activities are considered to be minimal and are not a significant impact on amphibian populations at the local level.

Brown hare

Brown hare – Direct killing / injury

343. As described above in relation to construction related impacts (Section 10.7.2), there is a small chance that brown hare will be killed or harmed by machinery and vehicle movements required during the decommissioning and restoration works. There is also the potential for hares to be killed or harmed by becoming trapped in any pits, pipings, chemical containers or wire mesh associated with Site activities. This is a potentially significant impact on brown hare at the local level.

Brown hare – Disturbance impacts

344. It is also possible that, in an unmitigated scenario, suitable habitat for brown hare located within the zone of influence will be disturbed during decommissioning and restoration works as a result of increased noise, vehicle movement and the presence of humans. This is judged to be a potentially significant impact on brown hare at the local level.

345. Potential impacts relating to fauna as a result of decommissioning and restoration activities are detailed in Table 10.37.

Table 10.37: Impacts related to fauna or fragmentation of associated habitats during decommissioning and restoration activities.

Level	Potential Impacts without Mitigation
Local	Disturbance to wintering birds (noise and visual). Disturbance to breeding birds (noise and visual). Killing / injury of brown hare during decommissioning and restoration activities. Disturbance to habitat utilised by brown hare.

10.8 Cumulative and Interactive Effects

346. Cumulative impacts are generally recognised as impacts of the proposed development that would not have a significant effect on their own but may be considered to have a significant effect or a greater significance of effect in combination with other developments.

347. In Appendix T of the Environment Statement is a list of the developments registered with the Council at the time of writing. The majority of these developments are small scale developments associated with existing structures, for example house extensions. Due to the small scale of these works within a parcel of land which has already been modified and is frequently disturb they are not considered further in this section of the report.

348. The list of development in Appendix T does include the following developments which will be considered in combination with the development at New Preston Road:

- Shale Gas Exploration site at Roseacre Wood – located approximately 6.5km north-east of Preston New Road. This development is exactly the same as the works proposed at Preston New Road. The developments could occur simultaneously excluding the hydraulic fracturing as these works are restricted by the presence of only one rig which can complete these works;
- Whyndyke Farm – located 1.5km north- west of Preston New Road. This is a mixed use development which includes 1500 dwellings, new primary school, local neighbourhood centres and 20ha of employment use. The site totals 90.86ha and will occur on land which is currently either grazed or under arable production. The site is bound by the M55 to the south, Preston New Road to the west and Marton Mere SSSI, agricultural land and existing development to the north;
- Upgrade of road close to/adjoining the B5410 – located 2km to the east of Preston New Road. The purpose of this road is too improve access to the local area including the airport. The land use is similar to that described above. Pasture or arable land, but more so than at Roseacre Wood, Preston New Road and Whyndyke Farm, the boundaries are demarked by ditches, hedgerows are less frequent although present; and
- Queensway - is located 3.4km to the south-east of New Preston Road. This is a residential development with associated services. Land use is typically pasture and arable and the fields are defined by a network of drains and hedgerows.

349. The interactive effects on ecological receptors of conservation value to be assessed in this section of the report include:

- Habitat loss; and
- Disturbance through increased noise and lighting.

350. This assessment of cumulative impacts is undertaken without any mitigation of impacts at either Preston New Road or any of the other developments which are the focus of this assessment.

In Combination effects of Proposed Developments

351. The impact assessment undertaken in Section 10.7 identified the following potentially significant impacts during all phases of the development.

Table 10.38 Significant Impacts of Preston New Road Development Site from Construction to Decommissioning.

Level	Potential Impacts without Mitigation
Local	Disturbance to SPA qualifying wintering bird species if works occurred from October – March, due to elevated noise levels and through visual disturbance. Loss of foraging habitat for wintering birds Loss of 40m of species poor hedgerow Loss of foraging habitat and connectivity for bats. Loss of habitat for breeding birds Loss of habitat for brown hare Disturbance caused by night lighting and 24 hour works on foraging and commuting bats. Noise and visual disturbance to breeding birds. Noise and visual disturbance to brown hare.

Level	Potential Impacts without Mitigation
	Killing and injuring of brown hare during construction. Killing and injuring of ground nesting birds during installation.

Table 10.39 Significant Impacts of the Array Sites from Construction to Decommissioning

Level	Potential Impacts without Mitigation
District	Potentially significant impact upon the four designated sites which have been designated for wintering and breeding birds during installation works over the winter period at 15 of the array sites, including those adjacent to Lytham Moss BHS.
Local	Killing / injury of ground nesting birds during installation activities. Disturbance to breeding birds during installation works through the bird breeding season. Disturbance to wintering birds during installation works over the winter period at a further 31 array sites which were identified to have winter bird potential but no evidence has been obtained to confirm this.

352. Taking account of the distance of the four proposed developments, including Roseacre Wood, Whyndyke Farm, Queensway and the road improvement works, from Preston New Road and the presence of major roads including the M55 and Preston New Road it is considered that the populations of brown hare, bats and breeding birds at Preston New Road will be isolated from populations of these species or species groups of these species or species groups at the development sites listed above. Therefore, at a local level it is considered that these additional developments will not have a cumulative impacts on the populations of brown hare, bats and breeding birds.

353. However, the SPA qualifying wintering birds are mobile moving between the SPA's along the west coast of Britain and foraging on adjacent farmland. Therefore, it is considered that cumulative development within the region could lead to significant impacts, in an unmitigated scenario, upon foraging and loafing wintering birds and subsequently on the SPA's due to loss of habitat and also through disturbance of wintering birds while outside of the SPA. This impact is considered to be of an international level as some of the developments are likely to be functionally linked to an SPA (Queensway – Ribble and Alt Estuary SPA), albeit that survey evidence for Preston New Road and Roseacre Wood suggest that there is no functional link to any of the SPA's. Further assessment of this conclusion is provided within the shadow Habitats Regulation Assessment (HRA) in Appendix J: Part 9 of this report.

Table 10.40 Significant Effects of Cumulative Development without Mitigation.

Level	Potential Impacts without Mitigation
International	Disturbance to SPA qualifying wintering bird species if works occurred from October – March, due to elevated noise levels and through visual disturbance. Loss of foraging habitat for wintering birds.

10.9 Mitigation Measures

354. A summary table of potential impacts on habitat and fauna, in an unmitigated scenario, associated with each phase of the development is provided in Table 10.41.

Table 10.41: Summary of potential impacts on habitat and fauna.

Phase of development	Level	Potential Impacts without Mitigation
Construction of Site, Access	Local	Loss of 40m of intact species-poor hedgerow.

Phase of development	Level	Potential Impacts without Mitigation
and Gas Pipeline		Loss of habitat for nesting birds. Disturbance to breeding birds (noise and visual). Loss of habitat for wintering birds Disturbance to wintering birds Loss of habitat for brown hare. Killing / injury of brown hare during construction activities. Disturbance to habitat utilised by brown hare.
	District	Loss of bat foraging habitat and impacts on connectivity. Disturbance caused by night lighting on foraging and commuting bats.
Drilling / Hydraulic Fracturing / Initial and Extended Flow Testing /	Local	Disturbance (noise and visual) on breeding birds. Disturbance (noise and visual) on wintering birds. Disturbance to habitat utilised by brown hare.
	District	Disturbance caused by night lighting and 24 hour drilling on foraging and commuting bats. Heat outputs from the two operational flare stack, only during initial flow.
Decommissioning and Restoration	Local	Loss of habitat within Site boundary. Disturbance to breeding birds (noise and visual). Disturbance to wintering birds (noise and visual). Killing / injury of brown hare during decommissioning and restoration activities. Disturbance to habitat utilised by brown hare.
Installation of Surface and Buried Arrays – Construction	District	Potentially significant impact upon the four designated sites which have been designated for wintering and breeding birds during installation works over the winter period at 15 of the array sites, including those adjacent to Lytham Moss BHS.
	Local	Killing / injury of ground nesting birds during installation activities. Disturbance to breeding birds for installation works during the bird breeding season. Disturbance to wintering birds for installation works over the winter period.
Installation of Surface and Buried Arrays – Operation	N/A	

10.9.1 Biodiversity Mitigation Strategy

355. An essential part of the mitigation will be the preparation of an over-arching Biodiversity Mitigation Strategy (BMS) which will encompass both the construction and operational activities associated with each phase of the development (See Section 10.9.1 – 10.9.6 below). The BMS will provide details of the generic mitigation measures included within the Environmental Operating Standards (EOS), the working Method Statements, monitoring programmes and details of habitat enhancement and creation measures and associated management plans.

356. The BMS will be approved by the Local Planning Authority (LPA) and will be implemented and overseen by an appointed Ecological Clerk of Works who will

undertake routine compliance checks to ensure all measures are being undertaken to an appropriate standard. Should any adverse impacts on sensitive ecological receptors be identified following the compliance checks and monitoring programmes, then additional measures will be put in place, as recommended by the appointed Ecological Clerk of Works, to minimise any identified adverse impacts identified.

357. Key generic measures included within the EOS will comprise best practise working methods and will include:

- Ecological pre-start checks prior to construction for protected / notable species (e.g. badgers, brown hare).
- Programming of site / vegetation clearance to avoid interference with bird nesting habitat between March and August.
- Ecological pre-start checks prior to each new phase of the Project (e.g. drilling, hydraulic fracturing, initial flow testing, extended flow testing and decommissioning).
- Provision of tool box talks and training to all site personnel prior to construction and each phase of the Project (e.g. drilling, hydraulic fracturing, initial flow testing, extended flow testing and decommissioning).
- Regular compliance checks to be undertaken by the appointed Ecological Clerk of Works.
- Yearly reassessment of trees located within the zone of influence for bats to determine the presence of new features deemed to provide suitable bat roosting opportunities.
- Use of buffer zones where the works and access routes are in close proximity to sensitive habitats.
- Application of the site specific mitigation measures outlined within the IAQM mitigation matrix to reduce dust emitting activities (See Chapter 6: Air Quality; Section 6.9.1).
- Use of road sweeping during construction and subsequent operational activities in accordance with PPG6[162] to limit sediment polluted water affecting adjacent agricultural farmland, field drains and waterbodies (See Chapter 19: Water Resources and Flood Risk; Section 19.9.1).
- Procedures for a call out service for the appointed Ecological Clerk of Works will be put in place for the duration of the construction works and subsequent operational phases.

358. Specific mitigation measures relating to key habitats and species, which will be undertaken in addition to the above measures, during each phase of the Project are provided in further detail in Sections 10.9.1 – 10.9.6 below.

[162] Environment Agency (2010) *'Working at construction and demolition sites: PPG6 Pollution Prevention Guidelines'* 2nd edition 2012 Environment Agency: Horizon House.

10.9.2 Mitigation Measures for Installation of Surface and Buried Arrays

10.9.2.1 Construction

359. A Method Statement will be prepared detailing best practices working methods and mitigation measures required in relation to the installation of the array stations. This Method Statement will be prepared and overseen by the appointed Ecological Clerk of Works in agreement with the Local Planning Authority. The Method Statement will include (Specific mitigation measures relating to key species are provided in further details below):

- No work will be undertaken within at least 10m of the canopy of a tree identified to contain a potential bat roosting feature to avoid any potential adverse impacts on bats. This will be demarcated by temporary fencing on site prior to any works taking place to prevent damage or accidental encroachment into this standoff zone.
- No work will be undertaken within 6m of a watercourse to avoid any potential adverse impacts on water voles. This will be demarcated by temporary fencing to prevent damage or accidental encroachment into this standoff zone.
- As an additional precautionary measure, for array stations located within unsuitable terrestrial habitat for amphibians within 50m to a waterbody, or where sites are directly connected to waterbodies by suitable terrestrial habitat, reasonable avoidance measures will be employed. This will mean that during the newt hibernation period (October – March) the working areas will be checked for the presence of amphibians, once confirmed to be absent, the vegetation will be cleared and the ground compacted. The site will be monitored every two weeks during the growing season and as necessary vegetation will be removed to keep the area clear. If any equipment/materials are to be stored on site they will be stored on pallets to ensure it does not create refugia. This approach is supported by Natural England in that reasonable avoidance measures are adopted rather than taking the route of precautionary licence application within area where the risk of encountering great crested newts is considered to be low.
- Vegetation clearance works will be programmed to avoid interference with bird nesting habitat between March and August.

360. Regular compliance checks will be undertaken by the appointed Ecological Clerk of Works to ensure that all measures provided within the detailed Method Statement are being correctly adopted and implemented for the duration of the installation works.

Wintering birds and Indirect Impacts on BHS and SPA

361. To avoid impacts during the two day installation works period at the 15 array stations identified to be of value to wintering birds, including Lytham Moss BHS, construction works will be undertaken outside of the wintering bird season.

Breeding birds

362. Where installation activities occur within the bird breeding season, pre-start checks for nesting birds will be undertaken by a the appointed Ecological Clerk of Works prior to works commencing. In the unlikely event that active bird nests are identified (works will only impact ground nesting birds and footprints are considered sub-optimal) then the footprint of the works will be altered to ensure that the installation works are legally

compliant with respect to nesting birds and to minimise any potential disturbance impacts. Alternatively vegetation will be managed/removed prior to the bird nesting season to ensure the site is not suitable for nesting birds.

10.9.2.2 Operation

Breeding and wintering birds

363. Monitoring data collected from the array sites will be downloaded remotely preventing the need for vehicles to approach the arrays, which will reduce the disturbance experienced by breeding and/or wintering birds.

364. However, it will be necessary to replace the batteries and check for faults weekly. In this situation the following mitigation will be implemented.

- Tool box talks and training will be provided to site personnel in relation to wintering and breeding birds prior to an individual undertaking any visits to an array site.
- Site personnel will not wear high visibility clothing when visiting sites.
- Flashing lights / beepers on vehicles will be switched off / muted for all site visits, where safe to do so.

10.9.2.3 Mitigation Measures for the Construction of Site, Access and Gas Pipeline

365. Details of the additional areas of compensatory and replacement planting will be provided within the BMS. Whilst there will be a loss of habitats deemed to be of low value (e.g. improved grazed grassland), opportunities to enhance the existing habitats and to ensure subsequent management will bring them into a more favourable condition will be incorporated into the Project. This particularly applies to the existing hedgerows and arable farmland. An indicative outline of measures which will be included is provided below and illustrated on Appendix J Figure 1: Indicative Biodiversity Mitigation Strategy.

Loss of 40m of Species Poor Hedgerow

366. To compensate for the loss of 40m of hedgerows as a result of the required access to Site and to the connection point for the proposed gas pipeline to grid gas, and disturbance to species as discussed below, species-rich hedgerows will be planted along existing boundary fence lines where a hedgerow is absent (approximately 1000m). In addition, gappy hedgerows will be enhanced with additional plantings (approximately 700m). Their indicative location is illustrated Appendix J Figure 1 Indicative Biodiversity Mitigation Strategy. These new hedgerows will link hedgerows which are currently disconnected. The new hedgerows are also proposed in some areas along fence lines set away from the well pad so that it will not be impacted by noise and light pollution.

367. The hedgerows will be comprised of two rows of hedgerow trees and shrubs planted in accordance with Lancashire County Council's guidance document titled 'Lancashire Trees and Woodlands'[163] which indicates that hedgerows should include a species mix as follows: hawthorn *Crataegus monogyna* – 70%, hazel *Corylus avellana* – 10%, blackthorn *Prunus spinosa* – 10%, and the final 10% chosen from a combination of (all,

[163] Blackpool Council and Lancashire County Council (unknown – accessed on line 16/05/2014). *Lancashire Trees and Woodland*. http://www.lancashire.gov.uk.

or some of) Dog rose *Rosa canina agg*, guelder rose *Viburnum opulus*, holly *Ilex aquifolium*, crab apple *Malus sylvestris* and Spindle *Euonymus europaeus*.

368. A management plan will be adopted and implemented to ensure the success of the newly planted sections of hedgerow. It is intended that the new hedgerow will qualify as additional areas of UK BAP habitat.

369. The new access point may require the removal of small number of semi mature trees (including sycamore). If any trees were to be removed they would be replaced on a ratio of two for one along either boundary fences or within existing hedgerows which lack standard trees (See Appendix J Figure 1: Indicative Biodiversity Mitigation Strategy). All replacement planting will utilise native species of local provenance in keeping with the habitats and species established within the wider landscape. Replacement tree species will be selected from the Figure 5 - Large and Medium Sized Trees.

Figure 5 Tree Species Recommended by Lancashire County Council

Local Native Species for Northwest England			
Large and Medium Sized Trees		Small Trees and Woody Shrubs	
Common alder	*Alnus glutinosa*	Blackthorn	*Prunus spinosa*
Crab apple	*Malus sylvestris*	Broom	*Cytisus scoparius*
Ash	*Fraxinus excelsior*	Alder buckthorn	*Frangula alnus*
Aspen	*Populus tremula*	Purging buckthorn	*Rhamnus catharticus*
Downy birch	*Betula pubescens*	Dogwood	*Cornus sanguinea*
Silver birch	*Betula pendula*	Elder	*Sambucus nigra*
Bird cherry	*Prunus padus*	Gorse	*Ulex europaeus*
Wild cherry (Gean)	*Prunus avium*	Guelder rose	*Viburnum opulus*
Wych elm	*Ulmus glabra*	Common hawthorn	*Crataegus monogyna*
Small-leaved lime	*Tilia cordata*	Midland hawthorn	*Crataegus laevigata*
Large-leaved lime	*Tilia platyphyllos*	Hazel	*Corylus avellana*
Field maple	*Acer campestre*	Holly	*Ilex aquifolium*
Common oak	*Quercus robur*	Juniper	*Juniperus communis*
Sessile oak	*Quercus petraea*	Privet	*Ligustrum vulgare*
Black poplar	*Populus nigra*	Dog rose	*Rosa canina*
Grey poplar	*Populus canescens*	Field rose	*Rosa arvensis*
Rowan	*Sorbus aucuparia*	Spindle	*Euonymus europaeus*
Wild Service tree	*Sorbus torminalis*	Spurge laurel	*Daphne laureola*
Whitebeam	*Sorbus aria*	Wayfaring tree	*Viburnum lantana*
Crack willow	*Salix fragilis*	Almond willow	*Salix triandra*
Goat willow	*Salix caprea*	Eared willow	*Salix aurita*
White willow	*Salix alba*	Grey willow	*Salix cinerea*
Yew	*Taxus baccata*	Osier willow	*Salix viminalis*
		Purple willow	*Salix purpurea*

370. A management plan will be adopted and implemented to ensure the successful establishment of all newly planted trees.

Loss of foraging habitat, connectivity and disturbance of bats due to general site lighting

371. To minimise potential impacts on foraging bats from lighting of critical equipment, the following measures will be implemented (See Chapter 15: Lighting for further details):

- All lighting will be directed onto the equipment only and away from suitable bat foraging habitat; including adjacent hedgerows (e.g. by fitting hoods to direct the light below the horizontal plane, preferably at an angle less than seventy degrees). .

- The operating lights will be designed so that the light levels (brightness) are as low as safely possible.
- Upward lighting will be minimised to avoid light pollution.
- The height of the lighting columns will be limited to reduce light spillage.

372. In order to monitor the impact of artificial lighting on bats, bat activity surveys will be undertaken during construction activities at the Site, during the active bat season (at least four times per active season), to assess if activity levels have changed to pre-works on Site.

373. There is the potential that even with the above measures in place light avoiding species such as brown long eared bats may be deterred from migrating along the hedgerow immediately to the north of the Site. It is intended that the new hedgerows located to the west of the Site would provide improved connectivity within the local area providing the bats with further options in relation to their route of commute to and from foraging resources.

374. The appointed Ecological Clerk of works will ensure that the above measures have been appropriately adopted and implemented for the duration of Project.

Loss of habitat for nesting/breeding birds and disturbance

375. The loss of 40m of suitable habitat for breeding birds and potential disturbance caused by increased noise levels and personnel and vehicle movements will be mitigated for by the planting of 1000m of hedgerow and the enhancement of a further 700m of gappy hedgerow. This will include hedgerows which will be set away from the well pad to provide habitat within which birds are unlikely to be disturbed by vehicle and personnel movements and noise levels will have been attenuated to current ambient noise levels for most operations on Site.

376. The sections of hedgerows identified for removal or trimming down will be removed/trimmed outside the main bird nesting season of March-August.

377. If construction occurs within the bird breeding season a detailed Method Statement will be prepared prior to works commencing. The purpose of the Method Statement is to implement measures to minimise any potential disturbance impacts (noise and visual) on breeding / nesting bird species within the zone of influence during construction activities undertaken within the bird breeding season. The Method Statement will prepared and implemented by the appointed Ecological Clerk of works and will include the following measures:

- Pre-start checks for nesting birds will be undertaken within all areas of suitable habitat located within the zone of influence surrounding the Site. This will be followed by weekly updated checks for the duration of the construction activities occurring within the bird breeding season. If it is found that nesting activity, during the breeding season, is less than recorded prior to works then the use of measures such as acoustic hoarding will be considered to attenuate noise levels.
- Tool box talks and training in relation to breeding birds will be provided to all site personnel prior to construction activities.
- To limit visual impacts, a band of native tree and scrub will be planted immediately surrounding the well pad (Chapter 14: Landscape and Visual). Species will be selected in accordance with the guidance documents produced by Lancashire County Council titled ‘Lancashire Trees and Woodland.

- A landscaped earth bund (approximately 2-3m in height) will be positioned to minimise noise being emitted towards adjacent intact hedgerows.
- The site lighting will be designed to minimise light spillage onto the intact hedgerow located adjacent to the Site by being focused on critical equipment only. This will include facing lighting away from the hedgerows and using fitted hoods (Chapter 15: Lighting).

378. Regular compliance checks will be undertaken by the appointed Ecological Clerk of Works to ensure that all measures provided within the detailed Method Statement are being correctly adopted and implemented. The compliance checks will also monitor the effectiveness of the measures being implemented in minimising potential disturbance impacts on any breeding bird species identified to be utilising habitats located within the zone of influence surrounding the Site.

Loss of habitat for wintering birds and disturbance

379. There is the potential for wintering birds to be present within the local area and there is the potential that these species will be displaced due to high or sudden noise levels and due to the movement of vehicles and personnel. To limit the effects of this displacement similar measures will be adopted as those detailed above for breeding birds. The Method Statement will prepared and implemented by the appointed Ecological Clerk of works and will include the following measures:

- Pre-start checks for wintering birds will be undertaken within all areas of suitable habitat located within the zone of influence surrounding the Site. This will be followed by weekly updated checks for the duration of the construction activities occurring within the wintering season. If it is found that number of wintering birds within the immediate zone of influence is less than that recorded in winter 2013/2014 or birds are taking flight more frequently then the use of measures such as acoustic hoarding will be considered to attenuate noise levels.
- Tool box talks and training in relation to wintering birds will be provided to all site personnel prior to construction activities.
- To limit visual impacts, a band of native tree and scrub will be planted immediately surrounding the well pad. (Chapter 14: Landscape and Visual). Species will be selected in accordance with the guidance documents produced by Lancashire County Council titled ‘Lancashire Trees and Woodland.
- A landscaped earth bund (approximately 2-3m in height) will be positioned to minimise noise being emitted towards adjacent intact hedgerows.
- The site lighting will be designed to minimise light spillage onto the intact hedgerow located adjacent to the Site. This will include facing lighting away from the hedgerows and using fitted hoods (Chapter 15: Lighting).

380. As compensation for disturbance to breeding and wintering birds mitigation will be implement across the wider agricultural landscape. (See Appendix J Figure 1: Indicative Biodiversity Mitigation Strategy) (full detailed will be provided within the BMS):

- The hedge corridors will be supplemented or buffered by the addition of a strip of species-rich grassland, at least 1m in width, which will run parallel to new and enhanced sections of hedgerow.
- Planting conservation / cover crops to provide additional food sources and cover for site fauna. This will entail the planting of mixed conservation crops / wildlife cover crops enhanced with wild flowers to maximise diversity of feeding habitat for a wide

range of seed and invertebrate eating birds. The continuity of this resource will also ensure successive foraging resources during the spring which will support bird species in attaining breeding condition. This will involve the creation of several cover crop areas measuring approximately 2.6ha in size across the wider study area.

- Appropriate areas of pasture will managed in favour of wintering birds.

Loss of habitat, disturbance and killing/injury of brown hare

381. The loss of habitat available for brown hare will be mitigated for by a combination the additional areas of pasture to be left ungrazed, the creation of the cover crop strips and the areas of replacement planting (See Figure 1 Indicative Biodiversity Mitigation Strategy). In addition, the establishment of approximately 1000m of new hedgerow (refer to *Loss of 40m of Species Poor Hedgerow)* will also provide enhanced habitat for brown hare.

382. A Method Statement detailing measures to be implemented and adopted to minimise potential adverse impacts on brown hare during construction will be prepared by the appointed Ecological Clerk of Works and approved by the Local Planning Authority prior to works commencing. The Method Statement will include the following measures:

- Pre-start checks for brown hare will be undertaken prior to any vegetation clearance / site preparation works. Regular checks for brown hare will then be undertaken for the duration of the construction activities to assess whether mitigation measures detailed below are being utilised by brown hare.
- Tool box talks and training will be provided to all site personnel in relation to brown hare prior to construction activities.
- The site security fencing will be made impenetrable to mammals and will be installed around the proposed working area (excluding access track and gas pipeline) as part of the initial Site set up. This will prohibit mammals, including brown hare, from entering the Site compound and being harmed by machinery.
- Any pits / excavations located outside the security fencing or prior to the installation of the fencing will either covered or will have mammal ramps positioned in them to allow any trapped animals to escape.
- Any works to be undertaken outside the Site compound will be fenced to protect and prevent damage and accidental encroachment into adjacent areas of habitat which may be utilised by brown hare.
- To limit visual impacts, a band of native tree and scrub will be planted immediately surrounding the well pad.
- The landscaped earth bund (approximately 2-3m in height) will be positioned along the boundaries of the Site compound so to minimise disturbance impacts (noise and visual) to adjacent boundary features and areas of arable habitat which may be utilised by brown hare.
- Creation of unmanaged field corners to provide brown hare within the wider landscape, which is currently absent due to the high intensity of agriculture within the local area.
- The site lighting will be designed to minimise light spillage onto adjacent areas of suitable habitat for brown hare, by being focused on critical equipment. This will include facing lighting away from the eastern boundary and using UV filters and fitted hoods.

383. Regular compliance checks will be undertaken by the appointed Ecological Clerk of Works to ensure that all measures provided within the detailed Method Statement are being correctly adopted and implemented during construction activities. The compliance checks will also monitor the effectiveness of the measures in minimising potential adverse impacts on brown hare utilising habitat located within the zone of influence surrounding the Site.

10.9.3 Mitigation Measures for Operational Activities including Drilling, Hydraulic Fracturing, Initial Flow Testing and Extended Flow Testing (refer to construction for gas pipeline mitigation)

384. The impact assessment of all of these operations identified the same sensitive receptors and the same potential impact pathways albeit that activity levels on Site will fluctuate and some operations will result in higher noise emissions. However, irrespective the mitigation has been designed to mitigate and where necessary compensate for a worse case scenario.

385. The significant impact pathways identified are as follows:

- Disturbance caused by night lighting and 24 hour operations on foraging and commuting bats. Heat outputs from the two operational flare stack altering bat foraging behaviour, only during initial flow.
- Disturbance (noise and visual) on breeding birds.
- Disturbance (noise and visual) on wintering birds.
- Disturbance to habitat utilised by brown hare.

386. These impacts were also identified for the construction phase of the development. Therefore, all mitigation proposed for the construction phase will be implemented in relation to disturbance and will not be repeated below. However, mitigation specific to the operational phase is detailed below.

Disturbance caused by night lighting, 24 hour operations and flare stacks on foraging and commuting bats.

387. The reader is referred to the mitigation detailed in the construction phase of works in relation to the management of lighting (section 10.9.2).

388. To attenuate noise impacts during 24 hour operations the following measure should be implemented:

- Tool box talks and training in relation to bats will be provided to all site personnel prior to operational activities.
- Large machinery such as drilling rig or that associated with hydraulic fracturing will be located away from suitable foraging bat habitat (e.g. away from the hedgerow along the eastern boundary within the centre of the Site).
- Flare stacks to be located aware from boundary features to reduce the potential for bats encountering these structures. The position of the stacks within a highly lit compound will deter bats from approaching these structures.

389. In order to monitor the impact of artificial lighting and 24 hour activities on bats and to ensure that the above measures negate potential adverse impacts on bats, bat activity

surveys will be undertaken during the operational phases during the active bat season (at least four times per active season). The surveys will also monitor activity along the newly created hedgerows to assess their value to this group of species.

Disturbance (noise and visual) on wintering and breeding birds

390. The reader is to referred to the mitigation detailed in the construction phase of works in relation to the management of noise and visual disturbance on wintering and breeding birds. These mitigation measures will be applicable during the operation phase of development (section 10.9.2).

391. In addition, to the measures detailed within the construction phase the measures below will be implemented to reduce disturbance further:

- Large machinery such as drilling rig or that associated with hydraulic fracturing will be located away from suitable habitat for breeding birds (e.g. away from the hedgerow along the eastern boundary within the centre of the Site).
- 'Soft start ups' will be employed (i.e. starting up pieces of machinery one by one and working up to the full activity levels gradually). This is to minimise any potential disturbance impacts as a result of impulsive / irregular noises emitted during operational activities.
- Identify fields within the local area which can be managed in favour of wintering birds such as pink foot geese. This would require that vegetation is cut to a height less than 10cm prior to the wintering season. Ideally within the mitigation there would be a mix of agricultural leys as described above and stubble.
- Netting will be erected along the perimeter fence so that movement within the compound will not be observed externally. Therefore, reducing the potential for visual disturbance of wintering birds. This will be checked each week and maintained as appropriate.

392. Regular compliance checks will be undertaken by the appointed Ecological Clerk of Works to ensure that all measures provided within the detailed Method Statement are being correctly adopted and implemented. The compliance checks will also monitor the effectiveness of the measures being implemented in minimising potential disturbance impacts on any breeding bird species identified to be utilising habitats located within the zone of influence surrounding the Site and the usage of the compensatory habitat (new hedgerows).

Disturbance to habitat utilised by brown hare

393. The impacts on brown hare during the operational phase of the development will only relate to disturbance, therefore, mitigation for this species during the operational phase is detailed below rather than referring the reader to the construction phase.

394. A Method Statement detailing measures to be implemented and adopted to minimise potential adverse impacts on brown hare during drilling activities will be prepared prior to works commencing. This is in combination to the inbuilt mitigation measures for brown hare implemented as part of the design and setup of the Site compound (e.g. with the siting of the landscaped earth bund and site cabins and the areas of landscaping around the perimeter of the Site; Section 10.9.2). The Method Statement will prepared and implemented by the appointed Ecological Clerk of Works and will include the following measures:

- Pre-start checks for brown hare will be undertaken prior to the commencement of operational activities. Regular checks for brown hare will then be undertaken for the duration of works.
- Tool box talks and training will be provided to all site personnel in relation to brown hare prior to operational activities.
- Large machinery such as drilling rig or that associated with hydraulic fracturing will be located away from suitable habitat for brown hare.
- The site lighting will be designed to minimise light spillage onto adjacent areas of suitable habitat for brown hare. This will include facing lighting away from the eastern boundary and using fitted hoods.

395. Regular compliance checks will be undertaken by the appointed Ecological Clerk of Works to ensure that all measures provided within the detailed Method Statement are being correctly adopted and implemented during operational activities. The compliance checks will also monitor the effectiveness of the mitigation provided to identify whether brown hare use the cover crop and set aside field corners during the development.

10.9.4 Mitigation Measures for Decommissioning and Restoration

396. The impact assessment identified that ecological receptors and impact pathways were the same as the construction phase of development. These included:

- Disturbance to breeding birds and wintering birds (noise and visual).
- Killing / injury of brown hare during decommissioning and restoration activities.
- Disturbance to habitat utilised by brown hare.

397. The mitigation measures to be implemented to either mitigate or compensate for these impacts are detailed in section 10.9.1 and will not be repeated in this section excluding mitigation measure which solely relate to the decommissioning phase.

398. However, on decommissioning of the Site potentially new habitats will have developed depending on the duration of the project.

Loss of habitat within the Site boundary

399. Updated surveys will be undertaken of the artificially created habitats and features located within the Site boundary (e.g. water drainage channels, vegetated earth bund and landscaped areas) to determine whether or not such habitat support notable or protected species. Depending on the findings of the updated survey, appropriate measures shall be put in place, as recommended by the appointed Ecological Clerk of Works, to ensure that the works are legally compliant and in accordance with best practices during decommissioning activities.

Killing / injury of brown hare during decommissioning and restoration activities.

400. To prevent brown hare from being killed or injured during decommissioning:

- The site security fencing, which is impenetrable to mammals, will be one of the final items to be removed from the Site at the end of the decommissioning activities. Should additional restoration works be required once the site security fencing has been removed then temporary fencing will be utilised around the

working footprint. This will prohibit mammals, including brown hare, from entering the working footprint.

10.9.5 Cumulative and Interactive Effects

401. The cumulative assessment looked at the impacts of undertaking more than one operational activity at once as Preston New Road and assessed the potential cumulative impact of multiple developments within the local area.

402. The sensitive receptors and impact pathways for cumulative operational activities were the same as undertaking one operation in isolation, excluding a logarithmic increase in noise on Site which was not considered significant within the noise report (Arup Acoustics, March 2014).

403. Therefore, the implementation of the mitigation measures detailed in section 10.9.3 of this report will be suitable mitigation if operations were to occur at the same time on the well pad.

404. The assessment of cumulative impacts as a result of multiple development within the local area identified the only significant routes of impact as:

- Loss of foraging habitat for wintering birds.
- Disturbance to SPA qualifying wintering bird species if works occurred from October – March, due to elevated noise levels and through visual disturbance.

405. The mitigation detailed from section 10.9.1 – 10.9.5 aims to prevent impacts upon wintering birds and subsequently the international, national and local designated sites whose qualifying features are wintering birds, and some breeding birds. It is considered that on implementation of these mitigation and compensation measures that the impact on SPA qualifying bird species will be neutral.

406. It is also assumed that if the developments off site were to occur that they will have to also implemented mitigation/compensation measures that will ensure that the functionality of the SPA is not compromised.

10.10 Residual Effects

407. It is judged that there will be no significant residual effects once the mitigation measures, described above in Section 10.9, have been implemented. It is envisaged that the results of the compliance checks and inbuilt monitoring, which will be undertaken as part of all phases of the Project, will provide further evidence that there are no significant residual effects, once all the mitigation measures have been adopted. Should any adverse impacts on sensitive ecological receptors be identified following the compliance checks and inbuilt monitoring, then additional measures will be put in place, as recommended by the appointed Ecological Clerk of Works, to minimise any identified adverse impacts identified.

10.10.1 Summary of Residual Effects at the Site

Loss of hedgerow

408. The development will result in the loss of 40m of hedgerow and the lowering of approximately 345m. To mitigate for this loss and to compensate for impact to fauna it is proposed that approximately 1000m of new hedgerow is installed along existing field

boundaries which are currently fenced with approximately 700m of existing hedgerow enhanced with additional plantings Appendix J Figure 1. Therefore, it has been assessed that there will be no significant impacts upon hedgerows.

Bats

409. The impacts assessment identified that during the life cycle of the project there is the potential for bats which are using linear features surrounding the main Site to be displaced due to increased lighting levels. As detailed above a range of measures will be employed to reduce this impact e.g. focused lighting and screening planting. However, to compensate for displacement, if it were to occur, it is also proposed that field boundaries currently fenced are planted with hedgerows. The purpose of this is to provide the bats with additional foraging habitat and alternative connective linkages. Therefore, it is assessed that there will be no significant residual impacts upon bats.

Breeding Birds

410. Low numbers of breeding birds were recorded within the hedgerows surrounding the proposed Site. There is the potential for birds to be displaced due to increased noise, visual movement and light upon the Site. A broad range of mitigation measures are to be adopted in relation to Site management to reduce these potential impacts (e.g. focused lighting, removing flashing lights where possible, plantings to reduce disturbance to adjacent hedgerows) However, to compensate for any disturbance that could occur, new hedgerows will be planted within close proximity of the Site and cover crop in the form of set aside strips will be created to provide improved shelter and foraging within the local area. Therefore, it is considered that the development will not lead to significant residual impacts.

Wintering Birds

411. The wintering bird survey found that in winter 2013/2014 that numbers of wintering birds were typically low within the local area, excluding one day when pink footed geese and lapwing were flushed by shooting in the area resulting in a large flock frequently taking flight and landing in the field that the gas pipeline will be constructed. To mitigation for the potential disturbance to a small number of wintering birds a range of measures have been adopted to reduce disturbance from noise and visual movement. It is therefore considered that there will be no significant residual impacts upon wintering birds.

Brown Hare

412. Brown hare have been recorded in the local area albeit that the Site as grazed pasture provides suboptimal habitat for this species. To reduce impacts on this species a range of measures have been adopted to reduce noise and visual disturbance on Site and avoid accidental killing, injury or death. Detailed in section 10.9. To provide compensation for disturbance it is proposed that field corners are left to grow long to provide cover which is currently absent within the immediate landscape. It is therefore considered that there will be no residual impacts on brown hare.

10.10.2 Summary of Residual Effects at the Site

Habitats

413. The arrays will be constructed within habitats which are either species poor e.g. improved grassland or frequent within the landscape e.g. tall ruderal herb. The arrays have been sited to prevent impacts upon habitats of value including standard trees and hedgerows.

Wintering birds and BHS and SPA's

414. To reduce the potential for impact on wintering birds and subsequently the SPA's, it is intended that the 15 sites which will be constructed in fields known to be used by wintering birds, including the two adjacent to Lytham Moss BHS will occur outside of the wintering bird season. To reduce impacts during operation a method of works has been developed to enable the remote download of data significantly reducing the number of vehicle visits to the arrays and the potential disturbance that this could cause. It is considered that through the implementation of these measures that there will not be a significant impact.

Breeding birds

415. To prevent significant impacts on breeding birds a pre-start check will be completed. In the unlikely event of their presence the working footprint will be modified to prevent impact. Therefore, the impact will not be significant.

10.11 Assessment Summary Matrix

416. The assessment summary matrix (Table 10.42) outlines the effects identified and the significance of the effects. As stated above in Section 10.10, although it is judged that there will be no significant residual impacts, the inbuilt monitoring which will be undertaken during each phase of the project will provide confirmation of this.

Table 10.42: Ecology assessment summary matrix

Description of effect	Significance prior to mitigation	Mitigation	Residual effect
Installation of the Surface and Buried array			
Disturbance to wintering birds during installation works and operation and subsequently Lytham Moss BHS and the SPA's.	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9, such as construction of the most sensitive sites outside of the wintering bird season, and as detailed within the BMS.	**Not Significant**
Disturbance to breeding birds (visual and noise) during installation works and operation.	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9, such as pre start up checks, and within the BMS. Avoid siting towers at array stations deemed to be of moderate or high potential for wintering birds.	**Not Significant**
Construction of the Site, Access and Gas Pipeline			
Loss of ~ 40m of intact species-poor hedgerow and the lowering of 345m of hedgerow.	Significant impact	Creation of approx. 1000m of new species-rich BAP compliant hedgerow plus enhancement of a further approx. 700m of gappy hedgerow. Loss of habitat to be offset by improvement / enhancement of existing hedgerows located at the	**Not Significant**

Description of effect	Significance prior to mitigation	Mitigation	Residual effect
		Site.	
Loss of bat foraging habitat and impacts on connectivity Disturbance caused by lighting on foraging and commuting bats	Significant impact	Areas of compensatory planting, additional planting and improvement / enhancement measures to existing farmland habitats will provide additional foraging opportunities and connective linkages for bats. Incorporation of mitigation measures detailed in Section 10.9 and the BMS.	**Not Significant**
Loss of habitat for nesting birds. Disturbance to breeding birds (noise and visual).	Significant impact	Areas of compensatory planting, additional planting and improvement / enhancement measures to existing farmland habitats will provide additional habitat for nesting birds. Incorporation of mitigation measures detailed in Section 10.9 and within the BMS.	**Not Significant**
Disturbance to wintering birds (noise and visual).	Significant impact	Incorporation of mitigation measures detailed in Section 10.9 and within the BMS.	**Not Significant**
Loss of habitat for brown hare. Disturbance to habitat utilised by brown hare (direct and indirect). Accidental killing or injury of brown hare by vehicles or workings.	Significant impact	Areas of compensatory planting, additional planting and improvement / enhancement measures to existing farmland habitats will provide additional habitat for brown hare. Incorporation of mitigation measures detailed in Section 10.9 and within the BMS.	**Not Significant**
Drilling, Hydraulic Fracturing, Initial Flow Testing, Extended Flow Testing			
Disturbance caused by lighting and 24 hour operations on foraging and commuting bats.	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 within the lighting designs and the BMS.	**Not Significant**
Disturbance to breeding birds (noise and visual).	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 and the BMS.	**Not Significant**
Disturbance to wintering birds (noise and visual).	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 and the BMS.	**Not Significant**
Disturbance to habitat utilised by brown hare.	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 and the BMS.	**Not Significant**
Decommissioning and Restoration			
Loss of habitats which have	Significant	Incorporation of mitigation	**Not Significant**

Description of effect	Significance prior to mitigation	Mitigation	Residual effect
developed e.g. landscape planting	Impact	measures detailed in Section 10.9 and within the BMS (e.g. wheel washing).	
Disturbance to breeding birds (noise and visual).	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 within the lighting designs and BMS.	**Not Significant**
Disturbance to wintering birds (noise and visual).	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 and the BMS.	**Not Significant**
Disturbance to habitat utilised by brown hare. Accidental killing or injury of brown hare by vehicles or workings.	Significant Impact	Incorporation of mitigation measures detailed in Section 10.9 and within the BMS.	**Not Significant**

11 Hydrogeology and ground gas

Chapter Summary- Hydrogeology and ground gas

This topic is concerned with the effects of the Project on the quality of the water environment, both groundwater and surface water. It is also concerned with the possible creation of subsurface pathways by the Project to sensitive features.

The assessment considers possible impacts associated with the following aspects of the Project:

- Well pad activities and materials in transit – such as potential spills;
- Well construction and integrity – such as potential escape of contaminants and ground gas from the well bore into the ground and groundwater;
- Fractures created by hydraulic fracturing – such as potential for movement of contaminants and ground gas along new subsurface pathways.

The design and management of operations will ensure that drilling, fracturing and other activities undertaken as part of the Project cannot result in release of any substance liable to cause pollution to surface water or groundwater.
The wells will be drilled, constructed and tested in accordance with regulatory requirements and industry guidance. The well design will comprise a two-barrier (minimum) cement-sealed design. When drilling through potentially sensitive groundwater units drilling fluids will be used which are non-hazardous to groundwater (under the Groundwater Daughter Directive).

Hydraulic fracturing will be undertaken in accordance with UKOOG and other industry guidance and regulatory requirements. Fracturing fluid chemical additives will be non-hazardous to groundwater (under the Groundwater Daughter Directive) and fracture growth will be monitored using the buried array.

Prior to and during exploration works groundwater and surface water quality will be monitored. When the exploratory wells are no longer needed they will be decommissioned in accordance with regulatory requirements and industry guidance.

The risks associated with the Project relevant to this topic have been considered in detail in this chapter.

By implementing the proposed measures the Project **will not result in a significant effect** on the quality of the water environment or other relevant potential receptors.

11.1 Introduction

1. This chapter provides an assessment of the risk of significant environmental impacts upon groundwater and associated receptors and of migration of ground gas that may result from the Project.

2. The Project comprises construction of a well pad site, drilling of up to 4 wells, with hydraulic fracturing and well testing of each well, with the specific objective of assessing the potential natural gas flow rates of the Bowland Shale. The Site is currently agricultural grassland. The Project also includes installation of seismic arrays across the local area, and Site decommissioning, comprising well plugging and abandonment and Site restoration.

3. This chapter is closely related to other chapters in this Environmental Statement: Chapter 4 The Proposed Development that describes the Project in detail; Chapter 12 Induced

Seismicity that considers the potential for seismic events as a result of hydraulic fracturing; Chapter 18 Water Resources considers impacts on the hydrological regimes within the vicinity of the application site; and Chapter 16 Resources and Waste that considers the environmental effects of waste generated by the development. The potential for migration of gas through the ground and via the well bore is considered in this chapter. The potential for leakage of gas from above ground well infrastructure and airborne contamination is assessed in Chapter 8.

4. The Hydrogeology and Ground Gas ES Chapter has the same structure as the other ES chapters.

5. This Chapter has been prepared by Arup with expert technical input and review from Dr Tony Batchelor and colleagues at GeoScience Ltd.

6. Appendix K to the ES includes additional information and analysis supporting the assessment presented in this chapter:

- Appendix K1: Hydrogeological supporting information;
- Appendix K2: Pad and surface activities;
- Appendix K3: Well integrity;
- Appendix K4: Hydraulic fracturing;
- Appendix K5: Ground gas migration.

11.2 Key development issues

7. The key aspects of the Project relevant to this assessment are as follows:

- Construction of the well pad on an area of agricultural grassland;
- Construction of an array of seismic monitoring locations;
- Storage and use of potentially polluting materials on the Site including drilling fluids and cuttings, hydraulic fracture fluid, diesel fuel and flowback fluid;
- Transport of potentially polluting materials to and from the Site;
- Drilling and construction of exploration wells, including horizontal sections in the target shale formation;
- Hydraulic fracturing of the shale target formation;
- Initial flow testing and extended flow testing of each well;
- Well servicing and temporary sealing (‘suspension’) of each well;
- If the Site is to be permanently decommissioned, permanent sealing of the wells (‘abandonment’) and restoring the site to agricultural use.

8. Issues considered in this chapter broadly fall into the following three areas:

- Releases of potentially polluting materials at the Site and in transit;
- Potential movement and release of contaminants and ground gas via the well bore, as a result of drilling and inadequate well integrity; and
- Potential movement of contaminants and ground gas through the ground via naturally occurring or induced fractures, as a result of hydraulic fracturing.

9. The associated risks of pollution of groundwater, surface water and adverse effects on human health, and migration of ground gas to sensitive receptors, potentially arising from these issues are considered in this chapter, with supporting detail in Appendix K.

11.3 Scoping and consultation

10. The scoping process that has been undertaken as part of this EIA for the Project has been discussed in detail in Chapter 2 of the ES.

11. A number of workshops and consultation events have been held since the inception of the Environmental Impact Assessment (EIA) (and Environmental Risk Assessment (ERA)) process, as described in the Statement of Community Involvement which accompanies the Planning Application. Concerns that were identified during these events assisted in the identification of issues associated with hydrogeology and ground gas.

12. A scoping report was submitted to Lancashire County Council (LCC) in February 2014 as part of the planning process. This gave consultees the opportunity to comment on the proposed content and methodology of the hydrogeology and ground gas section of the final ES. The responses received that are relevant to this chapter are summarised in Table 11.1 Summary of comments on the Scoping Report relevant to the Hydrogeology and Ground Gas Chapter. below.

Table 11.1 Summary of comments on the Scoping Report relevant to the Hydrogeology and Ground Gas Chapter.

Consultee and key relevant comments	Location where comment is addressed
Lancashire County Council Scoping Opinion	
• Geology: Sufficient information to characterise the geology should be presented.	• Section 11.6
• Well integrity: The risks to well integrity associated with induced seismicity should be considered.	• Section 11.7.3, 11.7.7 and Appendix K3
• Direction drilling control: Measures to prevent subsurface collision of boreholes should be described. In the event of collision ('merging') measures to be implemented should be described.	• Section 11.8 and Appendix K3
• Well interaction: Risk management and measures to ensure safe simultaneous fracturing and drilling on the same pad should be described.	• Section 11.8 and Appendix K3
• Water resources: Information on groundwater and surface water resources and their interaction should be presented and locations of any abstractions identified. Groundwater-bearing strata and the techniques used to protect them should be identified. Information on the surface water discharge should demonstrate receiving watercourses are protected.	• Section 11.6
• Monitoring: Surface water, groundwater and ground gas monitoring to assess impacts of drilling and fracturing. If possible provision to collect a Sherwood Sandstone groundwater sample during drilling should be included.	• Section 11.6 (see below)
• NORM: The Environment Agency note that the approach to assessment of NORM has not been explicitly described in the Scoping Report.	• Section 11.7 and Appendix K4
• Human health: Public Health England expect issues including human health receptors, emissions to water, land quality and contamination to be addressed.	• See PHE response below.
• Measures: Description of measures to prevent, reduce, and where possible offset any significant adverse effects on the environment	• Section 11.4.5 and Appendix K3 and K4

Consultee and key relevant comments	Location where comment is addressed
Environment Agency	
• West Lancashire Quaternary Sand and Gravels Aquifers not identified in scoping report. This groundwater body has been assessed as having good quantitative and chemical status.	• Section 11.6
• Surface water disposal: Information on the surface water discharge should demonstrate the receiving water environment is protected.	• Section 11.7 and Appendix K2
• Groundwater sampling: If possible provision to collect a Sherwood Sandstone groundwater sample during drilling should be included.	• Section 11.6.6
• Reuse of flowback fluid: If this is proposed at any time, then it should be assessed in the EIA.	• Section 11.7 and Appendix K4
• Fluids: All fluids used during construction and testing should be assessed including spacer fluids and cement.	• Section 11.7 and Appendix K3 and K4.
• Groundwater receptors: Defined as all groundwater bearing formations where fluid entering those formations could be considered a groundwater activity under the EPR 2010.	• Section 11.6.13
• Well integrity: The induced seismicity risks to well integrity should be assessed.	• Section 11.7.7 and Appendix K3
• Array boreholes: Best practice in borehole construction and pollution prevention measures must be employed.	• Section 11.7.2
• NORM: The approach to assessment of NORM has not been explicitly described in the Scoping Report. Ensure NORM is adequately presented and assessed. It would be prudent to collect baseline site soil samples for NORM analysis.	• Section 11.7.4 and Appendix K4. Also see Chapter 16 Resources and Waste.
• Groundwater abstraction: Any proposed groundwater abstraction will require assessment.	• Groundwater abstraction is not part of the Project.
Public Health England (PHE)	• See ES Health Chapter
Receptors: All relevant receptors, human health and environmental, should be identified.	• Section 11.6.13
• Fracturing fluid and low toxicity oil based mud drilling: Disclosure of composition and related toxicological data and analytical methodologies should be presented.	• Section 11.7.3 and 11.7.4 and Appendix K3 and K4
• Emissions: consider typical operational impacts as well as accidents and assess worst-case impacts.	• Section 11.7 and Appendix K2
• Impact assessment: predicted environmental concentrations should be compared to permitted concentrations in the affected media, including both long term and short term exposure.at a receptor.	• Appendix K4
• Assessment of emissions to water: consider potential human health impacts as well as ecological impacts.	• Section 11.7
• Pathways: consider all routes that may lead to population exposure, including via surface water abstraction off site and groundwater discharge to surface water and groundwater abstractions, and impacts to recreational users.	• As above and Appendix K
• Land contamination: A baseline site condition report should be prepared, including ground gas. Previous	• Section 11.4.5 and 11.6.

Consultee and key relevant comments	Location where comment is addressed
history of the site should be considered and ground contamination assessed. • Reuse of site soils: impacts associated with reuse of soils must be considered. • Flowback monitoring: the need for flowback monitoring should be considered. • Waste in transit: potential public health impacts associated with disposal routes and transport methods should be considered. • Accidents: Response to accidents with potential off-site emissions to be presented. • Chemical pollutants: CAS numbers should be presented, the most recent UK standards should be used and background exposure should be considered.	• Section 11.4.5 and 11.7.6 • Section 11.4.5 and Appendix K4 • Section 11.4.5 and 11.7.7 • Section 11.7.7, Appendix K2 • Section 11.7.4 and Appendix K4
Health and Safety Executive (HSE) • Well collision: Collision risk is low however directional drilling control measures should be described. • Simultaneous well operations: Potential for interaction between wells during drilling and fracturing and the resulting impact should be assessed. • Interaction of fractured zones between wells: The potential for interaction of fractured zone associated with each well should be considered.	• Section 11.8 and Appendix K3 • Section 11.8 and Appendix K3 • Section 11.8 and Appendix K3
Campaign for the Protection of Rural England (CPRE) • Fracturing fluid: What is added to keep sand in suspension? • Well integrity: The impact of induced seismicity on well integrity is potentially significant. • Agricultural land: Impact of fracturing operations could extend onto agricultural land. • Abandonment: Who will be responsible and for how long?	• Section 11.7.4 and Appendix K4 • Section 11.7.7 and Appendix K3 • Section 11.7.7 and ES Chapter on Land Use • Section 11.7.7 and Appendix K3
Fylde Council • Agricultural land: Potential impact on agricultural land in the area above the horizontal drilled wells and the wider area must be considered.	• Section 11.7.7 and ES Chapter on Land Use
Natural England • No specific comments relating to Hydrogeology and Ground Gas Chapter.	• n/a
United Utilities • No response received.	• n/a

11.4 Methodology

13. This section includes a review of legislation and guidance relating to groundwater protection and ground gas in the UK. Key studies that have assessed groundwater and ground gas risks associated with shale gas development are identified to guide the reader to relevant background information. The methodologies for establishing the baseline for hydrogeological and ground gas characteristics and for assessing the effects that are applied in this topic of the EIA are described. Finally mitigation measures that are

included in the Project design ('embedded mitigation') and are relevant to this topic are identified.

11.4.1 Legislation and guidance

11.4.1.1 Relevant legislation and regulation

14. The Department of Energy and Climate Change (DECC) recent publication *Onshore oil and gas exploration in the UK: regulation and best practice*[164]provides a roadmap and explains the permitting and permissions process for onshore hydrocarbon operations from DECC issue of petroleum exploration and development licence (PEDL) to site operations. The roadmap includes the planning process, public engagement process, environmental permitting, DECC and Health and Safety Executive (HSE) involvement and the well examination requirements. The DECC document *Environmental legislation applicable to the onshore hydrocarbon industry (England, Scotland and Wales)*[165] also provides a comprehensive list of relevant European and UK legislation.

15. This Environmental Statement has been prepared in accordance with the EIA Regulations, as described in ES Chapter 2. The environmental regulators are consultees to the planning process, and can advise LCC on the potential environmental impacts of planning applications. The local planning authority and the Environment Agency (the principal environmental regulator in England) can, in turn, seek expert advice from bodies such as Public Health England (PHE).

16. The installation of onshore gas wells within the UK is principally regulated by the HSE and DECC, with the HSE monitoring operations for well integrity and site safety under the following well-established regimes:

- The Offshore Installations and Wells (Design and Construction, etc) Regulations, 1996 (referred to as DCR) and HSE guidance[166]; and
- The Borehole Sites & Operations Regulations 1995 (referred to as BSOR) and HSE guidance[167].

17. The Environment Agency (EA) is responsible for regulation of waste and protection of water resources and has recently released the document *Onshore oil and gas exploratory operations: technical guidance*[168] to explain the environmental regulations relevant to the sector. Under the Environmental Permitting (England and Wales) Regulations 2010 (as amended) a range of activities proposed at the Site may require permitting including the following 'activities' defined by the regulations: groundwater activity, mining waste activity, radioactive substances activity, industrial emissions activity. The Water Resources Act 1991 requires operators to notify the EA of their intention to drill a well,

[164] Department of Energy and Climate Change (DECC), 2013d. Onshore oil and gas exploration in the UK: regulation and best practice. Ref. 13D/328. DECC, London, UK. 49pp.
[165]Department of Energy and Climate Change (DECC), 2013c. Environmental legislation applicable to the onshore hydrocarbon industry [Online]. Available from: https://www.gov.uk/oil-and-gas-onshore-exploration-and-production[Accessed 08/04/14].
[166] Health and Safety Executive (HSE), 2008a. DCR guidance - A guide to the well aspects of the Offshore Installation and Wells (Design and Construction, etc) Regulations 1996.
[167] Health and Safety Executive (HSE), 2008b. A guide to the Borehole Sites and Operations Regulations 1995. Guidance on Regulations. 2nd Edition. HSE Books, Richmond, UK. 58pp.
[168] Environment Agency (EA), 2013b. Onshore oil and gas exploratory operations: technical guidance (consultation draft). EA, Bristol, UK. 33pp.

such that the EA can review the proposals to ensure that they will be protective of water resources.

18. In November 2012 the EA and HSE signed a 'working together' agreement relating to unconventional gas stating their commitment to coordinated regulation and to ensuring there are no material gaps between the safety, environmental protection and planning considerations.

Groundwater regulation relating to shale gas

19. Groundwater is defined in European and domestic legislation as '*all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil*' and the European Groundwater Daughter Directive (GWDD)[169] describes groundwater as: '*a valuable natural resource and as such it should be protected from deterioration and chemical pollution. This is particularly important for groundwater dependent ecosystems and for the use of groundwater in water supply for human consumption*'.

20. The European Groundwater Directive (80/68/EC)[170] has historically ensured protection of groundwater and specifically prevented the entry of defined List I substances and prevented pollution by List II substances. This directive has been replaced by the Water Framework Directive (2000/60/EC)[171] and the Groundwater Daughter Directive (2006/118/EC). The GWDD, implemented in England and Wales by the Environmental Permitting (England & Wales) Regulations 2010[172] (EPR), is similar in its requirements to the original Groundwater Directive in that the entry of 'hazardous substances' into groundwater should be prevented and the entry of 'non-hazardous pollutants' should be limited to prevent pollution or significant or sustained upward trends in pollutant concentrations in groundwater. 'Hazardous substance' and 'non-hazardous pollutant' are defined in the Water Framework Directive and Groundwater Daughter Directive and discussed further in the document Environmental Permitting Guidance: Groundwater Activities[173].

21. The proposed hydraulic fracturing fluid chemical additives for this Project will be 'non-hazardous' (under the Water Framework Directive/Groundwater Daughter Directive) and the EA will regulate this.

22. Natural gas and naturally occurring formation fluids are also potentially contaminating and their entry into groundwater as a consequence of anthropogenic activity is also subject to these requirements. The EA document *Groundwater protection: Principles and practice*[174] includes Position Statement C6 on unconventional gas and confirms the regulator's approach to groundwater protection, as follows:

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[169] European Parliament and Council, 2006. Groundwater Daughter Directive to the Water Framework Directive. Ref. 2006/118/EC. 13pp.
[170] European Parliament and Council, 1980. European Council Directive of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC) (OJ L 20, 26.1.1980, p. 43)
[171] European Parliament and Council, 2000. Water Framework Directive. Ref. 2000/60/EC. 72pp.
[172] Environmental Protection (England and Wales), 2010b. The Environmental Permitting (England and Wales) Regulations (2010). Ref. SI 675. 211pp.
[173] Department for Environment, Food and Rural Affairs (Defra), 2010. Environmental Permitting: Environmental Permitting Guidance for Groundwater Activities. For the Environmental Permitting (England and Wales) Regulations 2010. Defra, London, UK. 43pp.
[174] Environment Agency (EA), 2013e. Groundwater protection: Principles and practice (GP3). August 2013 Version 1.1. EA, Bristol, UK.

23. *We wish to facilitate development of sustainable sources of energy, working in partnerships on initiatives where appropriate. However, we will object to UCG, CBM or shale gas extraction infrastructure or activity within Source Protection Zone 1 (SPZ1). Outside SPZ1, we will also object when the activity would have an unacceptable effect on groundwater. Where development does proceed, we expect BAT to protect groundwater to be applied where any associated drilling or operation of the boreholes/shafts passes through a groundwater resource. Elsewhere, established good practice should be followed. Groundwater that is currently used as a resource or provides flow to surface waters and wetlands, or may be used as a resource in the future must be afforded a high degree of protection. A high level of protection will also extend to some deep formations that contain groundwater that would be suitable for use following treatment if necessary, or that may be used for artificial storage and recovery. For other formations groundwater must also be protected but we would not seek to apply the same degree of protection.*

24. Groundwater receptors to be considered in this assessment were identified by the EA in their response to the Scoping Report as '*all groundwater bearing formations where fluid entering those formations could be considered a groundwater activity under the Environmental Permitting Regulations 2010'*. Section 11.6.13 identifies the key groundwater receptors for this topic of the EIA.

Industry and regulatory good practice guidelines

25. The following are detailed UK-specific industry good practice guidelines:

- UK Onshore Operators Group (UKOOG, 2013) *Onshore Shale Gas Well Guidelines*[175];
- Oil and Gas UK (2012a) *Well integrity guidelines*[176]*;*
- Oil and Gas UK (2012b) *Guidance on suspension and abandonment*[177]*;*
- Oil and Gas UK (2012c) *Guidelines on qualification of materials for the suspension and abandonment of wells*[178].

26. Cuadrilla has stated it will comply with these guidelines and they are referred to where appropriate in this Chapter.

27. The UKOOG (2013) Onshore Shale Gas Well Guidelines: Exploration and Appraisal Phase[175] provide the following summary of overarching principles that should be applied relating specifically to hydraulic fracturing and environmental protection:

- *To safeguard the quality of surface water and groundwater resources, through sound wellbore construction practices, sourcing fresh water alternatives where appropriate, and to recycle water for re-use, if practicable.*
- *To measure and disclose water usage with the aim of minimising environmental impacts and the use of potable water supplies.*
- *To support the development of fracturing fluids and additives with the least environmental risks.*

[175] United Kingdom Onshore Operators' Group (UKOOG), 2013. UK Onshore Shale Gas Well Guidelines. Exploration and appraisal phase. The United Kingdom Onshore Operators' Group.
[176] Oil and Gas UK, 2012a. Well Integrity Guidelines. Report number: OP069. London: Oil and Gas UK.
[177] Oil and Gas UK, 2012b. Guidelines for the suspension and abandonment of wells. Report number: OP071a. London: Oil and Gas UK.
[178] Oil and Gas UK, 2012c. Guidelines on qualification of materials for the suspension and abandonment of wells. . Report number: OP071b. London: Oil and Gas UK.

- *To continue to advance, collaborate on and communicate technologies and best practices that minimise the potential environmental risks of hydraulic fracturing.*
- *To eliminate or, if not practicable, to minimise any fugitive emissions.*
- *To make public the substances used in hydraulic fracturing fluids.*
- *The hydraulic fracturing programme should emphasise and commit the operator to environmental protection.*

28. The Environment Agency Pollution Prevention Guidelines (available on the EA website) were developed to address risks at construction and industrial sites and are also relevant to protection of the environment from well pad activities:

- EA PPG1 General guide to the prevention of pollution;
- EA PPG2 Above ground oil storage tanks;
- EA PPG3 Use and design of oil separators in surface water drainage systems;
- EA PPG6 Working at construction and demolition sites;
- EA PPG7 Refuelling facilities: Good practice guidelines;
- EA PPG8 Safe storage and disposal of used oils;
- EA PPG18 Managing fire water and major spillages;
- EA PPG21 Pollution incident response planning;
- EA PPG22 Dealing with spills;
- EA PPG26 Drums and intermediate bulk containers.

29. The DECC regulatory roadmap[164] systematically identifies the notification and permitting requirements for each site, including: PON (petroleum operations notices) notifications to DECC, British Geological Survey (BGS) notification of intention to drill, environmental permits, HSE notification of intention to drill, provision to HSE of proposed well design following examination by independent well examiner, agreed data reporting methods with DECC, agreed fracturing monitoring with DECC, submission of hydraulic fracturing programme to DECC.

30. To supplement UK guidance Cuadrilla has also utilised guidance from the Canadian Alberta Energy Regulator, in particular guidance related to well integrity *Directive 083: Hydraulic Fracturing – Subsurface Integrity*[179].

11.4.1.2 Ground gas regulation and guidance

31. The current policy and legislative context for ground gases in England falls under several regimes depending on the source and receptor of the ground gas (including environmental permitting for landfill sources and the contaminated land regime, planning and development control, and health and safety requirements).

32. UK guidance on ground gas risk assessment focuses on the protection of human health by assessment of ground gas beneath proposed and existing developments and the risk of ground gas migrating into enclosed spaces (typically buildings). The guidance concentrates on characterising the shallow ground gas regime where plausible pathways to the ground surface are present and identifying the level of mitigation required in new or existing buildings based on the gas regime.

33. A number of relevant CIRIA reports and British Standards have been consulted as part of this study[180181182183].

[179] Alberta Energy Regulator (AER), 2013. Directive 083: Hydraulic Fracturing – Subsurface Integrity. 14pp.

34. The guidance supports the application of risk assessment when assessing the risks posed by ground gases and recommends that a conceptual model is developed as part of a risk assessment identifying the potential sources, pathways and receptors. Plausible pollutant linkages (where there is a source, pathway and receptor) can then be assessed and the need for mitigation determined.

35. The EA has issued a report on monitoring and control of fugitive methane from unconventional gas operations[184]. This guidance document primarily relates to fugitive emissions of methane from above ground infrastructure (see ES Chapter 8), but it does note the following points relating to gas migration below ground:

- Consideration may need to be given to minimising risk of methane reaching the surface via pathways from well infrastructure with control of these risks built into the design of unconventional gas extraction project;
- An appropriate pre-operational monitoring survey will be important to ensure emissions can be identified and addressed;
- Methane can continue to be produced after well closure, at rates which are not commercially viable but which could result in methane seepages in the long term if seals or liners break down;
- After well closure, monitoring can be used as part of the maintenance of capped wells; and
- For deeper shale gas, release via the overlying rocks is less likely to pose a significant risk, although recent research[185] [186] has highlighted the importance of fully understanding the geological conditions.

11.4.1.3 Relevant planning policy and guidance

36. This assessment considers relevant planning policy and guidance including the *National Planning Policy Framework 2012 and supporting Technical Planning Practice Guidance*[187].

37. The Joint Lancashire Minerals and Waste Development Framework Core Strategy Development Plan Document, adopted in 2009[188], includes no specific reference to

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[180] Hooker, P. J. & Bannon, M. P., 1993. Methane: its occurrence and hazards in construction. London, CIRIA. Report number: R 130.
[181] O'Riordan, N. J. & Milloy, C. J., 1995. Risk assessment for methane and other gases from the ground. London, CIRIA. Report number: R 152.
[182] British Standards Institution (BSI), 2007. Code of Practice for the characterisation and remediation from gas in affected developments. Ref. BS 8485:2007. BSI, London, UK. 28pp.
[183] British Standards Institution (BSI), 2013. Guidance on investigations for ground gas - Permanent gases and Volatile Organic Compounds (VOCs). Ref. BS 8576:2013. BSI, London, UK. 120pp.
[184] Broomfield, M. & Donovan, B., 2012. Monitoring and control of fugitive methane from unconventional gas operations. Report number: SCHO0812BUWK-E-E. Environment Agency, Bristol, 116pp.
[185] Davies, R. J., Mathias, S. A., Moss, J., Hustoft, S. & Newport, L., 2012. Hydraulic fractures: How far can they go? Marine and Petroleum Geology. 37 (1), 1-6.
[186] Warner, N. R., Jackson, R. B., Darrah, T. H., Osborn, S. G., Down, A., Zhao, K., White, A. & Vengosh, A., 2012. Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania. Proceedings of the National Academy of Sciences. [Online], 15 August 2013. Available from: http://www.pnas.org/content/early/2012/07/03/1121181109.full.pdf.
[187] Communities and Local Government (March 2012) "National Planning Policy Framework" and "Technical Guidance to the National Planning Policy Framework"

groundwater or contamination. However, the associated Policy CS5 states an intention of the strategy is to ensure '*our natural resources including water, air, soil and biodiversity are protected from harm and opportunities are taken to enhance them.'*

38. The Joint Lancashire Minerals and Waste Local Plan Site Allocation and Development Management Policies document, September 2013[189] includes Policy DM2 on Development Management which states development will only be supported where impacts can be controlled in accordance with current best practice and recognised standards. Applications require provision of appropriate information to support the demonstration of control of emissions and quality of design.

39. Relevant policies in the adopted Fylde Borough Local Plan (FBLP) (as altered), October 2005[190] include Policy EP23 relating to protection of surface water and Policy EP24 relating to protection of groundwater. Similarly Fylde Local Plan to 2030 Part 1- Preferred Options[191] includes (draft) Policy CL1 Flood Alleviation and Water Efficiency states the council intends to implement decision making (including):

    - *Ensuring that watercourses, which are important habitats for water voles and other species, are protected from encroachment and adverse impacts and that water quality is maintained and improved; and*
    - *Ensuring that new development does not adversely affect the quality of groundwater.*

11.4.2 Key shale gas environmental reviews

40. Reviews of the environmental risks associated with shale gas exploitation have been undertaken by panels of experts or environmental regulators across a number of countries. Key studies relevant to the Project that have assessed groundwater and ground gas risks associated with shale gas development are identified below to guide the reader to relevant background information:

    - Fretwell et al (2012) *Review of assessment procedures for shale gas well casing installation*, Environment Agency[192]
    - Kibble et al. (2013) *Review of public health impacts of exposures to chemical and radioactive pollutants as a result of shale gas extraction: draft for comments* (Public Health England).[193] Broomfield, M. (2013) *Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations*

[188] The Joint Advisory Committee for Strategic Planning Lancashire County Council, Blackburn with Darwen Borough Council, Blackpool Council. (2009). Joint Lancashire Minerals and Waste Development Framework Core Strategy Development Plan Document.
[189] Joint Lancashire Minerals and Waste Local Plan Site Allocation and Development Management Policies (2013). Lancashire Minerals and Waste Local Plan.
[190] Fylde Borough Local Plan (FBLP) (as altered), October 2005 (2005). Fylde Borough Council
[191] Fylde Local Plan to 2030 Part 1- Preferred Options (2013). Fylde Borough Council
[192] Fretwell, B., Haines, T., Glazier, J., and Marsland, T., 2012. Review of assessment procedures for shale gas well casing installation. Ref. LIT 7311. AMEC Environment and Infrastructure Ltd. for the Environment Agency, Bristol, UK. 87pp
[193] Kibble, A., Cabianca, T., Darajtchieva, T., Gooding, T., Smithard, J., Kowalczyk, G., McColl, N.P., Singh, M., Vardoulakis, S., and Kamanyire, R., 2013. Review of the potential public health impacts of exposures to chemical and radioactive pollutants as a result of shale gas extraction: draft for comment. Public Health England PHE-CRCE-002

involving hydraulic fracturing in Europe, AEA Technology/European Commission DG Environment.[194]

- Considine, T. et al., (2012) *Environmental impacts during Marcellus Shale gas drilling: causes, impacts and remedies*. Shale Resources and Society Institute[195].
- Environment Agency (2013a) *An Environmental Risk Assessment for shale gas exploratory operations in England*[196].
- Ewen et al, (2012) *Hydrofracking risk assessment: Study concerning the safety and environmental compatibility of hydrofracking for natural gas production from unconventional reservoirs*, Berlin.[197]
- The Royal Society and Royal Academy of Engineering (2012) *Shale gas extraction in the UK: a review of hydraulic fracturing*.[198]
- Stuart, M. (2012) *Potential groundwater impact from exploitation of shale gas in the UK*, British Geological Survey.[199]

41. The three studies of particular relevance to this assessment - EA ERA [196], PHE review [193] and the Royal Society report[198] - conclude there are risks associated with shale gas exploration, but with effective management by the operator and an effective regulatory system the residual risk is low.

42. In addition to the studies listed above many academic and peer-reviewed papers have been produced relevant to this assessment. These are referenced where appropriate in this chapter and the supporting appendix.

11.4.3 Baseline methodology

43. The current 'baseline' conditions relating to groundwater, surface water and ground gas relevant to the Project have been characterised by desk study and undertaking a site reconnaissance visit. Additional data gathering by ground investigation, groundwater and surface water monitoring and ground gas monitoring is also planned.

44. The assessment of baseline conditions has been based on analysis and interpretation of this information to understand the hydrogeological system and interconnections relevant to the Project both at regional scale considering the whole Fylde peninsula, and at local scale, in the vicinity of the Site. In particular it has considered the nature and properties of the individual geological units and how these relate to the risk of gas and fluid migration.

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[194] Broomfield, M., 2013. Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe. AEA Technology Plc. for the European Commission DG Environment, Harwell, UK. 292pp

[195] Considine, T., Watson, R., Considine, N., and Martin, J., 2012. Environmental impacts during Marcellus Shale gas drilling: causes, impacts and remedies. Shale Resources and Society Institute, Buffalo, New York, USA. 52pp

[196] Environment Agency (EA), 2013a. An Environmental Risk Assessment for shale gas exploratory operations in England. Ref. LIT 8474. EA, Bristol, UK. 32pp.

[197] Ewen, C., Borchardt, D., Richter, S. & Hammerbacher, R., 2012. Hydrofracking Risk Assessment (Executive Summary). Study concerning the safety and environmental compatibility of hydrofracking for natural gas production from unconventional reservoirs. 27pp.

[198] The Royal Society and The Royal Academy of Engineering, 2012. Shale Gas Extraction in the UK: a Review of Hydraulic Fracturing. Available. http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/projects/shale-gas/2012-06-28-Shale-gas.pdf.

[199] Stuart, M. E., 2011. Potential groundwater impact from exploitation of shale gas in the UK. British Geological Survey Open Report. Report number: OR/12/001.

45. The assessment of baseline soil, groundwater and ground gas conditions has included the review of past and present site uses, EA records of pollution incidents and site investigation, monitoring and surveying reports. Desk study research has been carried out in accordance with the relevant sections of British Standards codes of practice BS 10175[200], and the Defra/EA Contaminated Land Report 11 (CLR11)[201].

46. The following key data sources have been used in preparation of the hydrogeological and ground gas baseline:

- British Geological Survey (BGS) 1:50,000 geological maps (solid and drift) and accompanying geological memoirs for Blackpool, Garstang, Southport and Preston areas[202 203 204 205];
- BGS borehole logs from GeoIndex records[206] ;
- Environment Agency (EA) groundwater modelling reports for the Sherwood Sandstone 'Fylde Aquifer'[207];
- EA groundwater quality and groundwater level monitoring data for the Fylde[208] ;
- EA watercourse gauging points located throughout the Fylde [208];
- EA records of abstraction licences (groundwater and surface water), deregulated licences and discharge consents within the Fylde [208];
- Local Authority records of private water supplies (groundwater and surface water abstractions) within the Fylde[209];
- Meteorological Office rainfall data for four sites within the Fylde (Fairhaven, Fleetwood, Thornton and Squires)[208];
- A Landmark Envirocheck Report (ref 49702769_1_1)[210] ;
- Published technical papers and reports on Fylde geology and hydrogeology, referenced where appropriate.

47. The following data provided by Cuadrilla has been used in the preparation of the hydrogeological baseline:

- Well Prognosis: Preston New Road-01 (Appendix B);
- End of Well Reports for Cuadrilla wells[211 212] ;

[200] British Standards Institution (BSI), 2011. Investigation of potentially contaminated sites. Code of practice. Ref. BS 10175:2011+A1:2013. BSI, London, UK. 140pp.
[201] Department for Environment, Food and Rural Affairs (Defra), 2004. Model Procedures for the Management of Land Contamination (CLR 11). HMSO, London, UK.
[202] Wilson, A.A., & Evans, W.B., 1990. Geology of the country around Blackpool. Memoir of the British Geological Survey, Sheet 66 (England and Wales). HMSO, London, UK. 82pp.
[203] Aitkenhead, N., Bridge, D. McG., Riley, N. J. & Kimbell, S. F., 1992. Geology of the country around Garstang. Memoir of the British Geological Survey, Sheet 67 (England and Wales). HMSO, London, UK. 120pp.
[204] British Geological Survey (BGS), 1990. Garstang. England and Wales Sheet 67. Solid Geology. 1:50,000. BGS, Nottingham, UK
[205] British Geological Survey (BGS), 1975. Blackpool. England and Wales Sheet 66. Solid and drift edition with Bouguer anomalies. 1:50,000. BGS, Nottingham, UK.
[206] British Geological Survey (BGS), 2013c. GeoIndex borehole records [Online]. Available from: http://mapapps.bgs.ac.uk/ [Accessed 20/09/13].
[207] Mott MacDonald, 1997. Fylde Aquifer/Wyre Catchment Water Resources Study. Final report. Environment Agency, North West Region, Warrington.
[208] Environment Agency (EA), 2013d. Response to Arup data request, dated 24/07/13.
[209] Fylde Council, 2013. Response to Arup request for information relating to private water supplies, dated 16/07/13.
[210] Envirocheck, 2013. Landmark Envirocheck Report for a site at Plumpton. For Cuadrilla Bowland Ltd
[211] Cuadrilla Resources, 2012a. Grange Hill-1 End of Well Report. Ref. LJ/01-1Z.

- Borehole records for Thistleton-1[213] and Elswick-1[214] ;
- Baseline monitoring reports for Cuadrilla sites [215];
- Report for Cuadrilla by Sence Ltd. *Assessment of the potential for short term groundwater abstraction*[216];
- Report for Cuadrilla by de Pater and Baisch relating to Preese Hall seismicity[217]; and
- Relevant cross sections from Cuadrilla 3D geophysical survey (see ES Induced Seismicity Chapter).

48. Additional data and figures supporting the baseline characterisation are included in Appendix K.

11.4.4 Assessment methodology

49. Detailed information relating to well pad construction, well design and construction, hydraulic fracturing, well testing, decommissioning and monitoring was provided by Cuadrilla to inform this assessment.

50. Chapter 4 of this ES describes the project and, where necessary, Appendix K includes more detail of those aspects particularly relevant to this chapter:

- Appendix K2 - Activities on the well pad and in transit (such as spills of potentially polluting material);
- Appendix K3 - Well integrity (such as the well bore potentially providing a pathway for contaminants or gas to reach the shallow subsurface environment);
- Appendix K4 - Induced fractures (such as the potential for fractures to create pathways for contaminants or gas to reach the shallow subsurface environment);
- Appendix K5 – Ground gas migration.

51. The prescribed format for each chapter of this ES requires assessment of impacts at each of the following project stages:

- Construction of well pad and access;
- Installation of surface and buried arrays;
- Drilling;
- Hydraulic fracturing;
- Initial flow testing and extended flow testing;
- Decommissioning and restoration.

52. Therefore the assessment presented in this chapter considers each of these stages in turn, with risks at each stage being referenced to surface activities, well integrity and induced fractures, or a combination of these as appropriate.

53. It is important to note that this chapter assesses risks in terms of the impact and resulting effects and their probability of occurrence. There are no planned environmental impacts

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[212] Cuadrilla Resources. 2012b Preese Hall-1 End of Well Report. Ref. LJ/06-5.
[213] British Geological Survey (BGS), 2013c. GeoIndex borehole records [Online]. Available from: http://mapapps.bgs.ac.uk/ [Accessed 20/09/13].
[214] Pettit, W. and Christie, A.D., 1990. Geological Completion Report Elswick-1, Gas Council (Exploration) Ltd.
[215]Ground Gas Solutions (GGS), 2013. Shale Gas Exploration Site at Grange Hill, Singleton. Baseline Monitoring Report. Ref. GGS222-02/BMR1. GGS, Manchester, UK. 66pp.
[216] Sence Ltd., 2009. Proposed hydrofracturing of deep gas wells. Assessment of potential for short term groundwater abstraction.
[217] de Pater, C. J. & Baisch, S., 2011. Geomechanical Study of Bowland Shale Seismicity. Synthesis Report. For Cuadrilla Resources Ltd. 57pp.

resulting from the Project relevant to hydrogeology and ground gas, as described below. This is in contrast with other ES chapters, such as Noise and Transport, where certain impacts will unavoidably occur as a result of the Project.

54. The approach applied in the Environment Agency document *An environmental risk assessment for shale gas exploratory operations*[196] has been followed for this assessment, requiring:

- Identification of hazards and potential source-pathway-receptor (S-P-R) linkages;
- Estimation of the probability of the risk being realised;
- Identification of consequences;
- Estimation of the magnitude of the risk;
- Identification of the risk management options ('mitigation measures');
- Estimation of residual risk.

55. A conceptual model is created to describe the scenario in which the risks could occur. The conceptual model uses the S-P-R (Source-Pathway-Receptor) methodology as recommended by DEFRA[218] and promoted by the Royal Society[198] as best practice where:

- The source is the activity that can allow the risk from the hazard to be realised;
- The pathway is the route by which the source can reach the receptor; and
- The receptor is the specific component of the local environment and/or community that could be reached by the hazard.

56. For a risk to be realised, all three elements of the potential source-pathway-receptor (S-P-R) linkage must be present.

57. A number of the S-P-R linkages identified in the conceptual models presented in the assessment (Section 11.7) require several coinciding pathways to exist to realise the risk. Each of these constituent pathways has its own probability and consequence (i.e. a discrete risk), and the ultimate receptor could be described as indirect or secondary. Where multiple pathways are required to realise the risk the probability of all the required pathways coinciding must be considered. The probability of all the required pathways coinciding may be so low as to be considered negligible, i.e. there is no plausible linkage, and therefore it is not appropriate to assign a risk magnitude. This is the case for a number of potential risks initially identified (some as a result of public concerns) but after assessment (Section 11.7.7) are considered to have no plausible linkage.

58. Relevant receptors considered in this assessment are discussed in Section 11.6.13 and include the following:

- Groundwater;
- Surface water and supported ecology;
- Off-site human health;
- On-site human health (site workers and visitors);
- Crops and livestock.

59. The methodology for assessment of significance detailed below is based on the Environment Agency document *An environmental risk assessment for shale gas exploratory operations*[196]. This approach is also consistent with the Preston New Road Environmental Risk Assessment produced by Arup for DECC in parallel with this EIA.

[218] Department for Environment, Food and Rural Affairs (Defra), 2011. Guidelines for Environmental Risk Assessment and Management: Green Leaves III. 84pp

Table 11.2. Likelihood scale for hydrogeology and ground gas assessment.

Likelihood	Descriptor[196]	Comment/clarifications
High	Repeated occurrences expected	Very likely to occur in the short term and almost certain to occur over the long term. Repeated occurrences expected based on experience in comparable industries. Where no comparable industry experience is available, a cautious approach will typically be adopted to allow for uncertainty.
Medium	Can be expected to occur several times per year	An event is possible, but not inevitable, in the short term, and likely over the long term.
Low	Infrequent occurrence	The linkage occurring is by no means certain in the long term and is less likely in the shorter term. May have been reported in the past in other similar industries.
Very Low	Rarely encountered, never reported, or highly unlikely	It is improbable that an event would occur even in the long term. Very few, if any, industry examples are available.

Table 11.3. Consequence scale for hydrogeology and ground gas assessment

Consequence	Environmental descriptor[196]	Additional comments/clarifications
High	A major environmental incident resulting in significant damage to the environment and/or harm to human health.	Irreversible adverse change to an ecological receptor. Short term (acute) risk to human health likely to result in “significant harm” as defined by the Statutory Guidance to the Environment Protection Act 1990, Part 2A. Significant pollution of controlled waters as defined by the Environment Protection Act 1990, Part 2A.
Medium	Moderate, localised effect on people and/or the environment in the vicinity of the incident.	Moderate effect on a sensitive water resource characterised by a breach in a regulatory standard. A significant effect on an ecological receptor or ecosystem.
Low	Minor environmental effect which may breach a regulatory standard but is localised to the point of release with no significant impact on the environment or human health.	No effect to a high sensitivity receptor (for example a groundwater Source Protection Zone or SSSI).
Very Low	Slight environmental effect that does not exceed a regulatory standard.	No appreciable effect on human health.

Table 11.4 Risk magnitude matrix[196] (All risks in this Chapter are considered to be adverse).

Probability	High	Low	Medium	High	High
	Medium	Low	Medium	Medium	High
	Low	Low	Low	Medium	Medium
	Very Low	Low	Low	Low	Medium
		Very Low	Low	Medium	High
		Consequence			

60. In this assessment, based on professional judgement, significant environmental effects are those assessed to be either Medium or High. Where significant adverse effects have been identified further mitigation is likely to be required, as identified in Table 11.5.

Table 11.5 Description of risk magnitude and required action for hydrogeology and ground gas assessment.

Risk magnitude	Description/action
High	There is a high to medium probability that there is a pathway for the source to reach the receptor and result in significant adverse effect to a sensitive receptor or evidence exists of significant adverse effect to the receptor. Additional mitigation is required as a priority and may include further investigation to understand and, if appropriate, reassess the significance of the risk.
Medium	Risks must be acted upon, but they do not pose such an immediate threat and thus the project can continue while the risk response measures are integrated and/or performed. Additional mitigation may be required and mitigation may include further investigation to understand and, if appropriate, reassess the significance of the risk.
Low	Risks may not require additional responses – it may be effective enough simply to monitor the risk to ensure that it does not arise during the project description.

61. For each stage of the Project the conceptual model of potential S-P-R linkages is identified in the Assessment section (Section 11.7.1 to 11.7.6) and the probabilities and consequences are subsequently considered (Section 11.7.7 and 11.7.8).

62. When undertaking the risk assessment embedded mitigation (defined as mitigation which has already been implemented or is a confirmed part of the Project design) has been included. For example, the mitigation measures to be employed during well drilling and installation have been included in the assessment of potential pollutant linkages. Embedded mitigation considered as part of the Project is identified in the section below.

11.4.5 Embedded mitigation

63. Multiple measures to mitigate risk are embedded in the design of the proposed exploratory shale gas operations at the Site. Those aspects of embedded mitigation which are particularly relevant to hydrogeological and ground gas risks are identified below and

described in Appendix K. They have been sub-divided according to which element or aspect of the Project they are considered to apply to.

64. **Management and procedures**

- Cuadrilla's Health Safety, Security and Environment (HSSE) Risk Management Framework has been put in place to ensure management of operational risks. Site operational health and safety will comply with the provisions of the Borehole Sites and Operations Regulations 1995 (BSOR), and the implementation of the site health and safety procedures, record keeping, monitoring and auditing will be regulated by Health and Safety Executive (HSE). Any equipment malfunction or failure on site will be managed through implementation of the Cuadrilla HSSE Risk Management Framework. Site specific emergency response plans will enable rapid and appropriate response to unplanned events in coordination with local emergency services where necessary.
- Cuadrilla's Environmental Operating Standards (EOS) document sets out the standards and procedures for environmental management to which Cuadrilla is committed on all sites (see ES Chapter 4). Underneath the EOS, a site specific Environmental Management and Monitoring Plan (EMMP) will be prepared. The EMMP will include (amongst other things) monitoring locations, analytical suites and frequencies. The EOS and EMMP documents will provide a framework to implement all the measures identified as embedded mitigation by the EIA.
- The Site will be operated under an Environmental Permit, regulated by the EA that requires that the design and operation of the regulated activities on the Site meet the necessary standards described as Best Available Techniques (BAT).
- During operation, data collection and reporting to the relevant regulatory bodies (DECC, EA, HSE, BGS) will comply with existing statutory requirements under established systems, such as oil and gas petroleum operations notices (PON) and in addition information relating to hydraulic fracturing (such as post-fracture report) will be recorded for regulatory inspection.

65. **Mitigation associated with well pad and surface activities**

- The proposed Site drainage design and well pad containment system comprises a welded HDPE membrane overlain by a minimum 300mm thick layer of drainage stone, draining to perimeter ditches. Discharge to a watercourse via an interceptor would only occur with EA approval. The well pad containment capacity has been assessed by Arup (Appendix K) as adequate for the volume of potentially polluting materials on the pad.
- All potentially polluting materials used on the pad (including drilling fluid and arisings, hydraulic fracturing fluid and additives, flowback fluid, diesel fuel) will be stored in suitable vessels in designated locations on the pad and managed in accordance with good practice and regulatory requirements. Site spill kits and procedures will be in place with access to 24/7 emergency response.
- HGV routes for Site vehicles will be agreed with the relevant authorities, considering the potential for accidents and selecting the most appropriate route. Registered waste carriers will be used where appropriate.
- Baseline soil sampling (including naturally occurring radioactive material (NORM) analysis) to inform the initial Site Condition Report (for the environmental permit) and post decommissioning soil sampling to inform the final Site Condition Report to confirm remediation to a satisfactory state.

66. **Mitigation associated with well integrity**

- The Project wells will be drilled, constructed and integrity tested in accordance with regulatory requirements (DECC and HSE) and industry guidance (Oil and Gas UK and UKOOG) and Cuadrilla's Mining Waste Management Plan (approved and enforceable by the EA) to ensure drilling, fracturing, produced fluids and the target shale zone are isolated from groundwater receptors. The design will comprise a minimum two-barrier, cement-sealed well design with surface casing set below the Sherwood Sandstoneand additional intermediate casing set prior to entry into the target zone. Details of proposed well construction will be provided to an Independent Well Examiner for review and comment. Cuadrilla will then address any issues or queries related to well construction before proceeding to hydraulic fracturing. In addition, an end of well report (EOWR) will be produced by Cuadrilla at the end of well construction operations and provided confidentially to DECC. The EOWR provides a comprehensive account of well construction activities, including the well examination process. The EOWR is made public after four years.
- No hazardous substances (under the Groundwater Directive) will be used in drilling fluids above the Manchester Marls Formation. If needed, low toxicity oil based muds (LTOBM) will only be used below the Manchester Marls Formation and after installation of adequate isolation casings and cement, and with the approval of the Environment Agency.
- The protective barriers for new wells will be detailed in Cuadrilla's well programmes, summarised below. Appropriate verification will be performed during and following installation (i.e. pressure testing, FIT, and wireline logging such as CBLs) to confirm well integrity prior to hydraulic fracturing.
- During hydraulic fracturing and well testing operations, continuous pressure monitoring will be performed in uncemented annular space between production and intermediate casings to verify barrier integrity.
- Once a decision has been made to abandon the well, the proposed abandonment design will be developed in accordance with regulatory requirements at the time of abandonment and industry best practices. The well abandonment plan will be approved by the relevant regulators (DECC, HSE and EA) in advance of undertaking the works.

67. **Mitigation associated with hydraulic fracturing**

- A Hydraulic Fracturing Programme will be prepared in accordance with the requirements of DECC[219];
- In accordance with UKOOG guidelines, Cuadrilla will disclose the composition of the proposed fracturing fluid prior to use and will only use substances approved for use by the.
- Sampling and analysis of hydraulic fracturing fluid and flowback fluid will be undertaken and environmental monitoring testing suites will be reviewed and amended accordingly.
- Seismic monitoring will be undertaken before, during and after hydraulic fracturing activities to ensure mitigation of seismicity of a magnitude that could be felt at the surface. Monitoring results will be assessed using a traffic light system (TLS) in

[219] Department of Energy and Climate Change (DECC), 2014. Extended well tests and Hydraulic Fracture Plan [Online]. Available from: https://www.gov.uk/oil-and-gas-onshore-exploration-and-production [Accessed 8/4/14].

accordance with DECC guidance, which is proposed as part of the induced seismicity mitigation system, and has been designed to pause or stop well stimulation activities when threshold magnitude seismic events are induced (see ES Induced Seismicity Chapter).

- The propagation of fractures during well stimulation will be evaluated from data collected from a microseismic monitoring array network. During hydraulic fracturing activities, a sub-set of the microseismic monitoring data (i.e. the portion of the network providing real-time data) will be assessed. This assessment will be part of the decision making tools used to adjust the hydraulic fracturing operations, including duration and intensity of injection, to ensure that potential environmental impacts related to fracture propagation are adequately minimised (see ES Induced Seismicity Chapter).

68. **Mitigation comprising environmental monitoring**

- Monitoring of gas and groundwater in monitoring wells around the pad and in nearby surface watercourses will be undertaken prior to construction (baseline monitoring), during the well pad construction and well drilling, fracturing and flow testing, and decommissioning (well abandonment and site restoration) stages. The locations, frequencies, suites and methods of monitoring for gas and groundwater will be described in the Environmental Management and Monitoring Plan and be agreed with the EA. This is consistent with recommendations in recent reports by Public Health England[193] and EA[220] .
- Monitoring of ambient air on the drill pad and in the well cellar will be undertaken during operation and would indicate if significant volumes of ground gas were being released from the well casings at the surface.
- Whilst monitoring of abandoned wells is not a past or current regulatory requirement, groundwater monitoring at the Site will be performed for a minimum of one year following abandonment of the exploratory wells or in accordance with extant best practice or regulatory requirements at the time of abandonment.

69. For the remainder of this chapter the mitigation measures integral to the design and management of the Project listed above are assumed to be implemented. Thus these measures are considered when assessing risks in the assessment below.

11.5 Assumptions and limitations

70. The assumptions on which this assessment is based are in accord with recognised assessment methods for hydrogeology, subsurface contamination and ground gas issues.

71. When undertaking the risk assessment the measures to mitigate risk identified as ‘embedded mitigation’ have been assumed to apply.

72. The scheme parameters stated in Appendix B are assumed to apply to the Project.

73. It is assumed that Site management will be compliant with relevant health and safety legislation and will be regulated by the HSE. Risks to Site workers and visitors (‘on-site human health receptors’) associated with activities on the pad are not considered explicitly in this assessment.

[220] Environment Agency (EA), 2013b. Onshore oil and gas exploratory operations: technical guidance (consultation draft). EA, Bristol, UK. 33pp.

74. The assessment has been based on the interpretation of all available information on ground conditions. It is possible that other ground contamination or conditions, as yet undetected, may exist and consequently reliance on the findings of this report must be limited accordingly. Nonetheless it is considered that this does not significantly affect the robustness of the assessment.

11.6 Baseline

11.6.1 Topography, land use and surface water

75. Land use at the Site is agricultural grassland, currently used for grazing cattle. The nearest buildings to the Site are at Staining Wood Farm approximately 240m to the southwest (on the south side of the A583), Plumpton Hall and other properties in Little Plumpton approximately 400m to the east, and Moss House Farm, north of Moss House Lane 800m northwest of the site.

76. The Site is at an elevation of approximately 12.5mOD (relative to Ordnance Datum) and gently slopes to the northwest. The area including the Site drains towards a small tributary drain of Carr Bridge Brook (that starts approximately 250m northwest of the Site) and enters Carr Bridge Brook approximately 500m northwest of the Site. Carr Bridge Brook flows into Main Drain approximately 1.2km to the west. Main Drain flows in a north to south direction, discharging into the River Ribble estuary at Lytham St Anne's. Main Drain is referred to as Liggard Brook by the EA.

77. The EA has undertaken an assessment of the ecological and chemical status of major water courses in England and Wales, as required by the European Water Framework Directive (WFD)[171]. Those assessed nearest the Site include Liggard Brook (downstream of the minor road between Westby and Ballam) and the River Ribble, assessed in 2012[221]. The EA Water Framework Directive status objectives 2012 document[221] states the River Ribble and Liggard Brook have a moderate ecological status with no chemical status listed for either watercourse.

78. Several small ponds are present in the vicinity of the Site, likely to have been formed by excavating marl from Glacial Till for agricultural soil conditioning mainly in the nineteenth century. A marl pit pond is located in the same field as the Site, approximately 100m to the southeast. These ponds are likely to be used as drinking water by livestock and wild animals, to provide a habitat and potentially to irrigate the fields.

79. The section of the River Ribble into which Carr Bridge Brook discharges approximately 4km south of the Site, is part of the Ribble Estuary of Special Scientific Interest (SSSI), a Special Protection Area (SPA) and Ramsar Wetland Site.

80. There are no public rights of way across the land in the immediate vicinity of the Preston New Road Site.

[221] Environment Agency (EA), 2013e. Water Framework Directive – Surface Water Classification Status and Objectives [Online]. http://data.gov.uk/dataset/wfd-surface-water-classification-status-and-objectives [Accessed 18/09/13].

11.6.2 Superficial geology

81. The superficial deposits beneath the Site are glacial in origin. The BGS geological map indicates Glacial Till at the Site and extending for over 1km radius from the Site. The BGS 1:50,000 superficial geology mapping for the area is included in Appendix K.

82. British Geological Survey borehole records have been reviewed however there is no existing ground investigation information for the Site and the nearest available borehole records are approximately 1km northwest of the Site to the north of Moss House Farm on the M55. They show slightly sandy, slightly gravelly Clay to 3m depth; underlain by 4.1m of fine and medium Sand; below which is 1.6m of slightly sandy Clay, 4.1m of fine and medium Sand and then another sandy Clay to the base of the hole at 15m depth (-6.2mOD).

83. The nearest BGS borehole to Preston New Road that fully penetrates the superficial deposits is located 2km to the northwest at Mythop[213]. The log for this borehole does not describe the superficial deposits, however it does indicate the bedrock is at 34.1m depth (-21.9mOD). Other nearby boreholes which fully penetrate the superficial deposits are located at Weeton Camp (3km north), Kirkham (6km east) [213]. The thickness of the superficial deposits at these locations was relatively consistent, and ranged between 29 and 36m.

84. Site specific ground investigation would be required to fully understand the superficial stratigraphy at the Site (and will be undertaken when the groundwater monitoring wells are constructed. However the total thickness of superficial deposits overlying bedrock at the Site is likely to be around 30m. Considering the stratigraphy encountered across the Fylde three main stratigraphic units are predicted: Lower Boulder Clay, Middle Sands and Upper Boulder Clay. These distinct layers are illustrated in cross-sections presented in Appendix K1.

85. The **Lower Boulder Clay** is a heavily compacted purple-grey till, containing many erratics, and varies between 2 and 8m thick [222]. The Lower Boulder Clay is interpreted as being a 'lodgement till', which would have formed either by plastering of glacial debris from the sliding base of the moving ice sheet, or by continual shearing of soft sediment moving en masse beneath the ice.

86. The **Middle Sands** lie between the Upper and Lower Boulder Clay units. The principal lithology is sand with some gravel and local lenses of silt and clay[222]. Boreholes sunk along the M55 prove widespread but locally discontinuous sands of variable thickness beneath the surface tills. The formation of the Middle Sands has been interpreted as having been washed in underneath the ice sheet, which in its later stages is believed to have been floating on meltwater.

87. The **Upper Boulder Clay** occupies most of the surface outcrop of the glacial deposits, and is red-brown to blue-grey in colour. It is noticeably sandier and less compact in texture than the Lower Boulder Clay. The till locally contains thin sand layers[223] and laminated clay, silt and gravel[222]. This unit is typically 3 to 5m thick in western Fylde, and up to 20m thick in eastern Fylde. The Upper Boulder Clay has been interpreted as 'ablation till', settled after the meltwater at the base of the ice sheet drained away.

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[222] Aitkenhead, N., Bridge, D. McG., Riley, N. J. & Kimbell, S. F., 1992. Geology of the country around Garstang. Memoir of the British Geological Survey, Sheet 67 (England and Wales). HMSO, London, UK. 120pp.
[223] Wilson, A.A., & Evans, W.B., 1990. Geology of the country around Blackpool. Memoir of the British Geological Survey, Sheet 66 (England and Wales). HMSO, London, UK. 82pp.

88. Post-glacial deposits locally overlie the glacial deposits (see Appendix K Figure K1). These include peat, Marine and Estuarine Alluvium along the coast and extending inland up the estuaries of the rivers Wyre and Ribble, contemporary River Alluvium along the River Wyre, tributaries and along Main Dyke. Blown Sand is the most laterally extensive recent deposit though it is only present in coastal areas.

89. The superficial deposits in the Fylde have been exploited for peat cutting for fuel, for salt production by construction of salt pans along the estuarine River Wyre, and for marl extraction as a soil improver. The influence of marl extraction is widespread throughout the Fylde peninsula. The marl pits date from mainly the 18th and 19th century[224] to obtain calcareous clay, which was used as a source of lime to treat the naturally acidic soil at the surface. These pits were dug down on three sides with a working access area, are typically 3 to 5m deep and 10 to 30m wide, and subsequently became water filled.

11.6.3 Bedrock geology

90. The BGS solid geology mapping for the Fylde area is shown on Figure 1 (and Appendix K Figure K3) and indicates Triassic Mercia Mudstone at the Site. A cross section through central Fylde produced by the BGS[225] is shown on Appendix K Figure K4.

91. The predicted geology at the Preston New Road Site has been assessed by Cuadrilla using 3D geophysical survey data and geological data from deep wells in the region and is summarised in Table 11.6.

Table 11.6 Summary of geology at the Site (see Appendix B).

	Unit	Formation Top (TVDGL)	Thickness (m)
	Superficial deposits	-	30
Triassic	Mercia Mudstone Group	30	260
	Sherwood Sandstone Group	290	840
Permian	Manchester Marls	1130	160
	Collyhurst Sandstone	1290	60
Carboniferous	Millstone Grit	1350	190
	Upper Bowland Shale	1540	390
	Lower Bowland Shale	1930	810
	Hodder Mudstone	2740	-

92. The geological unit descriptions summarised below are taken from British Geological Survey Memoir for the country around Blackpool[226] and BGS memoir of Geology of Southport and Formby[227] unless otherwise stated.

[224] Day, P., Deadman, A. J., Greenwood, B. D. & Greenwood, E. F., 1982. A floristic appraisal of marl pits in parts of north-western England and northern Wales. Watsonia. 14, 153-165.
[225] British Geological Survey (BGS), 1990. Garstang. England and Wales Sheet 67. Solid Geology. 1:50,000. BGS, Nottingham, UK.
[226] Wilson, A.A., & Evans, W.B., 1990. Geology of the country around Blackpool. Memoir of the British Geological Survey, Sheet 66 (England and Wales). HMSO, London, UK. 82pp.
[227] Wray, D. A., and Cope, F. W., 1948. Geology of Southport and Formby. Memoir of the Geological Survey of Great Britain, Sheets 74 and 83 (England and Wales).

Mercia Mudstone (Triassic)

93. The Mercia Mudstone is subdivided into four formations in the area:

- The Hambleton Mudstone at the base (grey interlaminated mudstones and siltstones);
- The overlying Singleton Mudstone (reddish brown and structureless);
- Overlain by the Kirkham Mudstones (banded reddish brown and greenish grey mudstones interlaminated with siltstones); and
- The youngest of the Mercia Mudstone formations, the Breckells Mudstones (dominantly reddish brown and structureless)[226].

94. Halite beds are present in the Singleton and Kirkham Mudstones. At Preesall near Fleetwood, salt has been extracted by groundwater solution for industrial purposes[226]. Storage of gas in salt caverns in the Preesall Fleetwood area has been considered but not implemented.

Sherwood Sandstone Group (Triassic)

95. The Sherwood Sandstone is a thick sandstone sequence, described by the BGS as a red to red-brown and fine to medium-grained sandstone with occasional subordinate coarser beds[222.] Red silty mudstone beds, no thicker than 0.6m, are present with flakes or sub-angular clasts of similar mudstone present rarely within the sand units. The Sherwood Sandstone Group comprises the Ormskirk Sandstone and St Bees Sandstone, however they are not differentiated in this assessment.

Manchester Marls Formation (Permian)

96. The Manchester Marls Formation underlies the Sherwood Sandstone Group and is described by the BGS as '*a red marl (calcareous mudstone and siltstone) with thin beds of fossiliferous marine limestone and dolomite; locally green; sandy in places especially in top part; local breccias and pebbly beds.*'[228] The thickest evaporites occur in the Elswick graben where beds up to approximately 30m thick are present. In the Elswick-1 well log[Error! Bookmark not defined.] it is described as siltstone and claystone with minor anhydrite, dolomite and halite.

Collyhurst Sandstone (Permian)

97. The Collyhurst Sandstone is described as fine to very coarse conglomerate with abundant shale clastics and red brown limestone (generally argillaceous and crystalline) within a sandstone matrix and interbedded with red brown fine to medium sandstone containing intraclasts of mudstone and other pebbles and thinner beds of mudstone and crystalline limestone[222]. The thickness of the Collyhurst Sandstone varies considerably in the Fylde area. The Thistleton-1 borehole does not encounter this unit, however at the Elswick-1 well it is recorded as over 500m thick.

Lower Coal Measures Formation (Carboniferous)

98. The Lower Coal Measures Formation is absent across most of the Flyde area. While the Lower Coal Measures are not encountered in the Grange Hill-1, Elswick-1 and Thistleton-1 wells or prognosed at the Site, a 20m thick sequence of black mudstones was recorded in the Preese Hall-1 well.

Millstone Grit (Carboniferous)

99. The Millstone Grit comprises fine to very coarse grained feldspathic sandstones, interbedded with grey siltstones and mudstones, with subordinate marine shaly mudstone,

claystone, coals and seatearths[228]. The Millstone Grit also includes potentially gas-bearing shale units including the Sabden Shale and Upper Shale.

Craven Group (Carboniferous)

100. The Bowland Shale is composed of two units, the Upper Bowland Shale Formation and the Lower Bowland Shale. The Upper Bowland Shale Unit is described as:

101. "*Lithologically, the greater part of the formation consists of thinly interbedded, dark, fissile mudstone and weakly calcareous and dolomitic, blocky or platy silty mudstone and siltstone. In some parts of the sequence the carbonate content is higher, to the extent that locally mappable argillaceous limestones and dolomites occur… with individual beds up to 0.70m thick.*"[226]

102. The Lower Bowland Shale is composed of mudstone with variable amounts of sandstone and limestone. The BGS memoir for the country around Garstang describes the Lower Bowland Shale as:

103. "*Black, calcareous, foetid and petroliferous. Pyrite is common along joints and sometimes replaces bioclasts. Internal lamination is prevalent and the mudstones may be blocky or shaly. Fissile paper shales, which are so characteristic of the surrounding formation, are unusual. Interbedded limestones include argillaceous wackestones, packstones and breccias; sharp-based graded beds are common at some levels in the sequence. Nodular wackestones or "bullions", which result from localised early cementation of the mudstone, occur at discrete horizons. Fossils recovered from these nodules are undistorted by compaction and any fractures or cavities commonly bleed with mineral oil when freshly broken. The black mudstones at the base of the formation show a marked colour change from the pale and dark grey, locally olive and blue –grey colour of the Worston Shale Group, accompanied by a conspicuous reduction in bioturbation.*"[222]

104. The Hodder Mudstone underlies the Lower Bowland Shale and the BGS Lexicon of Named Rock Units describes the Hodder Mudstone as follows:

105. "*Predominantly grey to dark grey mudstone, with subordinate and variable detrital limestone, siltstone and sandstone. Mudmound reef (Waulsortian) limestones, limestone boulder conglomerates and breccias locally, near the base. Soft sediment deformation, slumps, debris flows and gravity slides are widespread.*" [228]

106. The effective porosity of samples from Bowland Shale and Hodder Mudstone averages 2.8% and the water saturation averages 25%. The average matrix permeability is 1E-5 md (millidarcy) and there is a good correlation between gas filled porosity and unconfined matrix permeability[229].

11.6.4 Geological structure

107. The Site is located within the geologic structural domain known as the Bowland Basin, a geological depositional basin predominantly active in the Carboniferous Period (c.300 to 360ma (million years ago)). The basin is defined by faults to the northeast (Craven) and

[228] British Geological Survey (BGS), 2014. Lexicon of named rock units [Online]. Available from: http://www.bgs.ac.uk/Lexicon/ [Accessed 11/03/14].
[229] Clarke, H., Turner, P., and Bustin, R.M., 2013. Unlocking the Resource Potential of the Bowland Basin, NW England. SPE 14UNCV-167776-MS. SPE/EAGE European Unconventional Conference and Exhibition held Vienna, Austria, 25–27 February 2014.

south (Pendle). Within the Bowland Basin itself are a series of smaller extensional faults striking roughly northnortheast-southsouthwest across the region[230] [222]. The Woodsfold Fault is shown on the BGS published mapping approximately 8km east at the surface (see Appendix K Figure K3). Geological structure is described in more detail in the ES Chapter on Induced Seismicity.

11.6.5 Groundwater in superficial deposits

108. Considering the superficial deposits expected at the Site, only the granular deposits (the Middle Sands) will contain significant groundwater. Groundwater flow direction in superficial deposits is likely to be westwards towards the Main Drain watercourse and the coast. Until ground investigation is undertaken at the Site, as proposed for drilling of environmental monitoring boreholes, the geological stratigraphy and groundwater flow direction will not be known in detail.

109. Groundwater quality within the superficial deposits is expected to be of good quality, as it will be relatively recent rainfall recharge, and could potentially be used for water supply, although obtaining an adequate sustainable yield may not be possible.

110. Groundwater within the superficial deposits is unlikely to be in hydraulic continuity with watercourses due to the low permeability of the Upper Boulder Clay. Similarly the man-made marl pit ponds within close proximity of the Site are unlikely to be groundwater fed as they were excavated to obtain calcareous clay ('marl').

111. The EA aquifer classification[231] identifies the glacial till deposits, mapped at surface at the Site, as Unproductive Strata, with predominantly granular deposits such as Middle Sands as Secondary A Aquifer (Appendix K Figure K9). The EA has not identified any groundwater vulnerability classification due to the presence of Unproductive Strata at surface.

112. The West Lancashire Quaternary Sand and Gravels Aquifer is defined by the EA as a groundwater body under the Water Framework Directive and is identified as present across the central Fylde area[232]. It is identified as having good quantitative and chemical status and predicted to have good quantitative and chemical status in 2015. This groundwater body is referred to in this ES chapter as the Middle Sands.

11.6.6 Groundwater in bedrock

Mercia Mudstone

113. The Mercia Mudstone Group that immediately underlies the superficial deposits comprises predominantly mudstone and siltstone having low permeability and is predicted to be approximately 260m thick at the Site. Some fracture flow may occur in this unit but, due to its low permeability, it is unlikely to yield groundwater at useful quantities. Furthermore the quality of the groundwater is likely to be poor due to dissolution of salt minerals. The EA classify the Mercia Mudstone Group as a Secondary

[230] Andrews, I. J., 2013. The Carboniferous Bowland Shale gas study: geology and resource estimation. British Geological Survey for Department of Energy and Climate Change, London. 56pp.
[231] Environment Agency (EA), 2013c. What's in your backyard? [Online] Available from: http://www.environment-agency.gov.uk/homeandleisure/37793.aspx [Accessed 15/08/13].
[232] Environment Agency (EA), 2009a. Water for life and livelihoods. River Basin Management Plan, North West River Basin District. EA, Bristol, UK. 83pp.

B aquifer (Appendix K Figure K10) and it is not defined as a groundwater body under the Water Framework Directive. The Mercia Mudstone beneath the Site is not considered a groundwater receptor in this assessment due to its low permeability and poor quality.

Sherwood Sandstone

114. At the Site the Sherwood Sandstone underlies the Mercia Mudstone at approximately 290m depth. In the Fylde area the north-south trending faults are reported to act as barriers or partial barriers to flow in the Sherwood Sandstone[233]. The overlying low permeability Mercia Mudstone reduces infiltration recharge to the Sherwood Sandstone. Consequently the Sherwood Sandstone groundwater beneath the Site is effectively isolated.

115. As it receives little recharge where overlain by Mercia Mudstone the Sherwood Sandstone groundwater beneath the Site is likely to be old and to contain a high mineral content, from processes such as sandstone cement dissolution and interaction with the overlying Mercia Mudstone[234 235]. Groundwater quality data from an EA observation borehole at Kirkham indicates chloride concentration of 53,000mg/L to 91,000mg/L, compared to drinking water standard of 250mg/L, indicating that the Sherwood Sandstone is saline west of the Woodsfold Fault (Appendix K1). It is technically not possible to collect a representative sample of groundwater from the Sherwood Sandstone during drilling of the exploration wells; however geophysical logs will be interpreted to assess conductivity to provide an indication of salinity.

116. Approximately 8km east of the Site, across the Woodsfold Fault, the Sherwood Sandstone is near the surface, not overlain by Mercia Mudstone, and Sherwood Sandstone groundwater is of potable quality and used for public supply.

117. The EA classifies the Sherwood Sandstone as a Principal Aquifer (Appendix K Figure K10) and to the east of the Woodsfold Fault is defined as a groundwater body under the Water Framework Directive[232]. For this assessment the Sherwood Sandstone beneath the Site is considered a potential receptor. However it is important to note the specific conditions of the Sherwood Sandstone in this location (present at over 290m depth and probable poor quality) means it has low potential for future exploitation as a resource.

118. The possibility of using aquifer storage and recovery (ASR) has been considered, as has been implemented elsewhere in poor quality Sherwood Sandstone (e.g. Yorkshire Water Loftsome Bridge ASR scheme). ASR is a water resources management technique where a large quantity of potable water is injected into poor quality groundwater, displacing the poor quality water and enabling it to be stored and then pumped out when needed in the future, effectively creating an underground reservoir of good quality water. The Fylde is considered unlikely to be a suitable area for implementing ASR for a number of reasons, notably the source of potable water (usually an existing large capacity water treatment works) must be close to the target location, and the poor quality target location must be at shallow depth to keep drilling and pumping costs low. West of the Woodsfold Fault the

[233] Seymour, K. J., Ingram, J. A. & Gebbett, S. J., 2006. Structural controls on groundwater flow in the Permo-Triassic sandstones of NW England . Geological Society, London, Special Publications. 263, 169-185.
[234] Griffiths, K. J., Shand, P. & Ingram, J., 2003. Baseline Report Series: 8. The Permo-Triassic Sandstones of Manchester and East Cheshire. British Geological Survey Commissioned Report. Ref. CR/03/265N. BGS, London, UK. 51pp.
[235] Sage, R. C. & Lloyd, J. W., 1978. Drift deposit influences on the Triassic Sandstone aquifer of MW Lancashire as inferred by hydrochemistry. Quarterly Journal of Engineering Geology and Hydrogeology. 11, 209-218.

Sherwood Sandstone is likely to be poor quality, however it is present at great depth and ASR is highly unlikely to be cost effective. The 2013 United Utilities Water Resources Management Plan[236] does not consider ASR as a future supply option in the Fylde area, stating that *"ASR and Artificial Recharge scheme types are considered to offer no significant advantage over development of new boreholes. There is generally adequate water available within the existing aquifer systems and so the need for any artificial recharge in the North West at present is considered unnecessary".*

Manchester Marls Formation

119. The Manchester Marls Formation underlying the Sherwood Sandstone Group is a mudstone or siltstone with subordinate sandstone units. In the Elswick-1 well log[Error! Bookmark not defined.] it is described as siltstone and claystone with minor anhydrite, dolomite and halite, suggesting a very low permeability unit. It acts as a cap rock to the Collyhurst Sandstone gas reservoir at the Elswick-1 well, forming a conventional gas reservoir. The Manchester Marls Formation is continuous across the entire Project area (see ES Induced Seismicity Chapter), effectively forming a barrier to upward flow.

Collyhurst Sandstone

120. Where it occurs at outcrop, such as in Manchester, the Collyhurst Sandstone is defined by the EA as a Principal Aquifer. However at the Site, groundwater within the Collyhurst Sandstone is highly unlikely to be utilised for water supply in the future due to its great depth, the presence of hydrocarbons and likely elevated salinity of groundwater. It is also highly unlikely that the Collyhurst Sandstone is contributing to, or in hydraulic continuity with, shallow groundwater or surface water bodies, due to its great depth and the presence of the overlying Manchester Marl. Data from deep wells across the Fylde (including Thistleton-1, Elswick-1 and Cuadrilla wells) identified only traces of hydrocarbons above the Manchester Marls Formation but significant hydrocarbons below, which is further evidence of the capping properties of the Manchester Marls Formation[212 237 238].

Millstone Grit

121. Where it occurs at outcrop, such as in the Pennines, the Millstone Grit can be used as a source of groundwater supply from wells or abstraction boreholes and it is designated by the EA as a Secondary A Aquifer. Where the Millstone Grit is utilised as a source of water supply porosity has been measured to be between 24% and 36%[239] . This is significantly greater than measured porosity in the Millstone Grit in the deep Fylde wells, where the gas-saturated Millstone Grit sandstones, shales and gritstones are characterised by low porosity (<10%) and permeability (<1.0x10-1 md)[240].

[236] United Utilities, 2013. Draft Water Resources Management Plan 2013. United Utilities Water PLC.
[237] British Geological Survey (BGS), 2013c. GeoIndex borehole records [Online]. Available from: http://mapapps.bgs.ac.uk/ [Accessed 20/09/13].
[238] Pettit, W. and Christie, A.D., 1990. Geological Completion Report Elswick-1, Gas Council (Exploration) Ltd.
[239] Jones, H. K., Morris, B. L., Cheney, C. S., Brewerton, L. J., Merrin, P. D., Lewis, M. A., MacDonald, A. M., Coleby, L. M., Talbot, J. C., McKenzie, A. A., Bird, M. J., Cunningham, J. & Robinson, V. K., 2000. The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report. Report number: WD/00/4.
[240] Cuadrilla Resources, 2014. A geological summary of the information acquired in PEDL165 relating to the Millstone Grit, internal memo.

122. Therefore, at the Site, groundwater within the Millstone Grit is highly unlikely to be utilised for water supply in the future due to its great depth, low porosity and permeability and the presence of hydrocarbons and elevated salinity.

11.6.7 Influence of faults on hydrogeology

123. Faulting is a feature of the structural geology of the Fylde peninsula, as discussed above. This has an impact on the hydrogeology of the area, especially with regard to horizontal groundwater flow.

124. The Woodsfold Fault has a major influence on groundwater flow. The EA Fylde Aquifer groundwater model[241] covers the area of subcropping Sherwood Sandstone east of the Woodsfold Fault and north to the coast. The model uses the Woodsfold Fault as part of its western boundary, modelled as being impermeable, i.e. no significant groundwater flows across the fault. To refine the model calibration, the EA commissioned the BGS to produce structural maps using surface geophysical data and in addition new observation boreholes were drilled in areas of significant uncertainty[241 233]. The results of these investigations supported the hypothesis of the absence of flow across the Woodsfold Fault. Seymour et al. (2006)[233] reviewed the modelling data and concluded that '*the marked anisotropy in aquifer permeability caused by North-South faulting effectively isolated the UU* [United Utilities] *abstractions from the aquifer to the west*'. Mechanisms for producing low permeability across faults were noted to include the juxtaposition of different lithologies, granulation seams and fault plane infill.

125. East of the Woodsfold Fault, the groundwater levels and contours show the effect of long term groundwater abstraction at locations where there are centres of abstraction, for example around Garstang and Catterall. In the south the effect of north-south faulting is evident from the September 2010 groundwater contours (Appendix K Figure K6), with sharp changes in groundwater level across some of the mapped faults.

126. There is very little information on the Sherwood Sandstone in the area of central and western Fylde (including the Site). Groundwater contours have not been drawn for this area as there is very little data on groundwater levels in the Sherwood Sandstone. To the west of the Woodsfold Fault, owing to the great depth of the Sherwood Sandstone and the absence of any abstractions, the EA has only one monitoring borehole within the confined Sherwood Sandstone, located at Kirkham. The borehole log (BGS reference SD43SW6)[237] indicates that it is 445m deep and that the Sherwood Sandstone aquifer is confined below the Mercia Mudstone. The top of the Sherwood Sandstone is at 290m depth. EA hydrographs indicate that groundwater level in the Sherwood Sandstone Group immediately to the east of the fault is approximately 5 to 10mOD (relative to ordnance datum) in September 2010 (Appendix K Figure K6). Data from the Kirkham monitoring well indicates that the groundwater level to the west of the fault was at -16.8mOD in September 2010, a difference of 20 to 30m across the fault, which supports the hypothesis of the Woodsfold Fault forming a flow barrier. Groundwater quality data from the EA Kirkham observation borehole noted above provides evidence that the Sherwood Sandstone west of the Woodsfold Fault is saline and isolated from the good quality groundwater east of the fault.

[241] Mott MacDonald, 1997. Fylde Aquifer/Wyre Catchment Water Resources Study. Final report. Environment Agency, North West Region, Warrington.

11.6.8 Abstraction of groundwater and surface water

127. Groundwater is not widely exploited in the central and western Fylde, as shown on Figure 1 (and Appendix K Figure K7). The nearest recorded groundwater abstractions to the Site are from the superficial deposits for spray irrigation at Lytham Green Golf Club (approx. 4.5km to the south), Royal Lytham and St Anne's Golf Club (approx. 5.5km to the southwest) and St Anne's Old Links Golf Course (approx. 6km to the west)[208]. The geological map[225] indicates the near surface superficial deposits in the area of these abstractions is blown sand and it is likely that this deposit forms the groundwater bearing unit these abstractions draw from.

128. Approximately 5km to the northwest, Four Seasons Fisheries Ltd. also abstracts groundwater from the superficial deposits from two boreholes for pond top up water[208]. It is possible this abstraction draws from the Middle Sands however no geological logs of the boreholes are available.

129. The nearest recorded abstraction from the Sherwood Sandstone to the Preston New Road site is at Salwick Works, approximately 9km east and east of the Woodsfold Fault, shown on Figure 1. United Utilities operates a groundwater wellfield for public water supply abstracting from the Sherwood Sandstone aquifer to the east of the Woodsfold Fault. The nearest public supply borehole to the Site is located over 14km to the east and the outer edge of the nearest Source Protection Zone is located approximately 9km to the east (Appendix K Figure K8).

130. BGS borehole records, available online, indicate a number of boreholes have been drilled with the objective of providing water supply for farms and businesses in the central Fylde area[213]. However, these locations are not recorded as licensed abstractions or registered private water supplies, suggesting they were not developed as water supply boreholes possibly due to low yield or poor groundwater quality. It is possible other groundwater abstractions may exist, however to be unrecorded by the Environment Agency and local authorities they must supply less than $20m^3/d$, not be used for drinking water and have been developed since 2005 (when licensing rules changed). Deregulated abstractions, not requiring a licence after 2005, are also shown on Figure 1.

131. The nearest licensed surface water abstraction to the Site is approximately 3.5km to the south for agricultural spray irrigation. However the location is not located on a watercourse downstream of the Site. Therefore there are no recorded surface water abstractions relevant to the Site.

11.6.9 Groundwater-surface water interaction

132. Interaction between groundwater in the Sherwood Sandstone and surface water (rivers and watercourses) west of the Woodsfold Fault are unlikely, as the Sherwood Sandstone is overlain by Mercia Mudstone and low permeability glacial deposits across most of the area. To the east of the Woodsfold Fault, where the Mercia Mudstone is not present, the EA groundwater modelling report[241] notes that groundwater base flow discharges to the River Wyre and River Ribble.

133. There may be some discharge locally of groundwater from superficial deposits into surface watercourses. However in the vicinity of the Site the watercourses are realigned in ditches cut into the clay-rich glacial deposits and little groundwater-surface water interaction is expected.

11.6.10 Anthropogenic influences and historical land uses

134. Possible sources of soil or groundwater contamination as a result of previous land uses and activities have been assessed and are described below. Potential ground gas sources are considered in the following section. An Envirocheck Report was obtained for the Site which includes historical mapping and collates information stored on environmental databases[210].

135. There are no reported pollution incidents or waste transfer sites within 500m of the well pad. There is one consented discharge for treated sewage to watercourse within 500m, approximately 460m southwest at Staining Wood Farm. This discharge will not affect or be affected by the proposed development due to distance from the Site and the small size of the discharge.

136. Land use on and around the Site has remained relatively unchanged since the earliest Ordnance Survey mapping (1847) and has been used for agriculture. Numerous marl pits have been excavated, many now forming ponds, although over 20 pits have been infilled within 500m of the Site. One historical landfill is recorded by the EA approximately 600m southwest of the Site identified as 'Staining Wood Farm'. The EA records show a small circular area that corresponds with a marl pit, tipped with inert and industrial waste between 1986 and 1988.

137. Deep boreholes that penetrate the Manchester Marls Formation have the potential to act as a flow path for naturally poor quality groundwater and for ground gases from depth. Over the last four decades a number of deep boreholes have been drilled with the objective of hydrocarbon exploration in central and western Fylde. However the nearest of these to the Site is approximately 4km to the north, outside the area of possible influence from the Site.

138. The review of historical land use and activities has not identified any significant adverse possible effects on soil, groundwater or surface water quality at the Site. The environmental permit application will include a Site Condition Report that establishes pre-development quality of the Site and includes soil chemical testing. Baseline monitoring of groundwater and surface water will also be undertaken as described in 11.6.12 below.

11.6.11 Ground gas sources

139. It is important to establish the pre-development (baseline) condition of the Site relating to ground gas. Hazardous ground gases may be present in the ground in the vicinity of the Site associated with a range of possible anthropogenic and natural sources.

140. The possible ground gas sources located above the Manchester Marls Formation are:

- Shallow anthropogenic ground gas sources are shown in Appendix K Figure K13 and include the low and medium gas mains along the A583 and the high pressure gas main located 300m south of A583 and made ground (off-site infilled marl pits). Infilled marl pits are considered unlikely to be generating significant quantities of hazardous ground gases. Gas pipelines are a potential source of methane if leaks are present, however any significant leaks should be detected and repaired by the operator; and
- Superficial deposits. The gas generation potential of the superficial deposits at the Site is likely to be low.

141. Methane sources below the Manchester Marls are likely to be thermogenic in origin (see Appendix K5) and are:

- The Millstone Grit Group, particularly the Upper Shale and Sabden Shale units;
- The Bowland Shale and Hodder Mudstone, the target formations for Preston New Road exploratory drilling;
- The Collyhurst Sandstone, which acts as a gas reservoir at Elswick-1 well.

142. The Indicative Atlas of Radon in England and Wales[242] identifies the Fylde Peninsula as having between 0% and 1% of homes above the action level (of 200Bq/m^3). The map is based on geological mapping and the results of radon monitoring in homes and suggests that baseline radon levels in the shallow soils in the Fylde area are likely to be low.

143. Radon is likely to be present in ground gas from sources below the Manchester Marls Formation as a result of the higher concentrations of the ultimate source of radon, uranium, in shale (relative to other local rocks). Radon has a short half-life of 3.8 days and therefore concentrations quickly decline with distance from the source.

144. Further detail relating to ground gas baseline is presented in Appendix K5.

145. Baseline monitoring of ground gas in environmental monitoring wells around the well pad will also be undertaken as described in 11.6.12 below.

11.6.12 Monitoring of baseline

146. Groundwater and ground gas monitoring wells will be constructed around the well pad to monitor baseline and operational ground gas and groundwater conditions when appropriate permissions are secured (e.g. planning consent). The detailed monitoring scope and reporting procedures will be agreed with the regulators in advance and presented in the Environmental Management and Monitoring Plan (EMMP). Monitoring will be undertaken by a specialist contractor for Cuadrilla to define baseline conditions, as follows:

- Three boreholes will be drilled around the well pad perimeter, within the fence line. The first borehole will be drilled to prove the top of the Mercia Mudstone and to understand the superficial geological sequence;
- Dual installations are proposed in each of the three boreholes with one standpipe installed in the deeper granular fluvioglacial deposits and the other installed in the shallower superficial deposits, resulting in 6 monitoring wells suitable for ground gas and groundwater monitoring;
- Baseline monitoring period (pre-site development) for a duration and frequency adequate to establish baseline;
- Continuous gas and groundwater monitoring and sampling and laboratory analysis of gas from the monitoring well headspace and dissolved gas in groundwater;
- Sampling and laboratory analysis of groundwater quality;
- Surface water sampling and analysis from 4 to 6 appropriate locations for a duration and frequency adequate to establish baseline;
- Soil sampling and analysis from the well pad area to establish baseline soil quality.

[242] Miles, J. C. H., Appleton, J. D., Rees, D. M., Green, B. M. R., Adlam, K. A. M. & Myers, A. H., 2007. Indicative Atlas of Radon in England and Wales. Didcot, Oxfordshire, Health Protection Agency. Report number: HPA-RPD-033.

11.6.13 Groundwater receptors and other relevant receptors

147. The EA has stated (see scoping report response) that groundwater receptors that should be considered in this ES are the same as for environmental permitting, defined as all groundwater bearing formations where fluid entering those formations could be considered a groundwater activity under the Environmental Permitting Regulations. 'Groundwater' is defined in European and domestic legislation as '*all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil*'.

148. Groundwater in the granular horizons of the superficial deposits, referred to as the Middle Sands to be consistent with observations elsewhere in Fylde, is considered a groundwater receptor in this ES. By protecting groundwater quality in the Middle Sands, any current or future groundwater abstractions are also protected. Therefore groundwater abstractions are not considered as a discrete receptor in this assessment.

149. Groundwater in the Sherwood Sandstone is also considered a groundwater receptor in this ES. The Sherwood Sandstone in this location is very unlikely to be utilised as a groundwater resource (as it lies at over 250m depth and the water is of poor quality (see Section 11.6.6), and has no significant interaction with Middle Sands groundwater or surface water.

150. The Millstone Grit and Collyhurst Sandstone could be considered as containing 'groundwater' in accordance with the legal definition. However, as discussed in the baseline characterisation above, the units beneath the Manchester Marls Formation are isolated from Middle Sands groundwater and also from the deeper Sherwood Sandstone groundwater. A release as a result of the Project into the Millstone Grit and Collyhurst Sandstone would result in no perceivable environmental impact and they are therefore not considered as specific groundwater receptors subsequently in this ES. As a prudent approach Cuadrilla will apply for a groundwater activity permit in relation to the Millstone Grit (under the Environmental Permitting Regulations).

151. Surface water receptors include watercourses in the vicinity of the Site, the closest being a small tributary drain of Carr Bridge Brook (that starts approximately 250m northwest of the Site) and enters Carr Bridge Brook approximately 500m northwest of the site. Carr Bridge Brook flows into Main Drain approximately 1.2km to the west, eventually discharging into the River Ribble estuary east of Lytham. Marl pit ponds were excavated into clay and therefore will have little, if any, hydraulic conductivity with superficial groundwater. Watercourses and ponds are potentially direct receptors from surface/overland flow and potentially indirect receptors via groundwater discharge.

152. Direct human health receptors relevant to this assessment are: persons exposed to liquid contaminants released by a spray or jet from equipment; and persons exposed to ground gas accumulation via shallow soil (included as pathway via ground or groundwater). Indirect human health receptors are: a person off site exposed to contaminated water in a watercourse; persons off site exposed to spilled fluids following a road accident

153. Crops and livestock outside the Site boundary are also considered receptors in the assessment.

154. Operational health and safety risks to Site workers and visitors outwith the scope of this assessment are nonetheless addressed by Cuadrilla's Health Safety Security and Environment (HSSE) Risk Management Framework (see Chapter 4) and other legislation (such as Borehole Sites and Operations Regulations 1995) and regulated by the HSE.

11.7 Assessment

155. The assessment methodology described in Section 11.4.4 is applied in this section. The structure of this chapter must be consistent with the other ES chapters and therefore this section considers each Project stage in turn:

- Construction of the Site
- Installation of arrays
- Drilling
- Hydraulic fracturing
- Flow testing
- Decommissioning and restoration.

156. The Assessment presented below considers each of these stages in turn, with risks at each stage being grouped into risks associated with:

- Activities on the well pad and in transit, such as spills of potentially polluting material (see Appendix K2);
- Well construction and integrity, such as the well bore providing a pathway for contaminants (see Appendix K3); and
- Induced fractures, such as the potential for fractures to create pathways for contaminants (see Appendix K4).

157. For each stage of the Project conceptual models (presented as tabulated Source-Pathway-Receptor linkages) are presented.

158. In Sections 11.7.1 to 11.7.6 the hazards and potential sources relevant to each stage of the Project are identified and the conceptual models are presented. The probability of the risks being realised and the potential consequences are considered separately (in Section 11.7.7 and Section 11.7.8) to avoid repetition.

159. Table 11.7 summarises which risks are relevant at each stage, the conceptual model tables and the section below where they are discussed.

Table 11.7 Summary of risks at each stage and conceptual model location

Project Stage		**Risks are associated with :**		
		Well pad activities and transit	**Well integrity**	**Induced fractures**
11.7.1	Construction of the well pad and access	✓ Table 11.8	n/a	n/a
11.7.2	Installation of arrays	✓ Table 11.9	n/a	n/a
11.7.3	Drilling	✓ Table 11.10	✓ Table 11.11	n/a
11.7.4	Hydraulic fracturing	✓ Table 11.10	✓ Table 11.12	✓ Table 11.13
11.7.5	Flow testing	✓ Table 11.10	✓ Table 11.12	✓ Table 11.13
11.7.6	Decommissioning and restoration	✓ Table 11.8	✓ Table 11.14 and Table 11.12	✓ Table 11.13

11.7.1 Construction of the well pad and access

160. During the construction of the well pad and access road rainfall runoff from exposed soil will have elevated suspended solids that could have an adverse impact if allowed to discharge in an uncontrolled manner. Similarly spillage of diesel or release of lubricants from vehicles or construction plant could have an adverse impact on the water environment. A summary of the conceptual model for construction of the well pad and access road is provided in Table 11.8 below.

Table 11.8 Conceptual model for construction of well pad and access.

Source		Pathways		Receptor
Sediment in rainfall runoff during earthworks	→	Overland flow	→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology
Diesel or lubricants spilled from vehicles and plant during construction of pad or access	→	Seepage into the ground or overland flow	→	Middle Sands groundwater
			→	Crops and livestock
			→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology
			→	Off-site human health (contact with contaminated surface water or soil)

161. The probability of the risks being realised and the potential consequences are considered in Section 11.7.7 and 11.7.8.

11.7.2 Installation of surface and buried arrays

162. The construction of surface arrays (described in Chapter 4) will require excavation of a small pit (approx. 0.8m deep) at 8 locations. The buried array requires construction of boreholes up to 100m deep for installation of seismic monitoring instruments. Detailed design of each borehole and selection of appropriate methods has not yet been undertaken, however conventional drilling methods, applied routinely, such as for drilling water wells, will be used. The conceptual model of risks associated with installation of arrays is summarised in Table 11.911.9 below.

Table 11.9 Conceptual model for installation of arrays.

Source		Pathways		Receptor
Sediment in rainfall runoff, drilling muds or diesel from vehicles and plant during construction released due to failure of equipment, vehicle collision, or site operative error	→	Overland flow or infiltration into ground	→	Watercourses, ponds and any supported ecology
			→	Off-site human health (contact with contaminated surface water or soil)
			→	Middle Sands groundwater
			→	Crops and livestock
	→	Infiltration down annulus of a poorly constructed array borehole	→	Middle Sands groundwater

163. The probability of these risks being realised and the potential consequences are considered in Section 11.7.7 and 11.7.8.

11.7.3 Drilling

164. During the drilling stage of the deep gas exploratory wells at the Site, hazards are present associated with:

- Activities on the well pad activities and movement of materials to and from the Site (in transit); and
- Well construction and integrity (drilling fluids and ground gas and naturally poor quality groundwater).

Activities on the well pad or in transit during drilling

165. The conceptual model considers the potentially contaminating materials stored and used on the well pad and in transit during drilling as hazards:

- Drilling fluid and cuttings, including displacement fluid additives, and associated waste, well servicing and suspension fluids;
- Cement powder;
- Diesel fuel and other oils and lubricants;
- Wastewater from welfare facilities;
- Captured contaminated site drainage water;
- Fire fighting foam or water.

166. Materials will be stored in suitable vessels, with secondary containment of the fuel storage tanks, and managed in accordance with the Mining Waste Directive environmental permit, good practice and regulatory requirements (see Appendix K2). The well pad would be constructed with a minimum of 300mm aggregate laid over welded HDPE membrane with protective layers, draining to perimeter ditches (see ES Chapter 19 Water Resources). The well pad membrane provides containment for all Site activities in accordance with EA guidance. Discharge to a watercourse would only occur with EA approval and would be via an interceptor. A Pollution Incident Plan (under the Environmental Operating Standards, see Chapter 4) will be in place, requiring spill kits and access to 24 hour emergency response services. HGV routes for Site vehicles will be agreed with the relevant authorities, considering the potential for accidents and selecting the most appropriate route.

167. Mechanical failure of equipment has the potential to release drilling fluids at high pressure, which may result in the release as a spray across the Site or offsite. Such a release is prevented by implementation of Cuadrilla's HSSE Risk Management Framework (see Chapter 4) with competent Site staff using well maintained appropriate equipment; including testing of equipment components to high pressure before use; and appropriate automatic shut-down devices.

168. A summary of the conceptual model relating to surface activities during drilling is presented in Table 11.10 and shown graphically in Figure 2.

Table 11.10 Conceptual model relating to well pad activities and transit.

Source		Pathways		Receptor
Spillage of fluids on the well pad due to failure of equipment or infrastructure, vehicle collision, or Site operative error	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater
	→	Collection in Site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater
			→	Crops and livestock

Source		Pathways		Receptor
	→	Collection in Site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology
			→	Off-site human health (contact with contaminated water)
Fire fighting foam or water	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater
	→	Collection in Site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater
			→	Crops and livestock
	→	Collection in Site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology
			→	Off-site human health (contact with contaminated water)
Failure of equipment causes release of fluid at high pressure	→	Liquid spray off site through the Site boundary fence	→	Crops and livestock
			→	Off-site human health (a person standing outside the Site boundary fence)
Off site road traffic accident resulting in spill of potentially contaminating materials	→	Spill of contents of vehicle in transit onto public highway	→	Off-site human health (exposure to spilled material)
			→	Water environment along transit route

169. The Sherwood Sandstone is not considered a potential receptor relevant to surface and pad activities due to its presence at depth beneath the Mercia Mudstone.

Well construction and integrity during drilling stage

170. Subsurface hazards relevant to the drilling stage assessment are drilling fluids and ground gas and naturally poor quality groundwater.

171. Drilling fluids are designed to minimise loss to the adjacent rock formations during drilling, although it is inevitable that some small losses into the formation will occur. When drilling through potentially sensitive groundwater receptors (Middle Sands and Sherwood Sandstone) no chemicals considered to be hazardous to groundwater (as defined by the Groundwater Daughter Directive) will be used. Low toxicity oil based mud (LTOBM) will not be used above the Manchester Marls Formation and will only be employed for drilling in deeper formations where adequately isolating surface casing has been installed, cemented, and tested for integrity. Only fluids approved for use by the EA under the environmental permitting regime will be used. The composition of drilling fluids is considered in additional detail in Section K3.3.4 and the environmental permit application.

172. Construction of a well from the surface to a depth where the formation is potentially gas-bearing and groundwater is naturally poor quality presents the risk of creating a pathway to sensitive receptors as a result of poor well integrity. For the purpose of this assessment, well integrity is defined as a condition where uncontrolled and unacceptable releases to the environment are prevented. Integrity can be assured by maintaining adequate barriers between the hazards in the well and the environment.

173. The wells will be drilled, constructed and integrity tested in accordance with regulatory requirements (DECC and HSE) and industry guidance (Oil and Gas UK and UKOOG) to ensure protection of sensitive receptors. The design will comprise a minimum two-barrier, cement-sealed well design with surface casing set below the Sherwood Sandstone and additional intermediate casing set prior to entry into the target zone. Details of proposed well construction will be provided to an Independent Well Examiner for review and comment and provided to the HSE.

174. Additional detail relating to the well design, construction methods and potential for loss of integrity is presented in Appendix K3. A summary of the conceptual model relating to well construction and integrity issues during drilling is presented in Table 11.11. The well design and well barrier systems during the well construction phase are shown on Figure 11.3.

Table 11.11 Conceptual model of well construction and integrity issues during drilling.

Source		Pathways		Receptor
Drilling fluid and Naturally poor quality groundwater	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
Hazardous ground gases from below the Manchester Marls Formation	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater and use within a confined space	→	Off-site human health (users of groundwater abstractions)
	→	Loss of well integrity resulting in gas migration to shallow soils followed by entry into buildings (or other confined spaces) on or off site.	→	On-site human health (Site workers and visitors)
			→	Off-site human health (users of off-site enclosed spaces)

175. The probability of these risks being realised and the potential consequences are considered in Section 11.7.7 and 11.7.8.

11.7.4 Hydraulic fracturing

176. During the hydraulic fracturing stage of the Project hazards are associated with:

- Well pad activities and in transit;
- Well integrity (fracturing fluid, suspension fluids, ground gases and naturally poor quality groundwater);
- Induced fractures (fracturing fluid, ground gases and naturally poor quality groundwater).

Well pad activities and in transit during hydraulic fracturing

177. Potentially contaminating materials and fluids stored and used on the well pad and in transit during hydraulic fracturing are:

- Hydraulic fracturing fluid;
- Hydraulic fracturing fluid additives (prior to mixing);
- Flowback fluid;
- Well servicing and suspension fluids;
- Diesel fuel and other oils and lubricants;
- Wastewater from welfare facilities;
- Captured contaminated site drainage water;
- Fire fighting foam or water.

178. In accordance with UKOOG guidelines, Cuadrilla will disclose the composition of the proposed fracturing fluid additives prior to use and will only use substances approved for use by the EA. The composition of hydraulic fracturing fluid and flowback fluid is summarised in Chapter 4 and considered in more detail in Appendix K4. Sampling and analysis of hydraulic fracturing fluid and flowback fluid will be undertaken.

179. The measures discussed in Section 11.7.3 relating to material management and containment on the well pad and potential mechanical failure are also relevant to fracturing fluid and flowback management.

180. Flowback fluid management will comply with the requirements in the UKOOG guidance[175] and Mining Waste Directive environmental permit. Flowback fluid is stored in above ground steel tanks until being reused in fracturing fluid or removed off-site by road tanker to the designated treatment facility (ES Resources and Waste Chapter). The flowback tanks each have a capacity of approximately 70m^3 and are connected together to provide a total of 140m^3 combined storage capability. In the event that larger volumes of flowback fluid need to be stored, then tanks used to store freshwater for hydraulic fracturing purposes are of a suitable construction for flowback storage (see Appendix K2) and the well could be 'shut-in' (valves closed) to prevent further flowback production.

181. Assessment of potential human health exposure from naturally occurring radioactive material (NORM) in flowback and NORM monitoring is a requirement of the environmental permitting process. Flowback fluid samples will be analysed to assess NORM and chemical concentrations (see Appendix K4).

182. The conceptual model presented in Table 11.10 is also applicable to this section and is not repeated. Figure 2 shows graphically the conceptual model relating to pad activities during operations.

Well integrity during fracturing stage

183. Hazards during the fracturing stage relating to loss of well integrity are fracturing fluid and flowback, suspension fluid, ground gas and naturally poor quality groundwater.

184. Inadequate well integrity could result in a pathway for contaminants or gases to reach a sensitive receptor. Well integrity is assured by keeping adequate barriers in place to prevent a release into the environment. The Project wells will be drilled, constructed and integrity tested prior to fracturing in accordance with regulatory and industry guidance. The proposed well design and well barrier systems during the fracturing stage are shown on Figure 4.

185. During well servicing and suspension, fluid is placed within the well. The well casing will be intact across all groundwater receptors and will only be perforated across the low permeability target shale reservoirs. The volume of fluid used in well servicing and suspension is small compared to drilling and fracturing fluid volumes. Only EA-approved fluids will be used for suspension.

186. A summary of the conceptual model relating to well integrity during fracturing is presented in Table 11.12. A graphical conceptual model of well integrity risks is shown in Figure 5.

187. The probability of each of the risks identified in Table 11.12 being realised is discussed in 11.7.7 and considers the measures integral to the well design, construction and monitoring to ensure well integrity is maintained. Additional detail relating to the potential for loss of integrity is presented in Appendix K3.

Table 11.12 Conceptual model of well integrity issues during hydraulic fracturing.

Source		**Pathways**		**Receptor**
Hydraulic fracturing fluid Flowback fluid Naturally poor quality groundwater	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
	→	Loss of well integrity caused by hydraulic fracturing resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
	→	Loss of well integrity due to natural movement of faults resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
Hazardous ground gases from below the Manchester Marls Formation and dissolved in flowback	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater and use within a confined space	→	On-site human health (users of groundwater abstractions)
	→	Loss of well integrity resulting in gas migration to shallow soils followed by entry into buildings (or other confined spaces) on or off site.	→	Off-site human health (site workers and visitors)
			→	Off-site human health (users of off-site enclosed spaces)

Induced fractures

188. Hazards relating to induced fractures are: hydraulic fracture fluid, ground gases and naturally poor quality shale formation water released from the target formation. A conceptual model relating to induced fractures is summarised below, and shown graphically in Figure 5. The potential pathways to sensitive receptors that could be created by induced fractures are described and their probabilities considered in Section 11.7.7.

189. An overview of the proposed hydraulic fracturing process is described in Chapter 4. Detail relating to the monitoring and control of fracture propagation is included in Appendix K4.

Table 11.13Conceptual model relating to induced fractures.

Source		Pathways		Receptor
Hydraulic fracture fluid	→	Fractures propagating beyond the target zone and fracture interaction with preferential flow paths	→	Sherwood Sandstone groundwater
Naturally poor quality shale formation water (released from the Bowland Shale)	→		→	Middle Sands groundwater
Hazardous ground gases released from the Bowland Shale	→	Gas migration along induced fractures, natural fissures and faults to shallow groundwater and abstraction of groundwater for use within a confined space.	→	Off-site human health (users of groundwater abstractions)
	→	Gas migration along induced fractures, natural fissures and faults to shallow soils and above ground confined spaces on-site or off-site	→	On-site human health (site workers and visitors)
				Off-site human health (users of off-site enclosed spaces)
Residual fracturing fluid in Bowland Shale	→	Groundwater flow, including diffusion, through bedrock	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater

Note: Preferential flow paths refer to discontinuities, such as conductive faults or abandoned deep wells.

11.7.5 Initial and extend flow testing

190. No additional potential S-P-R linkages to those identified in preceding sections will occur during initial and extended flow testing. Risks identified in Tables 11.10 to 13 are also relevant to this stage, however repetition is avoided. Probability and consequences are discussed in Section 11.7.7 and 11.7.8.

11.7.6 Decommissioning and restoration

191. On completion of the proposed exploration activities at the Site, it will be decommissioned and restored as described in the ES Chapter 4. This will include exploratory well plugging and abandonment, removal of all plant and equipment, removal of the well pad and membrane, and restoration of the Site to agricultural use. Following a period of monitoring post-abandonment agreed with the regulators (minimum 12 months), the groundwater monitoring wells will be decommissioned in accordance with EA guidance[243]. At the time of plugging and abandonment, the extant regulatory requirements and industry best practices will be used to develop the well abandonment plan, which must be submitted to the regulators (see Appendix K3).

192. Following removal of the well pad and membrane soil chemical testing will be undertaken to assess the post-Project soil quality and inform the Site Condition Report required by the environmental permit. During these works the risks to the water environment are comparable to during well pad construction, as the exposed soils have the potential to result in sediment runoff, and the conceptual model in Table 8 is also relevant to decommissioning.

193. S-P-R linkages identified in Table 11.12 and Table 11.13 relating to well integrity and induced fractures are also relevant to this stage of the Project, however repetition is avoided.

194. The only additional potential S-P-R linkages to those considered in the assessments above relate to loss of well integrity due to long term well degradation, resulting in a pathway for buoyant gases from below the Manchester Marls Formation or for mixed hydraulic fracturing fluid and naturally poor quality groundwater residing in the wellbore, fractures or the surrounding rock formation The conceptual model is presented in Table 11.14. The probability of these risks being realised and the potential consequences are discussed in Section 11.7.7 and 11.7.8.

Table 11.14 Summary of conceptual model for well integrity post-abandonment

Source		Pathways		Receptor
Hydraulic fracturing fluid Naturally poor quality groundwater	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
	→	Loss of well integrity due to long term well degradation	→	Sherwood Sandstone groundwater
			→	Middle Sands groundwater
Ground gases from below the	→	Loss of well integrity due to long term well degradation - resulting in migration to shallow	→	Off-site human health (users of groundwater abstractions)

[243] Environment Agency (EA), 2012a. Good practice for decommissioning redundant boreholes and wells. Ref. LIT 6478 / 657_12. EA, Bristol, UK. 8pp.

Source		Pathways		Receptor
Manchester Marls Formation		groundwater and abstraction of groundwater for use within a confined space or migration into buildings or other confined spaces	→	Off-site human health (users of off-site enclosed spaces)

11.7.7 Assessment of probabilities

194. To determine the magnitude of each risk identified in the conceptual models (Tables 11.10 to 11.14) the probability of each S-P-R linkage is assessed, considering the mitigation measures integral to the Project (Section 11.4.5). In conjunction with the predicted consequences should the risk be realised (Section 11.7.8), the risk magnitude can be determined.

Contaminant release during well pad and access construction (Table 11.8**)**

195. During the construction of the well pad and access road rainfall runoff from exposed soil with elevated suspended solids could enter adjacent or nearby watercourses if allowed to discharge in an uncontrolled manner. Similarly spillage of diesel or release of lubricants from vehicles or construction plant could have an adverse impact on groundwater or surface water.

196. The nearest surface watercourse is a small man-made drain 200m to the northwest that flows into Carr Bridge Brook, with low lying agricultural fields between the Site and the watercourse. Near-surface geology at the Site is comprises low permeability glacial clay. Therefore the pathway to both surface and groundwater is indirect.

197. Implementation of the Environmental Monitoring and Management Plan (EMMP), agreed with the regulators, will ensure implementation of pollution prevention measures, including (inter alia) vehicle and fuel management, minimising soil exposure during works, and temporary management of Site drainage. Relevant industry guidance that will be applied includes Environment Agency *Working at construction and demolition sites: preventing pollution guidance* PPG6 [244].

198. The probability of S-P-R linkage associated with contaminant release during well pad and access construction is assessed as **Low**.

Contaminant release during installation of surface and buried arrays (Table 11.9**)**

199. During construction of the boreholes for installation of the seismic arrays, if the works are not effectively managed, contaminants such as suspended sediment from exposed soils and diesel or lubricants from vehicles could be released. However there is nothing unusual or novel in the requirements for the array boreholes, and a competent drilling contractor, compliant with health, safety and environmental protection requirements of legislation and industry good practice[245] [200] [246] will be appointed to ensure these risks are managed effectively. A site specific risk register will be produced by the contractor and used to inform selection of appropriate methods and environmental protection measures.

[244] Environment Agency (EA), 2012d. Pollution Prevention Guidelines. Working at construction and demolition sites: PPG6. 2nd Edition. EA, Bristol, UK. 78pp.
[245] Site Investigation Steering Group (SISG), 1993. Site Investigation in Construction Part 4: Guidelines for the Safe Investigation by Drilling of Landfills and Contaminated Land. London, Thomas Telford Ltd.
[246] British Drilling Association., 2008. Guidance for safe intrusive activities on contaminated or potentially contaminated land. British Drilling Assocation, Northampton, U.K. 50pp.

200. The probability of S-P-R linkage associated with contaminant release during installation of surface and buried arrays is assessed as **Low**.

Contaminant release due to defects in membrane (Table 11.12**)**

201. Appropriate storage vessels and management procedures will be in place to minimise the risk of spillages and equipment failure which might result in releases on the well pad (see Appendix K2). In the event of such an incident spill response procedures will be implemented. The well pad containment system includes a welded and verified HDPE membrane that underlies the entire well pad.

202. Site management procedures will prevent activities that could cause holes or tears in the liner as far as practicable, e.g. no sign posts penetrating the liner. However, although it is designed to be impermeable, defects comprising small holes and small tears may be present, that have developed during use due to loading and wear and tear. When rainwater or a liquid spill infiltrates the gravel surface of the pad it moves vertically to the membrane and will flow to the surface water ditches maintained at a lower elevation around the perimeter of the pad. Flow through any defects in the membrane will only occur if there is standing water on the membrane, a situation which may occur locally, particularly following a rainfall event or a spill. Therefore a very small release though the membrane could occur, but this is only part of the pathway to the receptor.

203. To reach the Middle Sands groundwater receptor the contaminant released must migrate vertically through the Upper Boulder Clay, which forms a low permeability barrier to infiltration. Contaminants that enter the Upper Boulder Clay will undergo attenuation processes including sorption and degradation reducing contaminant concentration. This pathway is represented on Figure 2.

204. The probability of S-P-R linkage associated with contaminant release due to defects in the membrane is assessed as **Low**.

Contaminant release due to overflow or discharge from well pad drainage system (Table 11.12**)**

205. The well pad drainage system is designed to have an excess capacity adequate to contain spills and rainfall events (see Appendix K2 and ES Water Resources Chapter).

206. During operations, the drainage is contained on site, and water collected in site drains will be used in drilling fluids and fracturing fluid and excess will be regularly pumped out and removed off site by a competent contractor. The storage capacity of the well pad could be exceeded in certain circumstances e.g. restriction of tanker movements preventing removal of water. Overflow onto the surrounding ground could occur by overtopping the perimeter drains; however the exterior bund is 50mm higher than pad surface so the pad would be inundated before this occurred. If overflow occurred it would probably be during heavy rainfall and any contaminants present would be highly diluted. If the system overflows to ground the contaminant pathway to the Middle Sands will be through the low permeability Upper Boulder Clay as described above.

207. Rainfall falling on the pad is collected in the voids of the well pad stone and drains to the perimeter ditches before overflowing from an interceptor suitably sized for the well pad. This is in line with requirements of 'Use and design of oil separators in surface water drainage systems: PPG3'[247]. Any drips or minor spills on the well pad will be retained in the stone voids above the membrane and then be mobilised by rainwater and flushed

[247] Environment Agency (EA), 2006c. Pollution Prevention Guidelines. Use and design of oil separators in surface water drainage systems: PPG3. EA, Bristol, UK. 8pp

through by the first storm. The granular nature of the well pad is such that over time, biological processes will provide some improvement to the water quality retained in the pad. The interceptor will remove remaining liquid hydrocarbons and fully treats all flows for the area served generated by rainfall rates up to 6.5mm/hour, which covers most low return period rainfall events. Flows above this rate bypass the separator. This is acceptable for the proposed Site since more extreme events would generate higher rainfall volumes and hence increase dilution. At existing well pads across the Fylde the EA has agreed to the discharge of surface water via an interceptor during non-operational periods. EA approval would be required for discharge to watercourse.

208. The probability of the S-P-R linkage associated with contaminants in overflow or discharge from the well pad drainage system is assessed as **Low**.

Liquid spray off site due to high pressure equipment failure (Table 11.12**)**

209. Mechanical failure of equipment, such as a pipework connection, during drilling or fracturing has the potential to release fluids at high pressure, which might result in the release of drilling mud, flowback fluid or fracturing fluid as a spray across the Site or off site beyond the perimeter fence. In the unlikely event that this type of release occurred it would be high pressure but low volume due to emergency shutdown procedures and close supervision. Such a release is mitigated by implementation of Cuadrilla's HSSE Risk Management Framework, including Environmental Operating Standards (see Chapter 4), with competent Site staff using well maintained equipment, including testing of equipment components to high pressure before use and automatic shut-down devices.

210. The probability of the S-P-R linkage associated with offsite spray due to high pressure equipment failure is assessed as **Low.**

Spill of contents of vehicle in transit onto public highway (Table 11.12**)**

211. A road traffic accident could occur involving a vehicle transporting potentially contaminating material, such as flowback fluid from the Site, resulting in release of the vehicle contents. Competent haulage contractors, who are licensed waste carriers, will be appointed in accordance with Cuadrilla's HSSE Framework (see Chapter 4). HGV routes to Site will be agreed with the relevant authorities (ES Transport Chapter). Vehicles will have spill kits and MSDS sheets. Cuadrilla's 24 hour emergency response contractor will respond to any incident.

212. The probability of the S-P-R linkage associated with spill from a vehicle in transit is assessed as **Low.**

Loss of well integrity due to poor well construction (Table 11.11 **and** Table 11.12**)**

213. Literature examples exist for migration of gas to shallow soil and groundwater as a result of poor well constructions, particularly in the United States [198 248 249 250 251]. No literature

[248] Jackson, R. E., Gorody, A. W., Mayer, B., Roy, J. W., Ryan, M. C. & Van Stempvoort, D. R., 2013. Groundwater Protection and Unconventional Gas Extraction: The Critical Need for Field-Based Hydrogeological Research. Groundwater. 51 (4), 488-510

[249] Gorody, A. W., 2012. Factors affecting the variability of stray gas concentration and composition in groundwater. Environmental Geosciences. 19 (1), 17-31.

[250] Osborn, S. G., Vengosh, A., Warner, N. R. & Jackson, R. B., 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences. [Online], 15 August 2013. Available from: http://www.pnas.org/content/early/2011/05/02/1100682108.full.pdf.

examples have been found which associate fracturing fluid contamination of shallow groundwater to poor well integrity[198 250 248 252].

214. The ReFINE research consortium recently produced a review of oil and gas well integrity pulling together available worldwide data[253]. Davies et al. adopted the distinction between well barrier failure and well integrity failure noted by King and King (2013)[254]. A 'well barrier failure' is defined as a failure in a single or multiple barriers, which does not lead to a release of contaminants to the environment. In contrast a 'well integrity failure' is a failure in the well protective system where a pathway is established that enables leaking into the surrounding environment. For the purpose of this EIA, a 'loss of well integrity' is defined as a condition where the well barrier system has failed resulting in an uncontrolled release to the environment. The definition used in this EIA is consistent with that of Oil & Gas UK[176].

215. The Davies (2014)[253] paper notes that in much of the available data, there is no distinction between a well barrier failure and well integrity failure. Thus it is unclear how many of the documented well barrier failures have translated to environmental contamination. The authors further noted the following:

- Worldwide there are at least 4 million onshore hydrocarbon wells, with at least 2.6 million wells drilled in the US since 1949.
- A dataset of international wells (including the UK) showed rates of well barrier failure varied widely. It is not known whether these 'well barrier failures' resulted in a release into the environment ('well integrity failure').
- The available data ranges from a variety of designs, construction techniques, and regulatory environments making it difficult to directly relate to the emerging UK shale gas industry.
- In the UK only two wells have evidence of well integrity failure based on available data.

216. The Project wells will be drilled, constructed and integrity tested in accordance with regulatory requirements (DECC andHSE) and industry guidance (Oil & Gas UK and UKOOG) (described in detail in Appendix K3). The well design will be reviewed by the relevant regulators and an independent well examiner. Well construction activities may be observed by relevant regulators and an independent well examiner.

217. Multiple well barrier systems (i.e. casing, cement, well head) provide protection for receptors from contaminant releases. Well design and barrier systems during well construction are shown on Figure 3 and during fracturing and testing on Figure 4. The barrier installation and testing/verification methods and results are described detail in Appendix K3. These multiple barriers between the hazards in the well bore and

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[251] Ohio Department of Natural Resources, 2008. Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio. September 1, 2008. Ohio Department of Natural Resources Division of Mineral Resources Management.

[252] Ground Water Protection Council (GWPC), 2011. State Oil and Gas Agency Groundwater Investigations, And Their Role in Advancing Regulatory Reforms, A Two-State Review: Ohio and Texas.

[253] Davies, R. J., Almond, S., Ward, R. S., Jackson, R. B., Adams, C., Worrall, F., Herringshaw, L. G., Gluyas, J. G. & Whitehead, M. A., 2014. Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. Marine and Petroleum Geology. (2014) http://dx.doi.org/10.1016/j.marpetgeo.2014.03.001

[254] King, G.E., and D.E. King, 2013. Environmental Risk Arising from Well-Construction Failure – Differences Between Barrier and Well Failure, and Estimates of Failure Frequency Across Common Well Types, Locations, and Well Age. SPE Production & Operations. Paper number 166142. November.

groundwater in the Sherwood Sandstone and Middle Sands significantly lower the potential for complete S-P-R linkages as a result of loss of well integrity.

218. Testing methods such as pressure testing, formation integrity testing (FIT), wireline logging (such as cement bond logs or CBL) will be used to verify that the integrity of the well system is constructed and maintained during the exploration activities (see Appendix K3). This includes verification and pressure monitoring prior to and during hydraulic fracturing and well testing operations.

219. Pathways from defects in well construction at depths below the Manchester Marls Formation would be long, tortuous and involve migration through multiple rock types with varying permeability providing attenuation along the pathway to the receptor. The pathway includes migration through the low permeability Manchester Marls Formation if defects in well construction occurred below the surface casing. The low permeability of this formation is also indicated by the presence of a naturally occurring gas reservoir in the Collyhurst Sandstone immediately underlying the Manchester Marls Formation, along with the low gas readings recorded in the Manchester Marls Formation and the overlying Sherwood Sandstone Group observed during the drilling of other deep wells in Fylde.

220. The probability of S-P-R linkages associated with release of fracturing fluid, flowback fluid and poor quality formation water due to loss of well integrity as a result of poor well construction is therefore considered to be **Very Low**.

Loss of well integrity caused by hydraulic fracturing (Table 11.12**)**

221. The potential for the hydraulic fracturing process to cause a loss in well integrity has been evaluated based on the following mechanisms:

- Damage to the casings and/or cement as a result of pressures induced by hydraulic fracturing;
- Induced seismic activity whereby damage is caused to the well by ground vibrations and/or movement along a fault or bedding plane.

222. Pressure within the well during hydraulic fracturing is monitored and controlled (see Appendix K4). Pressure relief valves are used to ensure that pressures do not exceed the allowable maximum pressure for a given casing or liner (see Appendix K3). Pumps are used to control flow rates and manage pressures within the system. These methods are designed to ensure that the worst-case fluid pressure predicted during hydraulic fracturing will remain below the maximum casing pressure tested. Thus it is assessed that the likelihood of compromising well integrity during hydraulic fracturing is **Low**.

223. An induced seismic event may cause the well cement or casing to be locally breached. However this is most likely to occur within or close to the targeted hydraulic fracturing zone where the intensity of any disturbance will be greatest and where the casing is intentionally perforated. Seismic events caused by hydraulic fracturing will be monitored during the fracturing using microseismic arrays which can measure the magnitude and location of induced seismicity. A traffic light system will be implemented during hydraulic fracturing as part of the requirements by DECC (see ES Induced Seismicity Chapter). Upper estimates of induced seismicity without any embedded mitigation (up to $3.1M_L$)[255]are relatively low. Thus a properly constructed well with multiple overlapping casing/cement barriers will be adequately protective of sensitive

[255] Upper limits of induced seismic are based on analysis of the Preese Hall site where injection volumes are greater than those proposed at the Site.

receptors from potential loss of well integrity due to seismic events. It is assessed that the likelihood of a loss of well integrity from induced or triggered seismicity is **Very Low**.

224. The upper estimates of induced seismicity (up to $3.1M_L$) can produce ground motions of up to 34mm/s (peak particle velocity or PPV). Based on the British Standard for underground pipelines[256], a PPV of 30 mm/s gives rise to a dynamic stress equivalent to approximately 5% of the allowable working stress in typical concrete, and even less in iron or steel. Furthermore, National Grid guidelines for vibrations in the vicinity of high pressure gas mains state that pipelines shall be limited to a maximum PPV of 75mm/s for vibration inducing operations. Thus, it is highly unlikely that ground vibration due to induced seismic events would be capable of damaging wells resulting in a loss of well integrity. Thus a properly constructed well, using industry standard cement and steel as well as the normal multiple overlapping casing/cement barriers will be adequately protective of impacts from 1 in 100year seismic events. As such, the likelihood has been assessed to be **Very Low**.

Loss of well integrity due to natural seismicity (Table 11.12**)**

225. Seismic events unrelated to hydraulic fracturing can originate from natural seismicity or from other off-site sources. These events could potentially result in ground vibrations and/or movement along a fault or bedding plane.

226. Natural seismicity is not expected to generate ground vibrations or movements which are more significant than those generated from induced seismicity (see ES Induced Seismicity Chapter). This is due to the very low probability of a significant natural seismic event being in close proximity to the Project site. Thus impacts to the well are similarly assessed as **Very Low**.

Loss of well integrity due to long term well degradation (Table 11.14**)**

227. The assessment of effects of well ageing on well integrity in abandoned wells is complex and an issue for all oil and gas wells, not specific to shale gas wells. Available evidence has been reviewed to assess possible long term well degradation effects at the Project (detail included in Appendix K3).

228. A study of the Alberta Energy Resources Conservation Board (ERCB) database of more than 315,000 oil, gas, and injection wells since the early 1900s could not establish a linkage between well age and test failures indicative of well integrity issues[257].[258] The study also indicated that fewer than 5% of all wells in the study had sustained casing pressures monitored in annular space sufficient to require well repair (i.e. well barrier failure) and/or detection of gas in nearby shallow soils (i.e. 'well integrity failure')[257]. Incomplete or absent annular cement providing a migration path and facilitating casing corrosion, and inadequate abandonment design were two of the main contributing factors to well integrity issues[257].

229. Whilst gas present in the annulus of wells does not mean that gas or liquid release into surrounding groundwater has or would occur, the presence of significant gas in the annulus suggests that there is a higher risk of such a leak occurring. This concurs with

[256] British Standards Institution (BSI), 2009. Code of practice for noise and vibration control on construction and open sites. Part 2: vibration BS5228-2:2009. BSI, London, UK
[257] Watson, T.L. & Bachu, S., 2009. Evaluation of the Potential for Gas CO2 Leakage Along Wellbores. Society of Petroleum Engineers.
[258] The Watson and Bachu 2009 study correlated well integrity loss with sustained casing pressure (i.e. pressure buildup in annular space) and/or detection of gas at shallow monitoring boreholes in the near vicinity of the production well).

Gorody 2012[249] who states that, '*the most common cause for stray gas migration arising from drilling operations is annular build up of gas pressure in and around casing cements.*'

230. Technical standards of well abandonment are defined in guidance[177] and regulatory involvement has increased in recent years in the UK. Davies et al (2014)[253] considers existing onshore UK wells, which number over 2000, and note that '*In the UK there have been a small number of reported pollution incidents associated with active wells and none with inactive abandoned wells*.' However as observed by Davies et al (2014) monitoring of abandoned wells does not take place in the UK (or any other jurisdiction). Whilst monitoring of abandoned wells is not a past or current regulatory requirement, the environmental monitoring wells at the Site will be monitored for a minimum of one year following abandonment of the exploratory wells or in accordance with prevailing best practice or regulatory requirements at the time of abandonment.

231. The risk that degradation over a long time period (i.e. decades or hundreds of years) could occur cannot be discounted. However only substantial degradation of multiple protective barriers of casing and cement would allow migration of contaminants or hazardous gases to shallow groundwater or soils.

232. The likelihood of this pathway occurring is assessed as Very Low for fracturing fluid and poor quality formation water, due to the presence of multiple protective barriers in the well design and the large distance between the potential sources below the Manchester Marls Formation and the shallow receptors. However due to the uncertainty resulting from an absence of data, a **Low** probability has been concluded. Should an environmental release be identified in the future, remedial actions are available that could be implemented to remove the loss of well integrity pathway and prevent ongoing environmental impact.

233. Ground gas migration via loss of well integrity is considered further in the following two sections below.

Ground gas migration due to loss of well integrity (Table 11.11**,** Table 11.12 **and** Table 11.14**)**

234. Migration of ground gas due to loss of well integrity requires additional consideration to fracturing fluids and formation water discussed above, due to gas buoyancy and the different receptors to be considered i.e. human health receptors, and not groundwater receptors (see Appendix K5). Possible hazardous ground gases include methane, carbon dioxide, carbon monoxide, hydrogen sulphide and radon. Expected ground gas composition is discussed in Appendix K5 and methane is the considered to the principal risk driver.

235. Methane in groundwater is not technically considered to be a health hazard as a result of ingestion and there is no UK drinking water standard for methane, however methane is a potential explosion hazard in certain circumstances. If methane accumulated in an enclosed space, either as a result of degassing from abstracted groundwater or gas migration through the floor slab, it could accumulate to potentially explosive concentration and this is considered further below.

236. Radon has a half life of only 3.8 days and therefore it is only considered to be a hazard if the time taken to migrate from the source of the radon (in this area Millstone Grit or Bowland Shale) to the receptor is short. As the potential pathways to human health receptors are long in terms of distance and travel time through the ground/groundwater (see below) radon is not considered to be a potential ground gas hazard.

237. *Gas migration to a groundwater abstraction* - No groundwater abstractions are recorded within 4.5km of the Site, and therefore there is no current existing pathway to users of groundwater abstractions; however it is possible that groundwater abstractions could be developed in the future. The depth to the Sherwood Sandstone (more than 250m) and its salinity, mean it is unlikely to be utilised for groundwater abstraction in the future. The Middle Sands groundwater may be of potable quality and may be used for local water supply. Consequently, the potential ground gas pathways to users of future groundwater abstractions from the Middle Sands have been considered within this section.

238. For this S-P-R linkage to occur an abstraction from the Middle Sands would need to be present, methane concentration within the abstracted groundwater would need to exceed 1.6mg/L to present an explosion risk (see Appendix K5) and the discharge point of the abstraction would need to be in a confined space where methane degassing from the groundwater could accumulate. Finally a spark would be required to ignite the methane once it had accumulated to 5% by volume or higher within the confined space.

239. *Gas migration into building or enclosed spaces* - Human health receptors on site are site workers and visitors to the operational Site. Enclosed spaces used by site workers and visitors are portacabins such as site offices, placed above the surface of the well pad comprising 300mm thick gravel over membrane. Human receptors off site are users of buildings or other confined spaces into which ground gas could enter and accumulate. There are several residential and agricultural buildings within a 1km radius of the Site, the nearest building to the Site is located approximately 240m southwest. The main potential pathway into buildings would be through cracks or service entries in floor slabs.

240. There is considered to be no plausible pathway, and therefore no S-P-R linkage, from shallow soils into portacabins on-site because they will have a metal floor placed on top of the granular well pad surface with no service penetrations (as compared to existing permanent buildings assumed to have aged concrete floor slabs with cracks). Two subsurface concrete structures are proposed on site: a sewer bottle and an interceptor, and both will be vented in accordance with manufacturer's instructions. As methane is less dense than air it would not be possible for methane to accumulate within these structures.

241. The minimum horizontal path distance from the well to the nearest off-site building will be 240m and further dilution and dispersion of gas would occur along this pathway. The presence of the low permeability boulder clay across the Site and surrounding area above the Middle Sands will restrict upward migration of gases to the surface (and from the surface into potential above ground confined spaces).

242. As noted above, literature examples exist for migration of gas to shallow soils and groundwater as a result of poor well construction practices [198 259 260 261 262]. In many of these literature examples the annulus of the wells had not been properly cemented

[259] Jackson, R. E., Gorody, A. W., Mayer, B., Roy, J. W., Ryan, M. C. & Van Stempvoort, D. R., 2013. Groundwater Protection and Unconventional Gas Extraction: The Critical Need for Field-Based Hydrogeological Research. Groundwater. 51 (4), 488-510

[260] Gorody, A. W., 2012. Factors affecting the variability of stray gas concentration and composition in groundwater. Environmental Geosciences. 19 (1), 17-31.

[261] Osborn, S. G., Vengosh, A., Warner, N. R. & Jackson, R. B., 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences. [Online], 15 August 2013. Available from: http://www.pnas.org/content/early/2011/05/02/1100682108.full.pdf.

[262] Ohio Department of Natural Resources, 2008. Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio. September 1, 2008. Ohio Department of Natural Resources Division of Mineral Resources Management.

creating a permeable vertical pathway to shallow depths. The Project wells will be drilled, constructed and integrity tested in accordance with regulatory and industry guidance with multiple protective barriers to gas migration (see Figures 3, 4 and 5 and Appendix K3). In addition, pressure and gas monitoring will be performed in the annuli of the production and intermediate casings. This monitoring data will be used to assess whether gas is migrating into annular spaces, either from the inner production casing or from other sources of ground gas below the Manchester Marls Formation such as the Collyhurst Sandstone or Millstone Grit. If monitored pressures were to increase then an investigation would be undertaken and additional mitigation and/or remediation of the well implemented (see Appendix K3).

243. If any pathways did occur across the multiple cement and casing layers to the Middle Sands gas migration would likely occur at very low rates and undergo substantial dilution and dispersion on entering the groundwater[263] . In particular the Manchester Marls Formation is estimated to be approximately 160m thick and of very low permeability and would therefore restrict gas migration. The Sherwood Sandstone Group above the Manchester Marls Formation is estimated to be approximately 840m thick which would allow significant dilution and dispersion. Furthermore a pathway through the low permeability Mercia Mudstone, which is estimated to be approximately 260m thick, would be required to reach the Middle Sands. The presence of thick low permeability strata would significantly reduce potential advective and diffusion flux rates. Consequently any gas flux reaching the Middle Sands would be expected to result in negligible or very low concentration.

244. In any case, groundwater in the Middle Sands will be monitored during Site operation for dissolved methane and carbon dioxide in monitoring wells around the well pad.

As described above multiple pathways must coincide for these risks to be realised. Considering the protective nature of UK well design, the dispersion and dilution which would occur along the pathway to the receptor, followed by abstraction or building entry and accumulation at explosive concentration, there is **no plausible pathway to result in S-P-R linkage**.

Induced fractures extend beyond the target zone (Table 11.13**)**

245. Propagation of fractures beyond the target zone has the potential to create a pathway for fracturing fluid or poor quality formation water to overlying formations and ultimately to identified receptors (gas migration is separately assessed below). However, no reported literature examples of this S-P-R linkage occurring have been identified[248 257].

246. As part of a DECC approved Hydraulic Fracturing Programme (HFP), data will be collected to further evaluate the predicted fracture growth. Initially, monitoring results from mini-fracture testing and the initial hydraulic fracturing stage will be used to evaluate the fracture growth potential. During the proposed hydraulic fracturing, fracture growth and termination are monitored by evaluating microseismic monitoring data during and after each fracturing stage and then adjusting the pumping parameters as necessary in order to control and manage fracture growth (see ES Chapter on Induced Seismicity).

247. Models indicate the likely predicted length of fracture growth from the wells is anticipated to be between approximately 50m and 150m (the variation is dependent on the

[263] Evans, D.J., 2008. An appraisal of underground gas storage technologies and incidents for the development of risk assessment methodology. Prepared by the British Geological Survey on behalf of the Health and Safety Executive, RR605. 59pp

volume of fracture fluid injected, with the upper estimate based on a volume of 765m^3, see ES Induced Seismicity Chapter).

248. *Fracture propagation through overlying formations* - At the Site, the Millstone Grit is predicted to overlie the Upper Bowland Shale (the uppermost unit to be fractured) and a total thickness of approximately 410m separates the Upper Bowland Shale from the base of the Sherwood Sandstone. In the event that a fracture extends from the Bowland Shale into a permeable unit, fracture propagation is expected to cease due to the geomechanical contrast between the formations. At the Site, the Millstone Grit would therefore limit vertical fracture extent (see Appendix K4). Hydraulic fracturing would not create a direct pathway through the Manchester Marls Formation into the Sherwood Sandstone. Therefore the probability of induced fractures creating a S-P-R linkage to receptors is **Very Low**.

249. *Fracture interaction with preferential flow paths* - The possibility that induced fractures might intersect natural faults or other discontinuities (such as existing deep boreholes) providing a pathway for contaminants or gases to enter shallower formations (and shallow groundwater) has also been evaluated. This potential mechanism is illustrated on Figure 5 which shows that no faults cross the Manchester Marls. As described in the Induced Seismicity ES Chapter (and Appendix K4) the fracturing programme has been designed to keep induced fractures offset from regional faults by a distance of two times the anticipated fracture length. Microseismic monitoring will be used to detect fracture growth. If, during hydraulic fracturing, monitoring data indicate possible interactions with a preferential flow pathway, the pumping of fracturing fluid would be terminated and the HFP would be adjusted as necessary.

250. If a fault or other discontinuity was encountered during hydraulic fracturing, the following would still need to occur in order to allow fluid migration by advection[264] up to groundwater receptors:

- A permeable pathway would need to be present along the full distance between the source (in the Bowland Shale) and the receptor (the Sherwood Sandstone or Middle Sands groundwater);
- A pressure gradient would be required to drive flow.

251. At the Site, local faults present in the Carboniferous formations have not been observed or interpreted (using 3D geophysical survey results and other information) to extend through the Manchester Marls to the Sherwood Sandstone or shallower formations and therefore no potential pathway through the Manchester Marls has been identified. This attribute is illustrated on Figure 11.5. Furthermore, once the hydraulic fracturing pressure is released, the high pressures applied during hydraulic fracturing would no longer be present.

252. While not nearby, the permeability of regional faults, such as the Woodsfold Fault as shown on Figure 5, is likely to be too low to allow significant groundwater flow and contaminant migration, even if they were somehow encountered. (Section 11.6.7). This is based on several lines of evidence:

- The presence of mudstone or marl along the majority of the length of the faults suggests that the fault is likely to be of low permeability due to development of fine grained low permeability material along the fault plane[265].

[264] Whilst migration via diffusion will occur alongside advection, diffusion would occur at very slow timescales (millions of years). Consequently, migration via diffusion is not considered to be a viable pathway and only advective flow is considered.

- The Woodsfold Fault (approximately 8km east of the Site) is considered to be a low permeability hydraulic barrier. The Woodsfold Fault effectively isolates the Sherwood Sandstone west of the fault from the Sherwood Sandstone east of the fault which is used for drinking water supply by United Utilities[233]. Due to the similarity in geologic formations and processes, the conditions of the Woodsfold Fault are likely to apply to the faults found further west.

253. While hydraulic fractures could potentially intersect existing faults at depth, this has been assessed and there is a **Very Low** likelihood of S-P-R linkage for fracturing fluid and poor quality groundwater. This is due to the likely lack of continuity through the Manchester Marls and the short-lived pressures associated with hydraulic fracturing.

254. Other deep wells could also act as preferential flow paths to groundwater receptors and management of fracture propagation and potential for interaction with offset wells will be addressed by Cuadrilla in the Hydraulic Fracture Plan for the Project wells to be submitted to DECC. However the distance of the nearest deep well from the Site (4km) eliminates deep wells from acting as a preferential flowpaths.

255. It is possible, although unlikely due to separation of fracturing zones, that fractures from one well may extend to another fractured well of the Project. However no environmental impact would result as the Project wells are all designed to withstand similar fracturing pressures, which would not be exceeded by an interconnecting induced fracture. No loss of well integrity would result since the only impact to the well would be in the target formation.

256. The potential for gas migration to human health receptors via induced fractures is considered separately below.

Gas migration via induced fractures (Table 11.13**)**

257. Following on from the discussion above regarding induced fracture pathways, the potential S-P-R linkage to human health receptors as a result of gas migration via induced fractures is considered below, due to gas buoyancy and the different receptors to be considered (i.e. human health receptors, and not groundwater receptors). This pathway has commonalities with the gas migration risks due to loss of well integrity described above, and duplication of text is avoided.

258. It is possible that a small proportion of the induced hydraulic fractures may reach a nearby fault. However identified faults have no continuity through the Manchester Marls. It is therefore considered highly unlikely that gases would be able to migrate along the fault from the Bowland Shale up into the Middle Sands.

259. If gas could migrate along the fault then the flow rates would be small and much dilution and dispersion would occur along the flowpath, particularly in the Sherwood Sandstone which is highly permeable and is estimated to be approximately 840m thick. It is likely that methane entering the Sherwood Sandstone would become dissolved in the groundwater and highly diluted.

260. <u>Gas migration to a groundwater abstraction</u> - As discussed above this S-P-R linkage requires an abstraction borehole pumping groundwater with dissolved methane, that then degasses in a confined space and results in methane accumulation to concentrations exceeding explosive limits (and ignition). Multiple pathways must coincide for this risk

[265] Evans, D. J. & Hough, E., 2009. Faulting at Preesall and other saltfields: information relevant to gas storage in the Preesall Halite. British Geological Survey Commissioned Report. Ref: CR/09/038. British Geological Survey, London, UK. 15pp.

to be realised and it is considered that as a result **no plausible pathway** exists, and therefore no S-P-R linkage is present.

261. Gas migration into building or enclosed spaces - This S-P-R linkage requires the migration of gases from the Bowland Shale to the top of the Mercia Mudstone, gas migration through the Middle Sands and low permeability Boulder Clay before migrating through cracks or service entries in building floor slabs and accumulating to concentrations exceeding explosive limits (and ignition). Considering the multiple pathways that must coincide for this risk to be realised, **no plausible pathway** is considered to exist and therefore no S-P-R linkage is present.

Residual fracturing fluid contaminants migrate to receptors (Table 11.13**)**

262. Not all the injected hydraulic fracturing fluid will return to the surface during flowback and testing and a proportion of the fracturing fluid will remain within the target shale formation and within the well. The potential for contaminants in the fluid in the shale formation to migrate vertically to shallow groundwater is assessed below. No reported literature cases of this S-P-R linkage occurring have been identified. Potential for residual fluid in the well is considered in 'Loss of well integrity due to long term well degradation' above.

263. The stratigraphy at the Site is formed of higher permeability sandstone units separated by low permeability mudstones and shales (as illustrated in Figure 5). Groundwater present below the Manchester Marls Formation is saline and of poor quality, and groundwater in the Sherwood Sandstone is also non-potable due to elevated salinity (Section 11.6.6).

264. The Sherwood Sandstone (the deepest groundwater receptor) is separated from the Bowland Shale by an estimated 410m thick sequence of rock which includes the very low permeability Manchester Marls Formation. Vertical advection between the target reservoir and shallow groundwater is not considered feasible due to the presence of these low permeability units.

265. Diffusive transport occurs where a concentration gradient exists, however diffusive contaminant transport is very slow across low permeability units such as the Bowland Shale and Manchester Marls Formation (i.e. geological times scales). In addition, the concentration gradient is unlikely to be significant between groundwater in the Bowland Shale and Millstone Grit which would further reduce the rate of diffusion.

266. It is therefore considered that there is **no plausible pathway** for contaminants to reach the Sherwood Sandstone or Middle Sands by vertical groundwater flow (advection) or via diffusion.

11.7.8 Assessment of consequences

267. The predicted consequences of realisation of the risks identified in the conceptual models above (Sections 11.7.1 to 11.7.6) are described in this section. In conjunction with the probabilities identified in Section 11.7.7 the risk magnitude can be assessed.

Potential impacts to groundwater in the Sherwood Sandstone

268. At the Site the Sherwood Sandstone is present at over 270m depth beneath the Mercia Mudstone and overlying the Manchester Marls, both low permeability units.

269. The Woodsfold Fault located 8km east of the site forms a regional groundwater flow barrier – to the east of the Woodsfold Fault the Sherwood Sandstone is near surface with good quality groundwater and to the west the Sherwood Sandstone is at several hundred

metres depths and saline. The Sherwood Sandstone is classified by the EA as a Principal Aquifer and, east of the Woodsfold Fault, a groundwater body under the Water Framework Directive. Surface water (including watercourses and ponds) is likely to be isolated from the Sherwood Sandstone by low permeability Boulder Clay and the Mercia Mudstone.

270. It is considered that if the S-P-R linkages to the Sherwood Sandstone identified in Sections 11.7.1 to 11.7.6 above were present the impact would be likely to be of **Low consequence** for the following reasons:

- Groundwater within the Sherwood Sandstone is not in hydraulic continuity with surface waters and has no significant interaction with Middle Sands groundwater;
- No groundwater abstractions are known to exploit the Sherwood Sandstone within 9km of the Site;
- Future abstraction is unlikely due to the depth of the Sherwood Sandstone and likely natural poor quality;
- No pathways have been identified that would allow large volumes of fluids to enter the Sherwood Sandstone;
- Significant dilution and attenuation (including dispersion and biodegradation) of contaminants would occur within the Sherwood Sandstone.

Potential impacts to groundwater in the Middle Sands

271. Groundwater in the granular horizons of the superficial deposits (referred to as the Middle Sands) is likely to be present beneath the Site, overlain by Upper Boulder Clay and underlain by Lower Boulder Clay and Mercia Mudstone. Groundwater quality within the Middle Sands is expected to be of good quality and could be used for water supply, although yields may be low.

272. The Middle Sands unit is designated a Secondary A Aquifer by the Environment Agency and a groundwater body under the Water Framework Directive (identified as West Lancashire Quaternary Sands and Gravels). The nearest recorded superficial deposit groundwater abstraction is 4.5km south of the Site.

273. Groundwater within the Middle Sands is unlikely to be locally in hydraulic continuity with watercourses due to the low permeability of the Upper Boulder Clay. Similarly the ponds within close proximity of the Site are unlikely to be groundwater fed as they were excavated to obtain calcareous clay (‘marl’).

274. Monitoring of groundwater in monitoring wells around the pad will be undertaken prior to construction (baseline monitoring), during the well pad construction and well drilling, fracturing and flow testing, and decommissioning (well abandonment and site restoration) stages. This could provide an early warning of any change in Middle Sands water quality and result in actions to limit the scale of any impacts.

275. It is considered that if pathways were present to the Middle Sands the impact would be likely to be of **Low consequence** for the following reasons:

- There are no known groundwater abstractions from the Middle Sands within 4.5km of the Site and future potential for exploitation is low;
- No pathways have been identified that would allow large volumes of fluids to enter the Middle Sands;
- Dilution and attenuation (including biodegradation and dispersion) of contaminants would occur within the Middle Sands;

- Groundwater within the Middle Sands is unlikely to be in hydraulic continuity with surface waters due to overlying low permeability Upper Boulder Clay present across the area;
- Groundwater monitoring around the well pad will provide early warning and allow remediation of any impact.

Potential impacts to 'groundwater' below the Manchester Marls Formation

276. The Millstone Grit and Collyhurst Sandstone could be considered as containing 'groundwater' in accordance with the legal definition. However, as discussed in the baseline characterisation, the units beneath the Manchester Marls are isolated from Middle Sands groundwater and also from the deeper Sherwood Sandstone groundwater. A release as a result of the Project into the Millstone Grit and Collyhurst Sandstone would result in no perceivable environmental impact and they are therefore not considered as specific groundwater receptors subsequently in this ES.

Potential impacts to surface water receptors

277. All watercourses in the vicinity of the Site have been realigned along field boundaries, the nearest being approximately 200m northwest of the well pad, flowing in a northwesterly direction towards Carr Bridge Drain and subsequently into Main Drain further downstream. Marl pit ponds are present close to but not downstream of the Site and they will have little interaction with groundwater. Discharge to watercourse of rainfall runoff collected in the pad drainage system will only be undertaken with EA approval.

278. Monitoring of surface water at locations around the Site will be undertaken prior to construction and throughout operations and for a period following abandonment. This could provide an indication of any change in surface water quality and result in actions to limit the scale of any impacts

279. It is considered that if pathways were present to the surface water receptors the impact would be likely to be of **Low consequence** for the following reasons:

- There are no ecological designations (e.g. SSSI) for surface water features in the vicinity ofthe Site;
- There are no recorded surface water abstractions of relevance to the Site;
- No pathways have been identified that would allow large volumes of contaminated fluids to be released into surface water;
- Dilution and attenuation of contaminants would occur along the flowpath to Main Drain to the River Ribble;
- Surface water monitoring will provide early warning and allow remediation of any impact.

Potential impacts to human health

280. The following human health receptors are considered in this chapter relating to hydrogeology and ground gas (see Section 11.6.13):

- Persons exposed to liquid contaminants released from well pad activities;
- Persons exposed to spilled fluids following a road accident off-site;
- Persons exposed to ground gas accumulation.

281. The potential exposure of a person to contaminated water in a watercourse downstream of the Site has been considered. Potential contaminants include drilling fluids, fracturing fluid and flowback fluid (discussed above and in Appendix K). However this risk could only be realised if failure of multiple environmental protection systems (see *Overflow of*

pad drainage system above) coincided with a rainfall event when a person was in contact with the watercourse (as discussed above the probability is considered Low). Overflow of the pad drainage system is most likely to occur during extreme rainfall, when contaminants present will be highly diluted. This S-P-R linkage is assessed as a **Low consequence** due to the relatively low toxicity of the highly diluted material (Appendix K Sections K3.3.4, K4.3 and K4.4).

282. Mechanical failure of equipment, such as a pipework connection, during drilling or fracturing has the potential to release fluids at high pressure, as a spray off site (the probability is discussed above). In the unlikely event that this type of release occurred it would be high pressure but low volume due to emergency shutdown procedures and close supervision. The S-P-R linkage, with a person standing outside the Site boundary, is considered to have a **Low consequence** due to the relatively low toxicity of the material (Appendix K Sections K3.3.4, K4.3 and K4.4) and probable low volume and short duration.

283. The likelihood of spillage of contents of a vehicle due to a road traffic accident is considered above (assessed as Low likelihood). The consequence of exposure to the spilled material is assessed to be **Low**, as a result of the relatively low toxicity of the material (Appendix K Sections K3.3.4, K4.3 and K4.4) and probable short duration of exposure.

284. S-P-R linkages associated with ground gas migration and human health impact have been considered in Section 11.7.7 and 'no plausible pathway' has been identified. Therefore the consequence is not considered.

285. The recent Public Health England report[193] provides a detailed assessment (including air quality impacts as well as water pathways) and concludes the '*evidence indicates that the potential risks to public health from exposure to the emissions associated with shale gas extraction are low if the operations are properly run and regulated*.'

Potential impacts to crops and livestock

286. S-P-R linkages that are relevant to crops and livestock are the same as those for human health outside the Site boundary, namely:

- Potential exposure of crops and livestock to contaminated water in a watercourse downstream of the Site; and
- Mechanical failure of equipment during drilling or fracturing could release fluids at high pressure as a spray off site.

287. As discussed above for the human health assessment above, S-P-R linkage to adjacent crops and livestock are considered to have **Low consequences** considering the possible release characteristics and likely localised area affected.

11.7.9 Assessment summary

288. In accordance with the methodology in 11.4.4, the assessed probabilities and consequences have been combined to provide a 'risk magnitude' for each S-P-R linkage. Table 15 summarises the assessment and identifies risk magnitude for each S-P-R linkage.

11.8 Cumulative and interactive effects

289. Cumulative effects with other relevant developments within the area surrounding the Project could include concurrent activities at Roseacre Wood, another Cuadrilla shale gas exploration site where exploration works may be on-going at the same time as activities at the Project. The Project well pad is located approximately 7km southwest of the Roseacre Wood well pad.

290. The distance between the two sites is too great for any interaction of fracture zones associated with wells from the two sites. The likelihood of there being a cumulative hydrogeology and ground gas related impact in the subsurface is low.

291. The Preston New Road and Roseacre Wood Sites drain into separate surface water sub-catchments. The Preston New Road Site is located in the River Ribble catchment and the Roseacre Wood Site drains into the River Wyre catchment. Therefore, the cumulative effects of surface water contamination risk are assessed as independent and therefore no plausible cumulative effect.

292. The potential cumulative effects of simultaneous activities on the Project well pad are also considered here, namely:

- In-combination effects of hydraulic fracturing and initial flow testing occurring together on the Project well pad;
- In-combination effects of initial flow testing and drilling occurring together on the Project well pad.

293. The management of possible interactions during drilling and fracturing will be implemented through assessment and appropriate mitigation and documented in the well programmes and the HFP (see Appendix K3.3.2). The HFP will include a site specific risk assessment considering potential for interactions with offset wells and other project wells, in accordance with industry good practice[266].

294. The potential for collision during drilling of a new well with another well on the same pad is routinely managed by the industry and multi-well pads for onshore hydrocarbon exploration have been developed across the UK.

295. At the planning stage the trajectories of the wells are designed in 3-dimensions for optimum separation and during drilling directional surveying will be used to reduce uncertainty in well location. The selection of the specific anti-collision techniques to be applied during drilling will be documented as part of the detailed operations programming.

296. Multiple activities on-site may take place, such as drilling wells while well testing or hydraulic fracturing (see ES Chapter 4). Prior to any simultaneous operations, Cuadrilla will prepare a simultaneous well operations plan and risk assessment specific for the project wells. Management of interactions between hydraulic fracturing zones between different wells would be documented in the HFP. If interaction does occur, each individual well on-site is designed to be capable of withstanding the range of pressures that would be produced. In addition, pressures will be closely monitored at each well during hydraulic fracturing activities.

[266] Energy Resources Conservation Board (ERCB), 2013. Directive 083: Hydraulic Fracturing – Subsurface Integrity. ERCB, Alberta Energy Regulator, Alberta, Canada. 14pp.

11.9 Mitigation measures

297. The risk associated with each potential S-P-R linkage has been evaluated according to the methodology given in Section 11.4. The findings of this evaluation are shown in Table 11.15.

298. The risk magnitude for each of the potential S-P-R linkages is assessed as Low. In accordance with the methodology presented in Section 11.4 no additional mitigation measures are considered necessary.

11.10 Residual effects

299. As no additional mitigation to those measures embedded in the Project have been identified as necessary the residual risk magnitudes are also assessed to be Low.

11.11 Assessment summary matrix

Table 11.15 Hydrogeology and ground gas assessment summary.

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
Project activity - Construction of well pad and access										
Sediment in rainfall runoff during earthworks	→	Overland flow	→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology	Low	Low	Low. Not significant.	None in addition to embedded mitigation	Low. Not significant.	Not applicable (N/A)
Diesel or lubricants spilled from vehicles and plant during construction of pad or access	→	Seepage into the ground or overland flow	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (contact with contaminated surface water or soil)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Project activity - Construction of surface and buried arrays										
Sediment in rainfall runoff, drilling muds or diesel from vehicles and plant during construction released due to failure of equipment, vehicle collision, or site operative error	→	Overland flow or infiltration into ground	→	Watercourses, ponds and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (exposure to contaminated surface water or soil)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Infiltration down annulus of a poorly constructed array borehole	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Project activity - Drilling										
Pad and surface activities (during drilling)										
Spillage of fluids on the well pad due to failure of equipment or infrastructure, vehicle collision, or site operative error	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
				Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
	→	Collection in site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (contact with contaminated water)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Fire fighting foam or water	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
				Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (contact with contaminated water)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Failure of equipment causes release of fluid at high pressure	→	Liquid spray off site through the Site boundary fence	→	Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (a person standing outside the Site boundary fence)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Off site road traffic accident resulting in spill of potentially contaminating materials	→	Spill of contents of vehicle in transit onto public highway	→	Off-site human health (exposure to spilled material)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Water environment along transit route	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Well construction and integrity (during drilling)										
Drilling fluids Naturally poor quality groundwater	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases from below the Manchester Marls	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater for use within a confined space	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
	→	Loss of well integrity resulting in gas migration to shallow soils followed by entry into buildings	→	On-site human health (site workers and visitors	No plausible linkage					

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
		(or other confined spaces) on or off site.	→	Off-site human health (users of off-site confined spaces)	No plausible linkage					
Project activity - Hydraulic fracturing										
***Pad and surface activities* (see '*Pad and surface risks during drilling*' identified above)**										
Well integrity (during fracturing)										
Hydraulic fracturing fluid Flowback fluid Naturally poor quality groundwater (from below the Manchester Marls)	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity caused by hydraulic fracturing resulting in release from the well	→	Sherwood Sandstone groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to induced seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases from below the Manchester Marls and dissolved in flowback fluidwell pad	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater for use within a confined space	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
	→	Loss of well integrity resulting in gas migration to shallow soils followed by vertical migration into buildings (or other confined spaces) on or off site.	→	On-site human health (site workers and visitors	No plausible linkage					
				Off-site human health (users of off-site confined spaces)	No plausible linkage					
Induced fractures										
Hydraulic fracture fluid Naturally poor quality groundwater (from the Bowland Shale)	→	Fractures propagating beyond the target zone which then connect to preferential flowpaths (natural discontinuities or deep boreholes)	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases (from below the Bowland Shale)	→	Gas migration along induced fractures, natural fissures and faults to shallow groundwater and abstraction of groundwater for use within a confined space.	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
	→	Gas migration along induced fractures, natural fissures and faults to shallow soils and above ground confined spaces on-site or off-site	→	On-site human health (site workers and visitors)	No plausible linkage					
			→	Off-site human health (users of off-site confined spaces)	No plausible linkage					

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
Residual fracturing fluid in Bowland Shale	→	Groundwater flow, including diffusion, through bedrock	→	Sherwood Sandstone groundwater	No plausible linkage					
			→	Middle Sands groundwater						
Project activity - Initial and extended flow testing										
There are no additional S-P-R linkages in the initial and extended flow testing stage to those identified above.										
Project activity - Decommissioning and restoration										
(Only additional S-P-R linkages to those identified above presented below)										
Hydraulic fracturing fluid Naturally poor quality groundwater (from below the Manchester Marls)	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to long term well degradation	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Ground gas (from below the Manchester Marls)	→	Loss of well integrity due to long term well degradation resulting in: migration to shallow groundwater and abstraction of groundwater for use within a confined space; or migration into buildings or other confined spaces.	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
			→	Off-site human health (users of off-site other enclosed spaces)	No plausible linkage					

11.12 Figures

Figure 11.1 Flyde hydrogeology summary.

Figure 11.2. Conceptual model of well pad and surface environmental protection.

Figure 11.3. Well design and well barrier systems (well construction and hydraulic fracturing phases).

Figure 11.4. Well design and well barrier systems (well testing phase).

Figure 11.5 Conceptual model of potential pathways for well integrity and induced fractures and relevant mitigation.

A3

Thistleton Fault

Woodsfold Fault

Mercia Mudstone Group
(Hambleton Mudstone Member)

Craven Group
(Bowland Shale Formation)

Manchester Marls Formation

Roseacre Wood Site

Mercia Mudstone Group
(Sidmouth Mudstone Formation)

Preston New Road Site

Kirkham

Mercia Mudstone Group
(Breckells Mudstone Formation)

Sherwood Sandstone Group

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Key

- Site Location
- Krirkham Groundwater Level Monitoring Well
- Groundwater Private Supply
- Surface Water Private Supply
- Environment Agency Groundwater Abstraction Licence
- Environment Agency Surface Water Abstraction Licence
- Deregulated Groundwater Abstraction
- Deregulated Surface Water Abstraction
- River/Stream (minor watercourses not shown)

Linear Features

- Fault

BRECKELLS MUDSTONE MEMBER	Mercia Mudstone Group
HAMBLETON MUDSTONE MEMBER	Mercia Mudstone Group
MYTHOP HALITE MEMBER	Mercia Mudstone Group
PREESALL HALITE MEMBER	Mercia Mudstone Group
ROSSALL HALITE MEMBER	Mercia Mudstone Group
SIDMOUTH MUDSTONE FORMATION	Mercia Mudstone Group
SINGLETON MUDSTONE MEMBER	Mercia Mudstone Group
MANCHESTER MARLS FORMATION	Cumbrian Coast Group
SHERWOOD SANDSTONE GROUP	Sherwood Sandstone Group
ROEBURNDALE MEMBER	Millstone Grit Group
PENDLE GRIT MEMBER	Millstone Grit Group
BOWLAND SHALE FORMATION	Craven Group

Notes

1. Geology Basemap: DiGMapGB-50 [V_7] (BGS, 1:50,000 scale) licenced to Cuadrilla Resources Ltd under licence 2010/018.

Issue	Date	By	Chkd	Appd
	21/05/2014	APS	NW	JF

Metres: 0, 750, 1,500, 3,000

ARUP

Client
Cuadrilla Bowland Ltd

Job Title
Preston New Road EIA

Fylde Hydrogeology Summary

Scale at A3
1:60,000

Job No
230382-00

Drawing Status
Final

Drawing No
Figure 11.1

Issue

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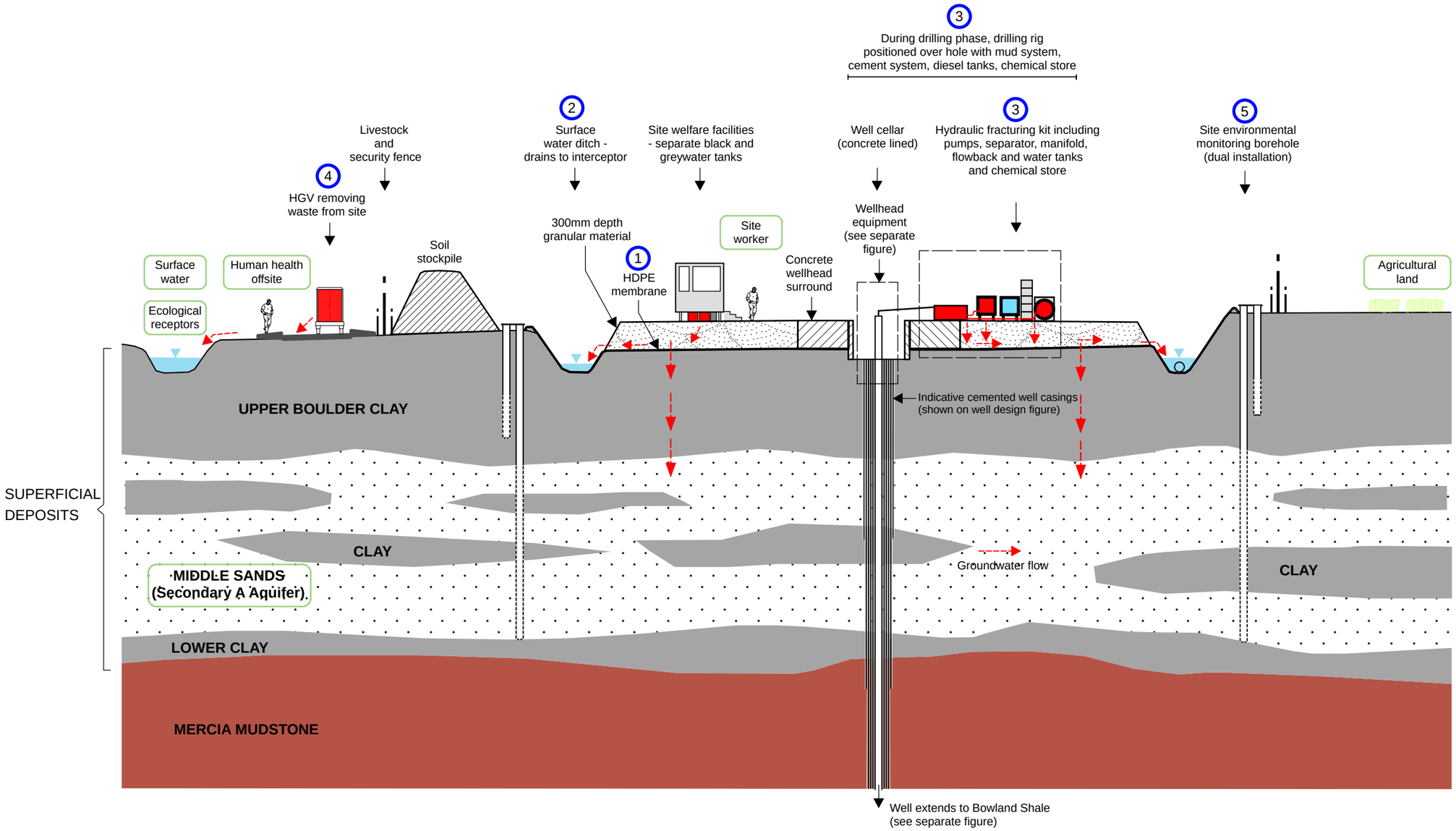
A3



Well pad and surface environmental protection measures

Site management in accordance with Environmental Operating Standard including:

1. Well pad design including HDPE membrane contains site spills and rainwater;
2. Discharge to watercourse only via interceptor and with EA approval, and not during operations;
3. Potentially contaminating materials stored and managed in accordance with good practice and regulatory requirements, diesel tank with secondary containment, 24 hour emergency response contractor, Pollution Incident Plan;
4. HGV routes agreed with relevant authorities, registered waste carriers with spill kits and management procedures, 24 hour emergency response contractor;
5. Environmental monitoring including from groundwater monitoring boreholes.

Legend

- Potential source
- Potential receptor
- Potential pathway
- (1) Environmental protection measure - see box below

Issue	Date	By	Chkd	Appd
.	.	.	.	.
01	2014-05-23	ST	JL	JL

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Conceptual Model of Well Pad and Surface Environmental Protection

Scale at A3
Not to scale

Job No: **230382-00**
Drawing Status: **Issue**
Drawing No: **Figure 11.2**
Issue: **01**

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MXD Location

A3

SHALLOW CONDUCTOR CASING 36" to 42" OD
Top of cement to surface (welded casings)
Note: Only installed if loose sands are encountered during driling

SHALLOW CONDUCTOR CASING 28" to 30" OD
Top of cement to surface
(welded casings)

DEEP CONDUCTOR CASING 18 5/8" to 20" OD
24" to 26" borehole diameter
Top of cement to surface
(Buttress threaded casing)

SURFACE CASING 13 3/8" OD
16" to 17 1/2" borehole diameter
Top of cement to surface
(Gas-tight threaded casing)

INTERMEDIATE CASING 9 5/8" OD
12 1/4" borehole diameter
Top of cement to 200m above surface casing shoe
(Gas-tight threaded casing)

At selected depth sidetrack will commence to 90° inclination.

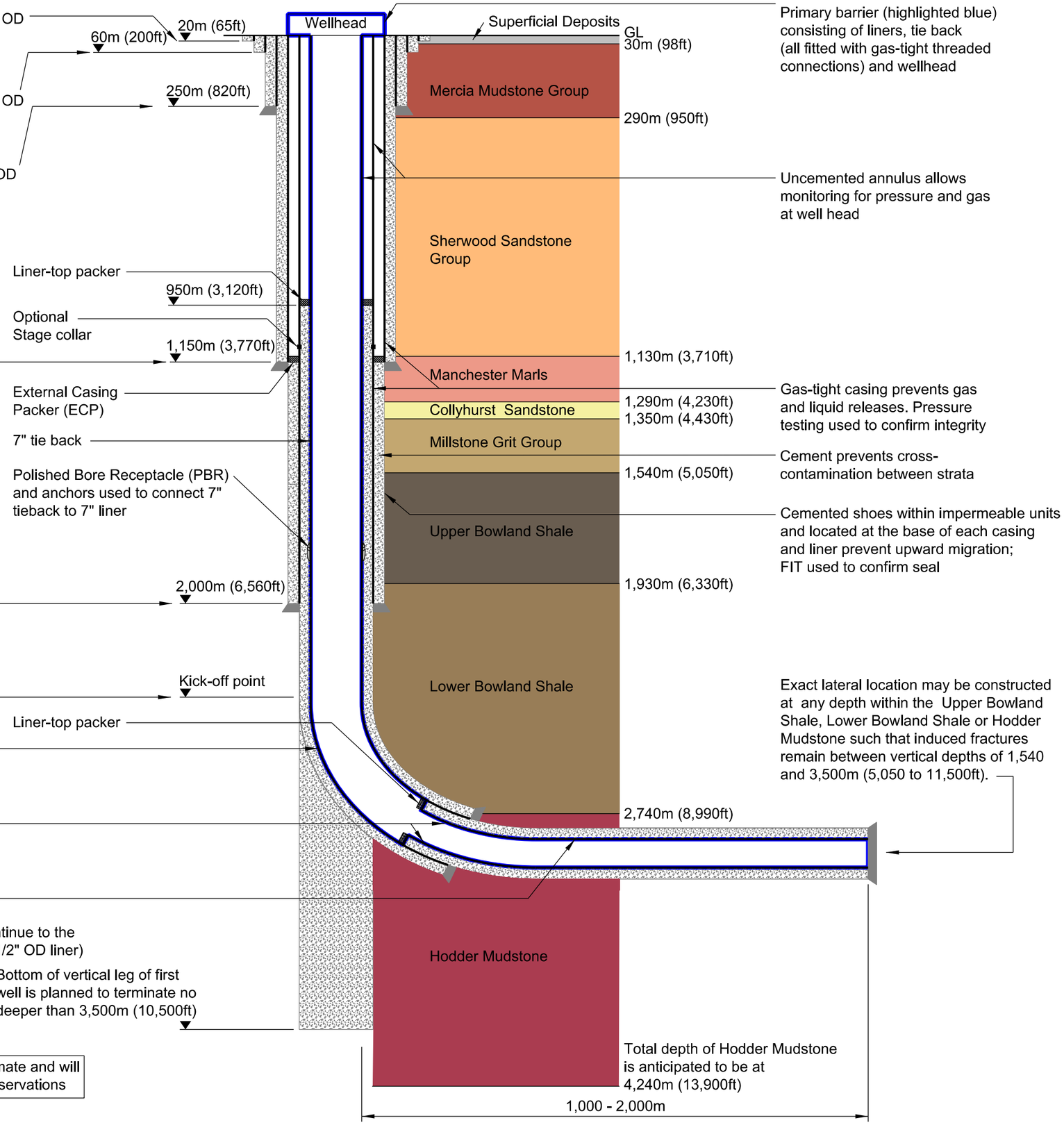
7" OD LINER
8 1/2" borehole diameter
Top of cement to liner

Overlap length is approximately 150m

HORIZONTAL PRODUCTION LINER
(4 1/2" OD) 6" borehole diameter
(Note: In some cases the 7" OD Liner may continue to the total drilling length instead of switching to a 4 1/2" OD liner)

Bottom of vertical leg of first well is planned to terminate no deeper than 3,500m (10,500ft)

All well construction depths are approximate and will be adjusted depending on geological observations



Primary barrier (highlighted blue) consisting of liners, tie back (all fitted with gas-tight threaded connections) and wellhead

Uncemented annulus allows monitoring for pressure and gas at well head

Gas-tight casing prevents gas and liquid releases. Pressure testing used to confirm integrity

Cement prevents cross-contamination between strata

Cemented shoes within impermeable units and located at the base of each casing and liner prevent upward migration; FIT used to confirm seal

Exact lateral location may be constructed at any depth within the Upper Bowland Shale, Lower Bowland Shale or Hodder Mudstone such that induced fractures remain between vertical depths of 1,540 and 3,500m (5,050 to 11,500ft).

KEY
Measured depth.....MD
Ground level.....GL
Outside diameter.....OD
True vertical depth below ground level.....TVDGL

Notes:
1. Vertical scale approximate, horizontal elements are not drawn to scale.
2. Formation depths shown are based on current geological prognosis developed by Cuadrilla.
3. Conceptual well design provided by Cuadrilla.
4. All posted depths are in TVDGL.
5. Depth of intermediate casing will depend on depth of lateral.

01	23/05/14	ST	MC	JL
Issue 01				

Issue	Date	By	Chkd	Appd

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Job Title
Preston New Road EIA

Well Design and Well Barrier Systems (Well Construction and Hydraulic Fracturing Phases)

Scale at A3 V 1:15000 (H - not to scale)

Discipline Geotechnics

Job No 230382-00

Drawing Status Issue

Drawing No Figure 11.3

Issue 01

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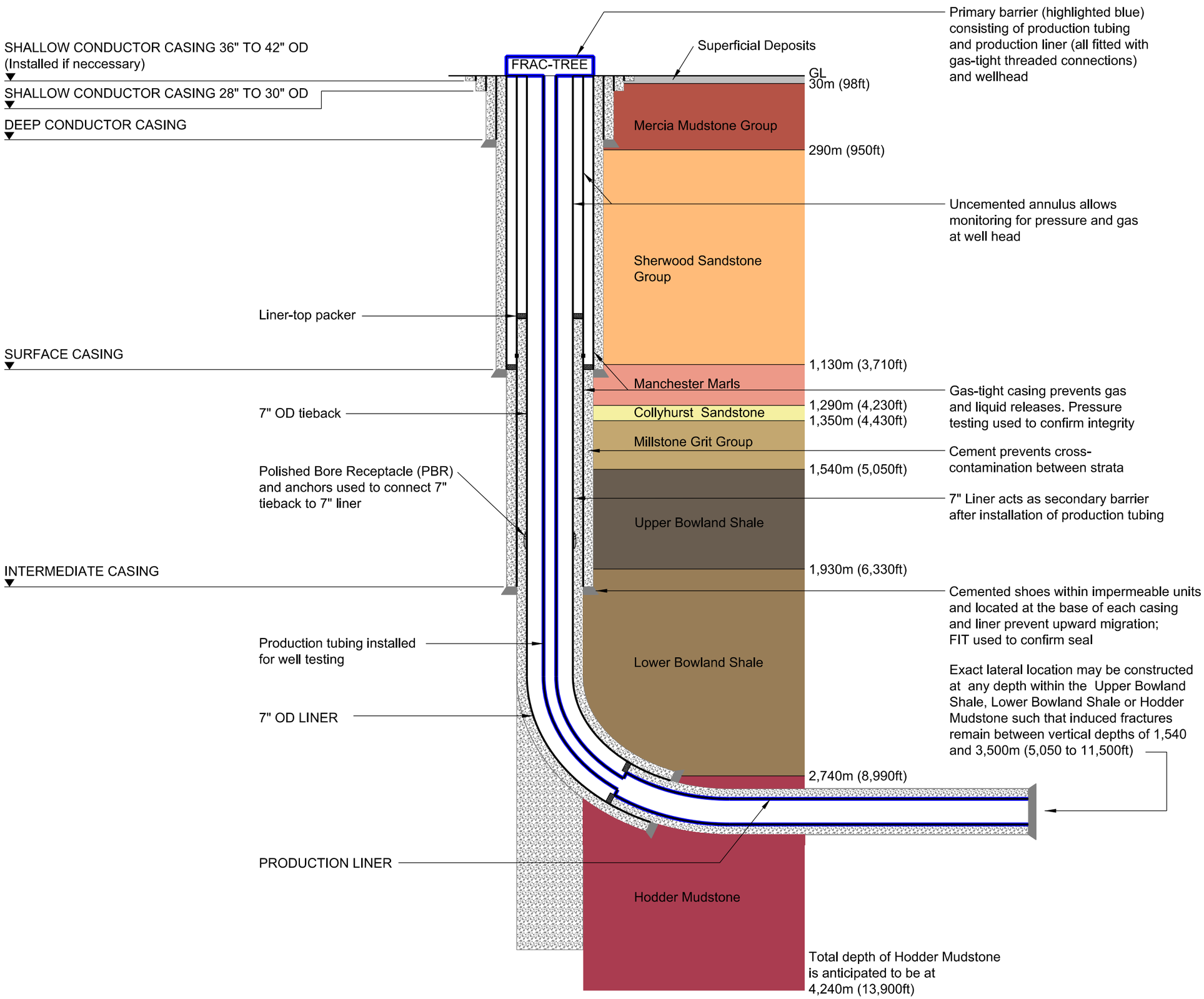

KEY
Measured depth.....MD
Ground level.....GL
Outside diameter.....OD
True vertical depth below ground level.....TVDGL

Notes:
1. Vertical scale approximate, horizontal elements are not drawn to scale.
2. Formation depths shown are based on current geological prognosis developed by Cuadrilla.
3. Conceptual well design provided by Cuadrilla.
4. All posted depths are in TVDGL.
5. Depth of intermediate casing will depend on depth of lateral.

Issue	Date	By	Chkd	Appd
01	23/05/14	ST	MC	JL

Issue 01

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Job Title
Preston New Road EIA

Well Design
and Well Barrier Systems
(Well Testing Phase)

Scale at A3 V 1:15000 (H - not to scale)

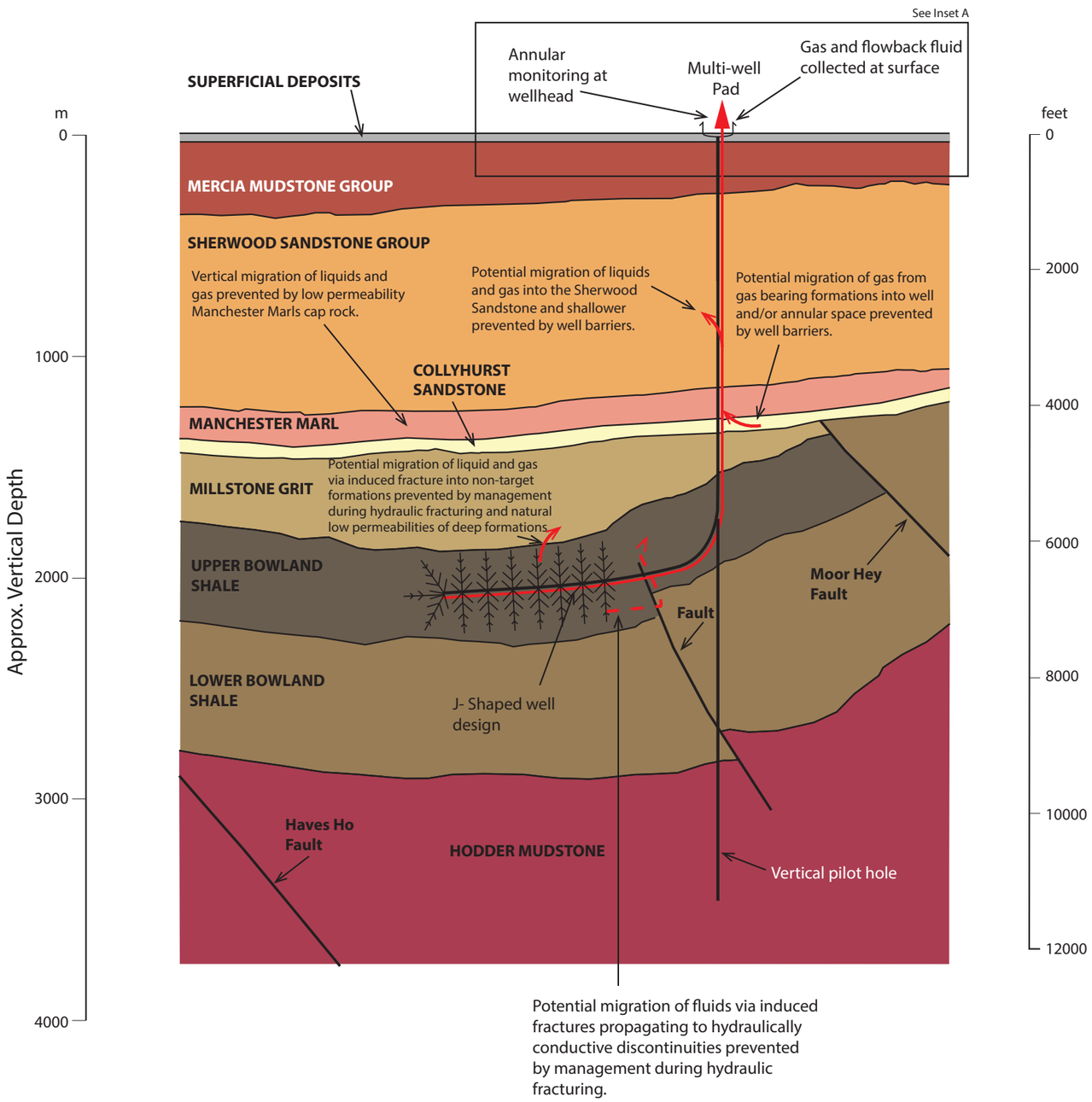
Discipline Geotechnics

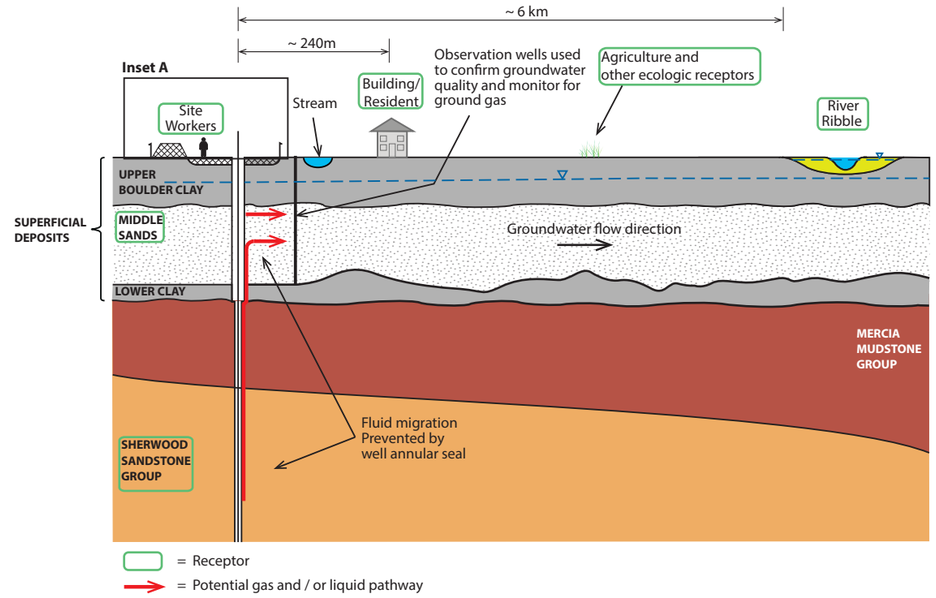
Job No 230382-00

Drawing Status Issue

Drawing No Figure 11.4

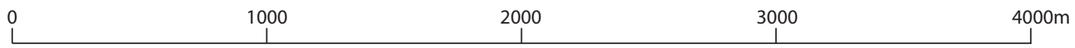
Issue 01





Notes:

- Liquids include fracture fluid, formation water and flowback fluid.
- Gas includes formation gas (such as methane) from Collyhurst Sandstone, Bowland Shale and Hodder Mudstone. Note that no sulphur containing gases have been detected such as hydrogen sulphide.
- Exact lateral location may be constructed at any depth within the Upper Bowland Shale, Lower Bowland Shale or Hodder Mudstone such that induced fractures remain between 1,540 and 3,500 m (5,050 and 11,500 ft).
- Up to 4 J-shaped wells to be installed at the Site. Only the first well will include a vertical pilot hole.



Final Issue	Date	By	Chkd	Appd
P1	23-05-2014	J S	MC	JL

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Client
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Job Title
Preston New Road

Conceptual model of potential pathways for well integrity and induced fractures and relevant mitigation

Not to scale

Job No	Drawing Status
230382-00	Issued

Drawing No	Issue
Figure 11.5	P0

MXD Location

12 Induced seismicity

Chapter Summary – Induced Seismicity

This chapter provides a discussion on the assessment of the effects of induced seismicity associated with the Project in relation to felt effects of seismicity and potential damage to buildings and infrastructure. Induced seismicity normally occurs during hydraulic fracturing due to the propagation of engineered fractures or, in extremely rare circumstances, due to the transmission of fluid pressure into a critically stressed fault.

Following the felt induced seismic event that was attributed to hydraulic fracturing of Cuadrilla's Preese Hall well, several measures have been incorporated into the Project as embedded mitigation. These measures are a requirement of the Department for Energy and Climate Change (DECC)[267], the United Kingdom Onshore Operators Group (UKOOG)[268] and were announced in Parliament as a written statement by the Secretary of State for Energy and Climate Change on December 13th 2012[270]. These measures include:

- Reviewing available information on geology, structure (including faults) and *in situ* stresses in the vicinity of the proposed Site to avoid hydraulically fracturing into, or close to, existing critically stressed faults[267,268,270,285,321];
- Carry out risk based geomechanical assessments of proposed hydraulic fracturing with regard to known faults (including maximum magnitude estimates) [268];
- Monitoring background induced and natural seismicity before, during and after hydraulic fracturing[267,285,321];
- Applying an evolutionary approach to risk assessment and mitigation (operational mitigation) –This stepped progressive approach to hydraulic fracturing will consist of an initial mini-fracture stage and modest initial pumped volumes building up to a maximum pump volume of 765m^3 per stage (less than half of the average volumes pumped per stage at Preese Hall). As this process continues, an understanding of the performance of the reservoir during hydraulic fracturing is developed[267,268,285,321];
- Monitor the extent of fracture growth during hydraulic fracturing using a buried microseismic array[267,268,285,321];
- Implementation of the Traffic Light System (via the surface seismic monitoring array);
- Flowback in the case of Amber (0.0 M_L) or Red (0.5M_L) seismic events between hydraulic fracturing stages in accordance with the Traffic Light System.

The Project proposals include hydraulic fracturing and extended well testing activities. Therefore, according to the DECC requirements[271], Cuadrilla are required to submit a description of the controls described above to mitigate induced seismicity in the Hydraulic Fracturing Programme (HFP). The HFP will be authorised by DECC prior to commencement of hydraulic fracturing activities.

With these measures implemented (as required by DECC and as recommended by UKOOG), this assessment concludes that the effects of induced seismicity associated with the Project are **not significant** and will reduce the likelihood of felt seismicity and mitigate against any damage to property or infrastructure. This assessment has also assessed potential cumulative effects and they are **not significant**.

[267] Department for Energy and Climate Change (DECC). (2014). Fracking UK shale: understanding earthquake risk. URL:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/283837/Seismic_v3.pdf [site accessed 22/05/2014]
[268] UK Onshore Operators Group (UKOOG). UK onshore shale gas well guidelines – exploration and appraisal phase. Issue 1. February 2013.

12.1 Introduction

1. This Chapter provides an assessment of the likely effects of induced seismicity associated with the Project, which comprises well pad construction, well drilling, hydraulic fracturing, well testing [flow testing], decommissioning and restoration. The installation of seismic monitoring arrays across the local area, associated with the Preston New Road operations is also assessed.

2. In the context of hydraulic fracturing for shale gas, the (physical) mechanisms involved in the production of seismic events includes stress changes on a plane of weakness (e.g. fault) caused by 1) the growth of the engineered fractures; and 2) the transmission of fluid pressure increase into a critically stressed fault[269].

3. It is noted that the terms 'induced seismicity' and 'triggered' seismicity are defined in the glossary at the beginning of the Environmental Statement and described within the explanation of key terms below (Section 12.1.1).

4. This chapter has been prepared by Arup with input from and consultations with internationally recognised technical experts in the fields of rock mechanics, hydraulic fracturing, induced seismicity, geophysical (seismic) interpretation and seismic monitoring.

5. In addition to the UK based guidance on hydraulic fracturing from DECC[267], relevant international guidance documents have been reviewed along with reports on hydraulic fracturing for shale gas in the UK and worldwide. DECC have recommended UKOOG shale gas well guidelines[268] be implemented. This assessment has also considered the requirements announced in Parliament via a written ministerial statement by the Secretary of State for Energy and Climate Change on December 13th 2012[270].

6. This Induced Seismicity Chapter is supported by Appendix L, which presents a detailed discussion of the assessment referred to in this Environmental Statement.

12.1.1 Explanation of Key Terms

7. This explanation of key terms provides definitions of key terms associated with Induced Seismicity defined for the purposes of this chapter. More detailed and comprehensive glossaries are found at the beginning of this ES.

   - **Buried array** – Cuadrilla will install a buried microseismic monitoring array (up to 100m below ground level) to confirm that hydraulic fracturing will not take place within or close to existing critically stressed regional faults. This array will comprise approximately 10 real time stations and approximately 70 store and harvest stations.
   - **Felt seismicity** – A seismic event that can be detected by humans. Typically an event with a magnitude between 1.0-2.0M_L is not felt, except by a very few people under especially favourable conditions[267].

[269] Frohlich, C., Brunt., M. (2013). Two-year survey of earthquakes and injection/production wells in the Eagle Ford Shale, Texas, prior to the $M_{W\ 4.8}$ 20 October 2011 earthquake. Earth and Planetary Science Letters. Vol.379, pp. 56-63.
[270] Department for Energy & Climate Change (2012). Written Ministerial statement by Edward Davey: Exploration for shale gas. <URL: https://www.gov.uk/government/speeches/written-ministerial-statement-by-edward-davey-exploration-for-shale-gas> [site accessed 28/04/2014].

- **Hydraulic fracturing** – The process of injecting pressurised fluid into rock formations with the aim of forming and or opening fractures in the rock mass. Proppant is usually added to hold fractures open after fluid pressure is reduced.
- **Hydraulic Fracture Programme (HFP) –** Before an operator can commence hydraulic fracture operations a HFP should be submitted and authorised by DECC. In accordance with DECC requirements on the HFP[271] (referred to as the 'frac plan' by DECC), the HFP should contain the following information:

  1) "*Depth structure maps showing mapped faults near the well and along the well path, with a summary assessment of faulting and formation stresses in the area and the risk that the frac operations could reactivate existing faults.*
  2) *Information on the local background seismicity (using BGS data or other data) and assessment of the risk of induced seismicity.*
  3) *Summary of the planned fraccing ops, including perf stages, pumping pressures and volumes.*
  4) *If in a field, a comparison of proposed activity to any previous frac operations and relationship to historical seismicity.*
  5) *Proposed measures to mitigate the risk of inducing an earthquake and monitoring of local seismicity during the operations.*
  6) *For shale gas fracs, a description of proposed real-time traffic light scheme for seismicity, and proposed method for fracture height monitoring."*
- **Induced seismic event** – Defined as seismic activity induced by stress or strain perturbations resulting from anthropogenic sources. Events are only categorised as induced, when they release less energy than it takes to initiate them[275].
- **Magnitude** – Magnitude is the value that characterises the relative size or energy released of an earthquake at the source. Magnitude is calculated on observations of the amplitude of the ground motions recorded by seismographs located locally and around the world[272]. There are a number of different magnitude scales, which can be converted by empirical relationships.
- In this document seismic events are referred to in 'local magnitude or M_L'. The local magnitude scale is commonly used in the field of induced seismicity due the suitability of this scale to shallow, low magnitude and short distance seismic events.
- **Microseismicity** – A small seismic event, usually with a magnitude less than 2.0[273].
- **Mini-fracture** – Before undertaking the main hydraulic fracturing stage, a pilot hydraulic fracturing stage or "mini-fracture" may be performed. This involves pumping small volumes of fracturing fluid (without any proppant) into the well. The

[271] Department for Energy and Climate Change (2014). <URL: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/79173/Extended_well_tests_and_Frac_Plan.docx>.
[272] Palacios, P., Molina, I., Segovia, M. (2006). The Gutenberg-Richter Law: Assumptions, Limitations and Interpretations. Statistics in Volcanology. Special Publications of IAVCEI. Vol.1, pp.115-127.
[273] Bohnhoff, M., Dresen , G., Ellsworth, L., Ito, H. (2010). Passive seismic monitoring of natural and induced earthquakes: Case studies, future directions and socio-economic relevance. In: Cloetingh, S., Negendank, J. (eds.), New Frontiers in Integrated Solid Earth Sciences, International Year of Planet Earth, DOI 10.1007/978-90-481-2737-5_7, Springer Science+Business B.V.

purpose of the mini-fracture is to evaluate the injection pressure required to generate fractures in the rock during the subsequent main hydraulic fracturing stage.

- **Regional fault –** A regional fault is here defined as fault identified by the British Geological Survey and presented on their 1:50,000 scale mapping.
- **Surface array –** Cuadrilla will install a surface seismic monitoring array, which will be used to collect seismic data before, during and after hydraulic fracturing. The seismic array will also be used for the purpose of implementing the TLS. This array will comprise 8 surface stations (buried in approximately 1m deep pits).
- **Traffic Light System –** This is a monitoring and decision-making tool regarding the duration and intensity of fluid injection during hydraulic fracturing stages (as it has been used in the geothermal industry). The traffic light system is based on the observed effect of small magnitude seismicity as a precursor to larger magnitude events (i.e. the trailing effect – described below). DECC[267] have recommended that a 0.5 M_L red light threshold be used to limit induced seismicity to below the level that may be felt by humans (see Section 12.9 for further details).
- **Trailing effect (post-injection magnitude increase) –** The unit increase in the magnitude of seismicity following the termination of injection. The driving force for this post-injection seismicity is temporary on-going pressure diffusion within the reservoir.
- The observed trailing effect of the induced seismicity at the Preese Hall-1 well was a magnitude unit increase of 0.9[276]. Observed trailing effects in other cases of reservoir stimulation have led to a magnitude unit increase of 0.8 after shut-in (i.e. Deep- Heat-Mining Project, Basel[274]). De Pater and Baisch (2011)[276] consider the post-injection magnitude increase of 0.9 magnitude units to represent a worst case scenario. For conservatism, this assessment considers a worst case post-injection magnitude increase of 1.0 magnitude units.
- **Triggered seismic event** – Seismic event that is caused by only a small change in stress or by migration of fluids into a pre-stressed, pre-existing fault. Triggered events are sometimes referred to as fault reactivation. Triggered seismic events release more energy than is required to initiate them[275].

12.2 Key development issues

8. Although this assessment considers all activities of the project, the hydraulic fracturing stage of the Project is the main consideration in terms of induced seismicity. The key development issues associated with induced seismicity include the following:

- The potential effects of ground motion, including felt vibrations, damage to structures, infrastructure and other elements of the built environment;
- The risk of the ground motion hazard causing equipment damage, in particular the integrity of the borehole and the casing;
- The growth of engineered fractures and the potential for the migration of hydraulic fracturing fluids and gases out of the fracturing zone; and

[274] Deichmann. N., Giardini, D. (2009). Earthquakes induced by the stimulation of an Enhanced Geothermal System below Basel (Switzerland). Seismological Research Letters. Vol. 80, pp.784-798.
[275] McGarr, A., Simpson, D., Seeber, L., (2002). Case histories of induced and triggered seismicity. International Handbook of Earthquake and Engineering Seismology. Vol 81A.

- The methods to monitor and limit the magnitude of seismic activity.

12.2.1 Induced seismicity associated with shale gas exploitation

9. Whilst felt seismicity associated with shale gas exploitation is not common, it is well documented internationally and recently within the UK[276,277]. Induced seismicity refers to seismic events, typically of very low magnitude, usually in the magnitude range of -3.0 to 0.0 M_L (local magnitude scale), which are induced by stress perturbations resulting from anthropogenic sources. A recent review of past induced seismic events associated with the millions of hydraulic fracturing stimulations that have occurred in the US, UK and Canada have shown that the vast majority of events do not exceed 0.0 M_L[278]. In the context of shale gas exploration and recovery, seismic events in the range of less than 0.0 M_L are often attributed to the initiation and growth of hydraulic fractures.

10. Although unlikely, larger events can occur, such as the 2.3 M_L seismic event that was attributed to hydraulic fracturing of the Preese Hall well, and the ground motions may be of sufficient amplitude to be felt at the surface. Macroseismic data (i.e. reported felt effects) from this event indicated that there were 23 reports of felt shaking and no confirmed damage[279]. A second smaller 1.5 M_L Preese Hall seismic event was reportedly felt by "*at least one person*"[280].

11. The mechanisms by which induced seismic events occur are discussed in Section L3.4 of Appendix L.

12. Recently three international cases of induced seismicity associated with hydraulic fracturing for the recovery of shale gas have been documented with seismic events with magnitudes greater than 2.0 M_L. To put this into context, of the 35,000 shale gas wells in operation in the US prior to 2012[281] and the estimated 2.5 million hydraulic fracturing stages that have been carried out prior to 2012[282], these three events in Garvin County, Oklahoma, USA (maximum magnitude of 2.9M_L)[283]; Horn River Basin, British Columbia, Canada (maximum magnitude of 3.8M_L)[284] and Preese Hall, Blackpool, UK (maximum magnitude of 2.3M_L)[276] are the only shale gas projects that have recorded seismic events above magnitude 2.0 M_L. These events are discussed in more detail in Section L3.4 of Appendix L.

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[276] De Pater, C.J., Baisch, S. (2011). Geomechanical study of Bowland Shale seismicity. Synthesis Report.
[277] Eisner, L., Styles, P., Clarke, H. (2013). Felt induced seismicity associated with shale gas hydraulic stimulation in Lancashire, UK. 75th EAGE Conference and Exhibition incorporating SPE EUROPEC 2013.
[278] Davies, R., Foulger, G., Bindley, A., Style, P. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. Marine and Petroleum Geology. Vol.45, pp.171-185.
[279] British Geological Survey. <URL: http://www.bgs.ac.uk/research/earthquakes/BlackpoolApril2011.html> [site accessed 11/09/2013]
[280] British Geological Survey. <URL: http://www.bgs.ac.uk/research/earthquakes/blackpoolMay2011.html> [site accessed 11/09/2013]
[281] National Research Council. (2013). Induced Seismicity Potential in Energy Technologies. Washington, DC: The National Academies Press.
[282] King, George (2012). Hydraulic Fracturing 101: What every Representative, Environmentalist, Regulator, Reported, investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells.
[283] Holland, A. (2012). Earthquakes possibly triggered by hydraulic fracturing in south-eastern Oklahoma. Oklahoma Geological Society. <URL:http://wichita.ogs.ou.edu/documents/Holland_SSA2012.pdf>
[284] BC Oil and Gas Commission. (2012). Investigation of observed seismicity in the Horn River Basin. <URL: www.bcogc.ca/node/8046/download?documentID=1270.>

12.3 Scoping and consultation

13. The scoping and consultation process that has been undertaken as part of this EIA for the Preston New Road well site has been discussed in detail within Chapter 5 of the ES.

14. The induced seismicity section of the Scoping Report contained outline descriptions of the baseline and key issues affecting the assessment. Additionally the outline assessment methodology was set out, which is briefly described in this document. The responses received from Lancashire County Council (LCC) and other relevant consultees are summarised within Section L4 of Appendix L. This summary also includes a description of the responses received during consultation undertaken by the Royal Society [285] and Royal Academy of Engineering. The key stakeholder for consultation with regard to induced seismicity will be DECC.

15. It is noted that the LCC response also states that the ES should include an assessment of "*the potential for the migration of fracking fluids into sensitive geological formations*". This has been addressed within the Hydrogeology and Ground Gas chapter of the ES - Chapter 11.

12.4 Methodology

12.4.1 Introduction

16. The methodologies for establishing the baseline for geological characteristics and for assessing the effects of construction, operation and decommissioning are described below. The assessment methodology is considered robust and appropriate and aligns with relevant legislation and policies, which are discussed in Section L2 of Appendix L.

12.4.2 Baseline methodology

17. The baseline conditions have been established through desk study review and interpretation and a site reconnaissance visit. The baseline conditions have been considered across the Fylde peninsula with a particular focus on the area in the vicinity of the Site.

Geological information

18. In accordance with industry best practice, characterisation of the geology of the site and the surrounding area is required. This comprises the superficial and solid geology and geological structure including the presence of faulting. The baseline conditions at the site and within the surrounding area have been interpreted through review of the following information:

- Preston New Road scheme parameters, including geology and well design (see Appendix B);
- BGS 1:50,000 scale geological map, sheet 66, Blackpool[286];
- BGS 1:50,000 scale geological map, sheet 75, Preston[287];

[285] The Royal Society and the Royal Academy of Engineering. (2012). Shale gas extraction in the UK: a review of hydraulic fracturing.

[286] British Geological Survey. (1990). Geology of the country around Blackpool. London: HMSO. With associated 1:50,000 map.

- BGS geological memoir for the area around Blackpool[288];
- BGS geological memoir for the area around Garstang[289];
- BGS geological memoir of the country around Southport and Formby[290];
- BGS geological memoir for the geology of the Irish Sea[291];
- BGS report on the geology and resource of the Bowland Shale[292];
- Cuadrilla 3D geophysical (seismic) geological interpretation including analysis of 2D seismic data and available regional gravity and magnetic data;
- De Pater and Baisch synthesis report on the seismicity associated with the hydraulic fracturing of the Preese Hall well[276];
- Cuadrilla Grange Hill end of well report[293];
- Elswick-1 geological well report[294];
- Thistleton-1 end of well report[295];
- Thistleton well log[296];
- Cuadrilla Preese Hall end of well report[297]
- Ground Gas Solutions baseline monitoring report at Grange Hill[298]; and
- Other relevant peer reviewed published literature on the local and regional geology along with in-house field experience and expertise.

19. Due to the relatively level nature of the topography of the area, no outcrops were encountered during the site walkover. Although outcrops could not be mapped, the observed effects of certain soils on vegetation types (e.g. reeds present in areas of peat) were used to inform the extent of certain superficial deposits. Field inspections of the Upper and Lower Bowland Shales in outcrops in the Bowland Fells to the east of the site were made.

Stress data

20. The stress regime of the area has been interpreted through review of the following information:

- De Pater and Baisch synthesis report on the seismicity associated with the hydraulic fracturing of the Preese Hall well[276];

[287] British Geological Survey. (2012). Preston. England and Wales Sheet 75. Bedrock and Superficial Deposits. 1:50,000 map.
[288] British Geological Survey. (1990). Geology of the country around Blackpool. London: HMSO
[289] British Geological Survey. (1992). Geology of the country around Garstang. London: HMSO
[290] British Geological Survey. (1992). Geology of the country around Southport and Formby. London: HMSO.
[291] British Geological Survey. (1995). The geology of the Irish Sea. London: HMSO
[292] Andrews, I.J. (2013). The Carboniferous Bowland Shale gas study: geology and resource estimation. British Geological Survey for Department of Energy and Climate Change, London, UK.
[293] Cuadrilla Resources Ltd. (2012). Grange Hill-1 End Of Well Report. Report. Ref. LJ/01-1Z.
[294] Gas Council (Exploration) Limited. (1991). Geological completion report. Elswick – 1.
[295] Gas Council (exploration) Limited. (1987). Geological completion report, Thistleton-1.
[296] British Gas. (1987). Thistleton-1 composite log (LJ/6-A).
[297] Cuadrilla Resources. (2012) Preese Hall-1 End of Well Report. Ref. LJ/06-5.
[298] Ground Gas Solutions. (2013). Baseline Monitoring Report. Shale Gas Exploration Site at Grange Hill, Singleton.

- Geosphere report on the mechanism of induced seismicity at the Preese Hall-1 well[299];
- GMI report on the wellbore failure analysis and geomechanical modelling in the Bowland Shale, Blackpool[300];
- StrataGen report of the geomechanical study of Bowland Shale seismicity[301].
- The World Stress Map database[302];
- Nirex paper on the Resolution of *in situ* stress orientation and magnitude at Sellafield[303];
- Tectonophysics journal article by Brian Baptie on seismogenesis and state of stress in the UK[304].

Background seismicity

21. The background seismicity of the region has been interpreted through review of the following information:

- Data obtained from the BGS for a 50km radius from the site [requested on 14/08/13];
- Seismik report on the seismicity associated with the hydraulic fracturing of the Preese Hall-1 well[305];
- De Pater & Baisch (2011)[276] synthesis report on the seismicity associated with the hydraulic fracturing of the Preese Hall well;
- Q-con GmbH report on background seismic monitoring at the Becconsall well between May and October 2012[306,307,308,309,310];
- Q-con GmbH report on siting and noise measurements for the Preston New Road Seismic Network[311];
- QJEG 'special edition' The Geology and Hydrogeology of the Sellafield Area[312] ; and
- Other relevant peer reviewed published literature on the local and regional seismicity along with in-house field experience and expertise.

[299]Geosphere Ltd. (2011). Geomechanical analysis of the Worston Shale microseismicity.
[300] GMI Geomechanics Services. (2011). Wellbore failure analysis and geomechanical modelling in the Bowland Shales, Blackpool, UK. GMI report for Cuadrilla.
[301] StrataGen Delft BV. (2011). Geomechanical study of Bowland Shale seismicity – Fracture geometry and injection mechanism.
[302] Heidbach, O. (2008). The World Stress Map database release 2008, s.l.: doi:10.1594/GFZ.WSM.Rel2008.
[303] Tunbridge, L.W. (1994). Resolution of *in situ* stress orientation and magnitude at Sellafield, s.1. Nirex.
[304] Baptie, B. (2010). Seismogenesis and state of stress in the UK. Tectonophysics, Volume 482, pp. 150-159.
[305] Seismik (2011). Seismic analysis of the events in the vicinity of the Preese Hall well.
[306] Q-con GmbH. (2012). Seismic Monitoring Report SMR-CUA-001_v2, s.l.: Q-con.
[307] Q-con GmbH. (2012). Seismic Monitoring Report SMR-CUA-002, s.l.: Q-con.
[308] Q-con GmbH. (2012). Seismic Monitoring Report SMR-CUA-003, s.l.: Q-con.
[309] Q-con GmbH. (2012). Seismic Monitoring Report SMR-CUA-004, s.l.: Q-con.
[310] Q-con GmbH. (2012). Seismic Monitoring Report SMR-CUA-005, s.l.: Q-con.
[311] Q-con GmbH. (2013). Plumpton Seismic Network – Siting & Noise Measurements. Q-con report CUA005.
[312] Chaplow, R. (1996) The geology and hydrogeology of Sellafield an overview. Quarterly Journal of Engineering Geology and Hydrogeology. 29 (Supplement 1), S1-S12.

Seismic receptors

22. The location and characteristics of seismic receptors were determined through desk based review and a site walkover. The purpose of the desk based review was to determine the locations of seismic receptors, such as vulnerable buildings, civil infrastructure, power related infrastructure and COMAH (control of major accident hazards) sites within the Site study area. The study area refers to a hypothetical site boundary that extends a radius distance of 5km from the Site in all directions. This was undertaken by reviewing several information sources including the Lancashire County Council – Maps & Related Information Online (MARIO) service[313] and the register of COMAH sites[314].

23. The size of the seismic study area was considered prior to the walkover. The radius was determined on the basis of a preliminary assessment of modelled ground motions. On the basis of this preliminary assessment a radius of 5km extending from the Preston New Road well site was considered reasonable to represent a study area for the purpose of carrying out the seismic walkover (see Section L6.10.2 of the Technical Appendix for more details).

24. The approach taken during the site walkover was to systematically visit all villages and clusters of buildings and the building condition and construction type was described. Most listed buildings are located within the centre of villages and were visited where access was possible. Civil infrastructure, including bridges, pipelines and major roads were also visited. The landscape was also considered and documented where relevant. Further detail of the site walkover is discussed in Section L6.10 of Appendix L.

Predicted future baseline

25. The predicted future baseline has been defined by consideration of potential changes to the baseline that may occur in the absence of the proposed development.

12.4.3 Assessment methodology for the effects from construction

26. The construction phase of the project comprises the construction of the well pad, drilling cellars, access tracks and groundwater monitoring boreholes and there is no mechanism for induced seismicity. It is concluded that there will be no effects in the context of induced seismicity associated with the construction phase of the Project. Therefore this has not been assessed further.

12.4.4 Assessment methodology for the effects from installation of surface and buried array

27. The installation of the surface array will comprise surface construction activities at discrete locations within a few kilometres of the Site and there is no mechanism for induced seismicity.

28. The installation of the buried array will comprise the drilling of shallow boreholes to depths of up to 100m below ground level at discrete locations within a few kilometres of the Site. These will be constructed using conventional rotary drilling techniques within the superficial deposits and shallow bedrock and there is no mechanism for induced seismicity.

[313] Lancashire County Council. <URL: http://mario.lancashire.gov.uk/agsmario/>
[314] Health and Safety Executive <URL: http://www.hse.gov.uk/comah/public-register.htm>

29. It is concluded that there will be no effects in the context of induced seismicity associated with the installation of the surface and buried seismic monitoring array. Therefore this has not been assessed further.

12.4.5 Assessment methodology for operational effects

30. The operational phase of the Project includes well drilling, hydraulic fracturing, initial flow testing and extended flow testing.

31. The assessment methodology for operational effects will broadly follow the semi quantitative protocol that has recently been developed by the Department of Energy (DoE) in the US to deal with the likely significant effects of induced seismicity associated with EGS activities[315].

32. The assessment methodology comprises the following key aspects for addressing induced seismicity and is used to consider drilling, hydraulic fracturing, flow testing and extended flow testing activities of the operational phases:

- Review and select criteria for assessment of ground borne vibration;
- Assessment of the potential hazard of induced seismic events during drilling, hydraulic fracturing, flow testing and extended flow testing;
- Quantify the effects from induced seismic events specific to the mechanisms associated with shale gas; and
- Develop a risk-based mitigation plan.

33. This assessment methodology follows the Source-Pathway-Receptor framework, which can be defined as a conceptual model, which presents the hypothesised relationships between "*the source of a hazard, the pathway by which exposure may occur, and the receptors – the features of the environment that could be harmed*".

Significance criteria

34. In order to quantify the likely significant effects, the risk (combination of probability and consequence) and subsequently the significance of the effect have been estimated. This has been carried out in accordance with the framework defined within Table 12.1 to Table 12.4 below.

35. To reduce the significance of the effects of induced seismicity, mitigation measures have been presented which will be deployed by the operator. The intention of these mitigation measures is to reduce the risk of felt magnitude seismic events occurring (generally greater than $1.5M_L$), rather than preventing very low magnitude seismic events (less than $0.5M_L$) occurring altogether. These mitigation measures are considered embedded mitigation measures and therefore will be considered as part of the assessment (see Section 12.5).

36. The consequence classification described in Table 12.1 below is based upon the effects of seismicity on structures and human response. This is based upon the well accepted European Macroseismic Scale (EMS) intensity scale, which classifies earthquake intensity in terms of observed effects, as described in Section L7.3.1 within Appendix L. It is noted that the for any magnitude earthquake, the ground motion and subsequent EMS

[315] US. Department of Energy. (2012). Protocol for addressing induced seismicity associated with Enhanced Geothermal Systems. January 2012. DOE/EE-0662.

intensity will vary depending on local environmental conditions such as the ground conditions within the surface geology.

Table 12.1: Classification of consequence (if ground motion hazard occurs at a site) with mitigation measures.

Classification	Definition
High consequence	A major incident resulting in significant damage. May be correlated to a seismic event of EMS intensity316 VIII, or USGS ShakeMap® intensity317 VIII or higher. **Physical damage to buildings and/or civil infrastructure** A seismic event that may cause significant structural damage to buildings and civil infrastructure. A few well-built ordinary buildings show serious failure of walls, while weak older structures may collapse. **Interference with human activity** A seismic event that is felt by all. Building collapse and significant structural damage may cause significant harm to humans, including fatalities.
Medium consequence	A moderate localised effect. May be correlated to a seismic event of EMS intensity[316] V to VII, or USGS ShakeMap® intensity[317] V to VII. **Physical damage to buildings and/or civil infrastructure** A seismic event that may cause minor non-structural damage to buildings and civil infrastructure, i.e. cracking of masonry building or window panes breaking to moderate levels of structural damage such as small cracks in walls and chimneys falling down. **Interference with human activity** A seismic event that is felt by all. Falling debris due to structural damage may cause some minor injuries
Low consequence	A localised minor effect with no significant impact. May be correlated to a seismic event of EMS intensity316 II to IV or USGS ShakeMap® intensity317 II to IV. **Physical damage to buildings and/or civil infrastructure** No damage to buildings or civil infrastructure. Windows, doors and dishes may rattle. **Interference with human activity** A seismic event that may be perceptible to a few to many people. May feel light trembling. No injuries anticipated.
Very Low consequence	Slight environmental effect. May be correlated to a seismic event of EMS intensity316 I or USGS ShakeMap® intensity317 I. **Physical damage to buildings and/or civil infrastructure** No damage to buildings or civil infrastructure. **Interference with human activity** An event below the level of human perception, which can only be detected using extremely sensitive measurement devices. No injuries.

Table 12.2: Classification of probability/likelihood (of ground motion hazard at a site)

Classification	Definition
High Likelihood	Seismic source, pathway and receptor exist. Established mechanism of seismicity that is anticipated to cause repeated occurrences per duration of exploration operations in the area. Based on typical events associated with hydraulic fracturing, a seismic event of less than magnitude 0 M_L is considered highly likely.
Medium Likelihood	Seismic source, pathway and receptor exist. Established mechanism of seismicity that is not inevitable. Anticipated to occur several times per duration of exploration operations in the area. Based on typical events associated with hydraulic fracturing, the likelihood of a

[316] Brune, J., (1970). Tectonic stress and the spectra of seismic shear waves from earthquake, Journal of Geophysical Research. Vol.75, pp.4997-5009.
[317] Wood, H.O., Neumann. (1931). Modified Mercalli intensity scale of 1931. Bulletin of the Seismology Society of America. Vol.21, pp.277-283.

Classification	Definition
	seismic event of magnitude >0.0 to 0.5 M_L is considered medium.
Low Likelihood	Seismic source, pathway and receptor exist. Established mechanism of seismicity, however the linkage is not certain and events anticipated to occur infrequently per duration of exploration operations in the area. Based on typical events associated with hydraulic fracturing, the likelihood of a seismic event of magnitude >0.5 to 1.5 M_L is considered low.
Very low likelihood	Rarely encountered, never reported, or highly unlikely. Based on typical events associated with hydraulic fracturing, the likelihood of a seismic event of magnitude >1.5 M_L is considered very low.

Table 12.3: Estimate of risk magnitude (NB: All risk magnitudes in the context of induced seismicity are considered to be **adverse**).

Risk Matrix		**Consequence**			
		High	**Medium**	**Low**	**Very Low**
Probability	**High likelihood**	***Major***	***Major***	***Major***	***Moderate***
	Medium likelihood	***Major***	***Major***	***Moderate***	***Minor***
	Low likelihood	***Major***	***Moderate***	***Minor***	***Minor***
	Very low likelihood	***Moderate***	***Minor***	***Minor***	***Negligible***

37. In this assessment, '**Significant'** environmental effects are those assessed to be either ***moderate*** or ***major***. '**Not significant'** environmental effects are those assessed to be ***minor*** or ***negligible***. Where **Significant** effects have been identified mitigation is required, as described in Table 12.4.

38. A description of the risk responses are presented within Table 12.4.

Table 12.4: Description of risk responses.

Risk magnitude	Description
Major	Major risks must be acted upon as a priority and reduced before the project can continue. The level of exposure is considered to be too high to continue.
Moderate	Moderate risks must be acted upon, but they do not pose such an immediate threat and thus the project can continue while the risk response measures are integrated and/or performed.
Minor	Minor risks may not require responses – it may be effective enough simply to monitor the risk to ensure that it does not rise during the project.
Negligible	Negligible risks do not require responses.

12.4.6 Assessment methodology for decommissioning and restoration effects

39. The methodology described above for operational effects is also appropriate for the assessment of decommissioning effects. However it is expected that there will be no effects in the context of induced seismicity associated with the decommission phase. As a consequence this is not assessed any further.

12.5 Assumptions and limitations

40. This section details the assumptions and limitations associated with the assessment of induced seismicity as a result of the Project. This includes a discussion of any embedded

mitigation, i.e. mitigation measures that are assumed to be in place as part of the assessment.

41. The key assumptions and limitation which form the basis of this assessment include the following:

- The interpretation of the 3D geophysical (seismic) survey has been carried out by Cuadrilla and reviewed by Arup and specialist consultant DMT.
- The interpretation of the 3D geophysical (seismic) survey, in the context of defining strata boundaries, has been made on the basis of a correlation between the results of the vertical seismic profile (VSP) and downhole geophysics. This data has come from other nearby wells including, Preese Hall, Grange Hill, Elswick and Thistleton. The interpretation of ground conditions is therefore based on geological information that does not specifically cover the Preston New Road site, however, interpretation of strata boundaries has been found to be consistent throughout all wells and it is unlikely that the ground conditions will vary to an extent that will affect the results of the assessment, particularly as information is available from the nearby Preese Hall well. The ground conditions are discussed in further detail in Section 12.6.2.
- Regional faults, as defined above in section 12.1.1, will be avoided during hydraulic fracturing operations, all other faults, described hereafter as small scale faults, may not be avoided during hydraulic fracturing operations, but will be mitigated against using the mitigation methods in this document.
- For the purpose of this assessment it is assumed that all faults within the area are 'critically stressed'. However in reality not all faults will be critically stressed.
- Prior to the submission of the HFP work will be carried out to understand whether nearby faults are indeed critically stressed or not. The findings of this study will be presented within the HFP that is required to be submitted and authorised by DECC before hydraulic fracturing can commence.
- Work on ground motion prediction for shallow, low seismicity earthquakes is limited, in particular for *induced* earthquakes *within the UK*. Therefore the results of ground motion prediction are constrained by the inherent limitations of available prediction equations. Consideration of ground motion prediction equations is included in Section 7 of Appendix L.
- British guidance on ground motion criteria does not specifically cover ground motions for earthquakes, therefore criteria is based on those within guidance documents for other ground motion inducing activities, such as blasting. Where earthquake specific criteria are available (in international guidance) this has been compared to British criteria.

42. Notwithstanding the limitations and assumptions regarding the ground conditions listed above, it is considered that these do not significantly affect the robustness of the assessment, and they are the best and most appropriate methodologies available at the time of writing.

Embedded mitigation measures

43. Embedded mitigation measures include those that are assumed to be in place as part of the assessment. In the context of the induced seismicity assessment, embedded mitigation measures are considered to include those defined within the Project proposals. The embedded mitigation measures are discussed in the relevant parts of Section 12.9 and in

more detail within Section L10 of Appendix L. The embedded mitigation measures include the following:

- Reviewing available information on geology, structure (including faults) and in situ stresses in the vicinity of the proposed Site to avoid hydraulically fracturing into, or close to, existing critically stressed faults;
- Carry out risk based geomechanical assessments of proposed hydraulic fracturing with regard to faults (including maximum magnitude estimates);
- Monitoring background induced and natural seismicity before, during and after hydraulic fracturing;
- Apply an evolutionary approach to risk assessment and mitigation (operational mitigation) –This stepped progressive approach to hydraulic fracturing will consist of an initial mini-fracture stage and modest initial pumped volumes building up to a maximum pump volume of 765m^3 per stage (less than half of the average volumes pumped per stage at Preese Hall). As this process continues, an understanding of the performance of the reservoir during hydraulic fracturing is developed;
- Monitor the extent of fracture growth during hydraulic fracturing using a buried microseismic array;
- Implementation of the Traffic Light System (via the surface seismic monitoring array); and
- Flowback in the case of Amber (0.0 M_L) or Red (0.5M_L) seismic events between hydraulic fracturing stages in accordance with the Traffic Light System.

44. The Project proposals include hydraulic fracturing and extended well testing activities. Therefore, according to the DECC requirements[271], Cuadrilla are required to submit a description of the controls described above to mitigate induced seismicity in the HFP. The HFP will be authorised by DECC prior to commencement of hydraulic fracturing activities.

12.6 Baseline

12.6.1 Introduction

45. The induced seismicity baseline presented below describes the relevant aspects of the geological setting of the site including regional and local geology, regional stress data, natural and background seismicity, maximum magnitude predictions and seismic receptors for the site. Section L6 in Appendix L presents a detailed description and supporting data on the induced seismicity baseline.

12.6.2 Baseline geological setting

Superficial Geology at Preston New Road

46. There is no existing site specific ground investigation information for the Preston New Road site. BGS information and geological well log information for the nearby Elswick[294] and Thistleton[296] wells have been used to establish the expected site geology. Quaternary superficial deposits overlie the Permo-Triassic bedrock in the Fylde area and are up to 50m thick (Allen et al. 1997) and 30m thick in the approximate vicinity of the Preston New Road well site. The superficial geology of the region can be split into glacial and

fluvio-glacial deposits of Devensian Age (120,000 to 10,000 years BP); and post glacial deposits of Flandrian Age (10,000 years BP to present).

47. Based on published information and BGS borehole logs in the vicinity of Preston New Road, the likely geological sequence is Glacial Till (Upper Boulder Clay) deposits over Middle Sands over Lower Boulder Clay. It is possible the Upper Boulder Clay may not be present at the Preston New Road or that post-glacial deposits (Alluvium) may be locally present.

48. Further detail on the regional superficial geology and local detail is provided in Section L6.4 of Appendix L.

Solid geology at the Site

49. There is no existing ground investigation information for the Preston New Road site. The geological stratigraphy has been taken from the BGS Memoir for the country around Southport and Formby (1989)[290]. A 3D geophysical (seismic) survey was carried out by Cuadrilla which provides an interpretation of the stratigraphy below the Preston New Road site (cross referenced against other deep boreholes in the area). This interpretation was made by Cuadrilla and reviewed by Arup and DMT. A summary of the anticipated geological stratigraphy is presented in Table 12.5 and a schematic representation of the geological model with key structural features in presented within Figure 12.1.

50. Immediately underlying the superficial deposits the solid geology comprises the Mercia Mudstone Group to approximately 275m below ground level. This is underlain by the Sherwood Sandstone Group over the Permian Cumbria Coast Group (Manchester Marl) and Appleby Group (Collyhurst Sandstone) over the Carboniferous Millstone Grit Group and Craven Group (Bowland Shale and Hodder Mudstone).

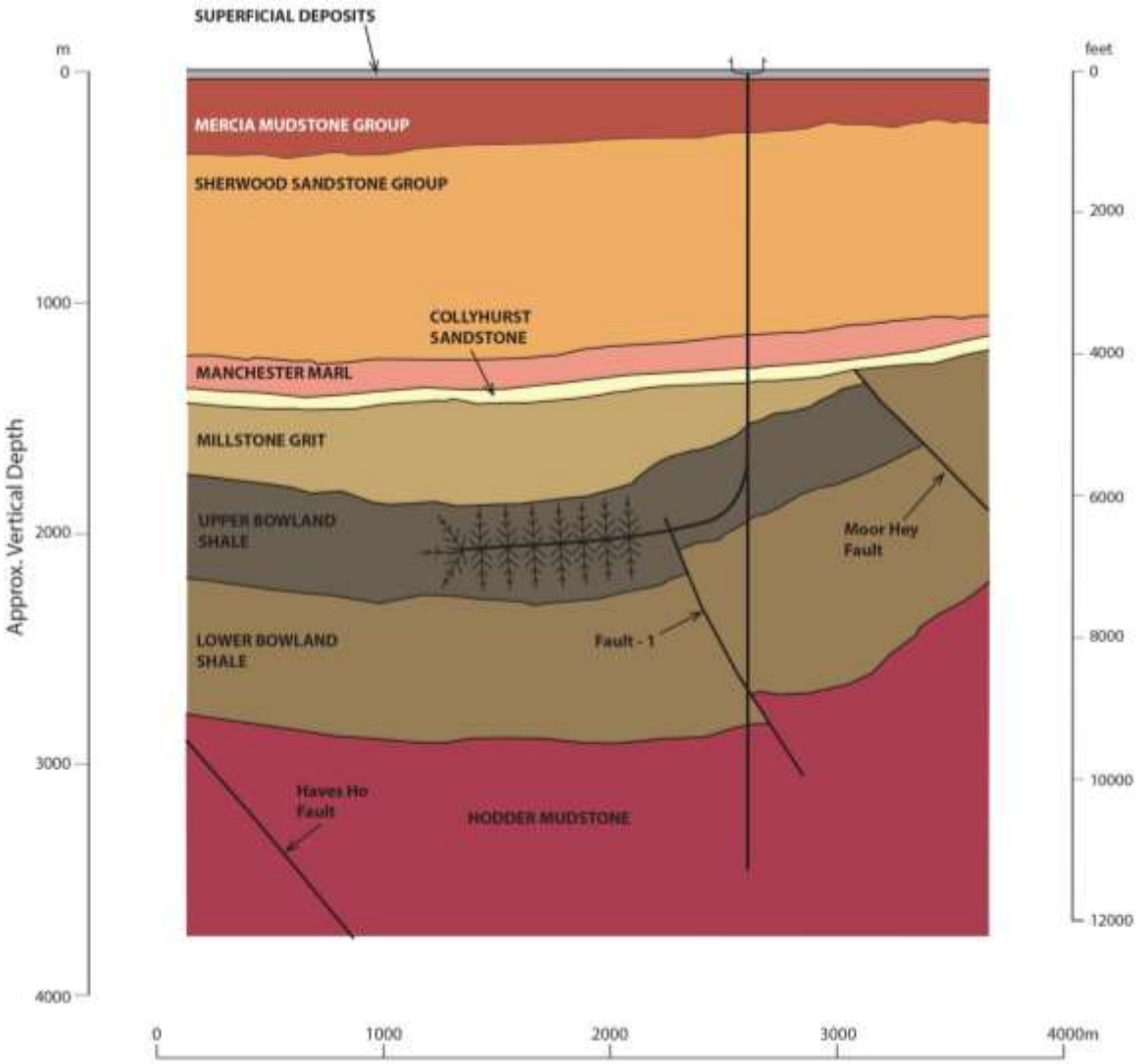
51. A description of the geological units is included in Section L6.3 of Appendix L.

Table 12.5: Summary of the site geology

Period	Group	Lithology
Quaternary	Glacial Deposits	Middle Sands
		Lower Boulder Clay
Triassic	Mercia Mudstone Group	Mercia Mudstone
	Sherwood Sandstone Group	Sherwood Sandstone
Permian	Cumbria Coast Group	Manchester Marls
	Appleby Group	Collyhurst Sandstone
Carboniferous	Millstone Grit Group	Millstone Grit
	Craven Group	Upper Bowland Shale
		Lower Bowland Shale
		Hodder Mudstone
	Bowland High Group	Clitheroe Limestone

Figure 12.1: Geological model for the Preston New Road well site presenting a schematic representation of the solid geology and key structural features within the vicinity of the Site. This figure is based on a north-west to south-east section through the Site as

presented on Figures 7 to 9 within the Section L6.3 of Appendix L. The interpretation of the 3D geophysical (seismic) survey was made by Cuadrilla and reviewed by Arup and DMT.



Geological structure at the Site

52. The site is located within a geological structural domain known as the Bowland Basin. The Bowland Basin is a geological depositional basin predominately active in the Carboniferous Period (c.300 to 360 million years ago (ma)). The basin is defined by faults to the north-east (Craven) and south (Pendle). The western side of the basin opens out towards the Irish Sea Basin while the northern side of the basin slopes upwards towards the higher ground of Cumbria[286].

53. Within the Bowland Basin are a series of regional extensional faults running roughly north north-east south south-west. The largest of these faults is the Woodsfold Fault, which outcrops at the surface approximately 6km east of the site and dips approximately west beneath the site. At the site the Woodsfold Fault is several kilometres below the target reservoir.

54. A number of other faults are present within the vicinity of the Site that also penetrate through the target reservoir (see Figure 12.1), including the Thistleton (and Larbreck) Fault, the Moorhey Fault and the Havesho Fault. These faults are antithetic to the Woodsfold Fault (dip to the east – opposite to the Woodsfold Fault) and their locations relative to the Site at various stratigraphic levels are presented in Figures 7 to 9 in Section L6.3 of Appendix L. The Moor Hey and Havesho Faults are previously unmapped by the BGS, but have been interpreted by Cuadrilla on the basis of the 3D geophysical (seismic) survey. The Havesho Fault is interpreted to extend through the Craven Group and outcrop at the surface, whereas the Moor Hey Fault is interpreted to terminate at the top of the Carboniferous strata defined by the Variscan unconformity.

55. The Thistleton Fault is approximately 1.8km and 1.9km south-east of the Site at the top of the Upper Bowland Shale and top of the Lower Bowland Shale respectively. The Moor Hey Fault is approximately 0.5km and 0.8km south-east of the Site at the top of the Upper Bowland Shale and top of the Lower Bowland Shale respectively. The Havesho Fault is approximately 3.3km and 3.1km north-west of the Site at the top of the Upper Bowland Shale and top of the Lower Bowland Shale respectively.

56. Two local faults (referred to as Fault-1 and Fault-2) that are constrained to the Lower Bowland Shale (and may extend into the underlying Hodder Mudstone), are present approximately 0.3km north-west and 1.2km north of the Site at the top of the Lower Bowland Shale. Fault-1 can be seen within the geological cross section presented within Figure 12.1. Fault-2 is situated outside of the Project Area (Red Line) and is presented within the depth structure map for the top of the Lower Bowland Shale (see Figure 9 within Section L6.3 of Appendix L).

57. In the context of this assessment of induced seismicity, it is assumed that all regional faults within the area of the well site are critically stressed. This is a worst case scenario and means that the mechanism of transmitting an increase in fluid pressure to a fault plane, and hence inducing seismicity, is considered to be feasible for all regional faults that are critically orientated. However in reality not all regional faults will be critically stressed, therefore prior to the commencement of hydraulic fracturing activities Cuadrilla will carry out a study to understand whether nearby regional faults are indeed critically stressed or not. The findings of this study will be presented within the HFP that is required to be submitted and authorised by DECC before hydraulic fracturing can commence.

58. Associated with the faulting in the region are a series of north north-west trending anticlines and synclines which are shown best in the outcropping Mercia Mudstones. The two main folds are the Preesall Syncline to the north and the Kirkham Syncline to the east. The Preesall Syncline forms part of the Preesall Graben and is bound to the east by the Preesall Fault. The Kirkham Syncline is the resultant fold from the graben formed between the Thistleton and Woodsfold Faults. Thickening of the Sherwood Sandstone Group forms the Elswick Dome in the centre of the fold. Between the Preesall and Kirkham Synclines is an anticline-syncline system comprised of two bordering anticlines and a central syncline. The largest component of this system is the most south-eastern fold which is termed the Weeton Anticline and runs down the western side of the Thistleton (and Larbreck Fault)[286].

59. The geological structure is discussed in more detail within Section L6.3 of Appendix L.

12.6.3 Regional stress data

60. The *in situ* stress field and its interaction with the faulting within the region is a key relationship in assessing the induced seismicity risk. Pre-existing faults will have formed under previous stress conditions but their reactivation and the orientation of the displacement that occurs is related to the current stress regime. It can be used to predict the orientation of potential fractures induced by hydraulic fracturing and the stress state of faults.

61. The *in situ* stress field may be defined by three principal compressive stresses, which are orientated perpendicular to each other, the vertical stress (σ_v) and two horizontal components, maximum horizontal stress ($\sigma_{h\ max}$) and minimum horizontal stress ($\sigma_{h\ min}$). Discontinuities will tend to open (width) in the direction of the least principal stress and grow/propagate in the direction of the maximum principal stress.

62. The GMI (2011)[300] report summarises the local stress in the vicinity of the Preese Hall well. The average $\sigma_{h\ max}$ azimuth from the Preese Hall-1 well was recorded as 173° ± 7°. The Preese Hall-1 well lies approximately 3.5km north of the Site. No specific information on the *in situ* stress field for the Site is available but it is expected that the orientation of the regional stress will be relatively consistent across the region however, the stress orientation and magnitude will be measured in the vertical pilot hole and will form the basis of the stress information used in the HFP that will be authorised by DECC before hydraulic fracturing can commence.

63. The de Pater & Baisch (2011)[276] report synthesizes the GMI (2011)[300] and StrataGen (2011)[301] reports and presents the magnitudes of the principle stresses with depth. The average values of σ_v, $\sigma_{h\ max}$ and $\sigma_{h\ min}$ are 62.2MPa, 73.4MPa and 43.6MPa respectively at a depth of approximately 2,440m as measured in Preese Hall-1.

64. The World Stress Map (2008)[302], Baptie (2010)[304] and Nuclear Decommissioning Authority (NDA) data (1994)[303] reports principle stresses lying within 10 to 20° of that recorded at Preese Hall. This difference in the orientation of principle stresses at Preese Hall compared to regional data is important to consider, but it is within reasonable ranges of the data presented by GMI (2011)[300] and therefore this is a reasonable source of data to establish the effect of regional *in situ* stresses on faults within the vicinity of the Site.

65. Based on the mechanisms outlined above, the orientation of faults within the area (north north-east to south south-west) and the existing *in situ* stress regime, any fault movement within the vicinity of the Site is expected to be strike slip[276]. A key consideration from stress field analysis in the Bowland Shales is that there are large differential stresses (i.e. the difference between $\sigma_{h\ min}$ and $\sigma_{h\ max}$ is large)[276]. The actual stress orientation and magnitude will be measured in the vertical pilot hole (the first well drilled) and will form the basis of the stress information used in the HFP that will be authorised by DECC before hydraulic fracturing can commence.

12.6.4 Natural seismicity

66. In global terms the UK is not considered a particularly active seismic region. The UK is located within the European tectonic plate and as such seismicity is lower than more well-known seismically active areas such as California and Japan that are located at plate boundaries. However, the country can still be considered to have a low to moderate rate of seismicity, high enough to sustain a threat to sensitive installations such as nuclear

power stations[318]. Within the United Kingdom, West Lancashire is interpreted to be a relatively lower seismicity region.

67. The British Geological Survey holds an extensive record of seismic events in the UK with data going back to before the 1700's. The records vary in both quality and sensitivity over time, with a marked improvement of the quality of data from 1970 onwards due to the introduction of a dedicated monitoring program. The data suggests a magnitude 3.7M_L may occur every year, a 4.7M_L every 10 years and a 5.6M_L every 100 years somewhere in the UK[318]. Currently the BGS earthquake catalogue does not contain information on events less than 2.0 M_L, however, in accordance with the Guttenberg-Richter relationship, it is expected that over 2000 events at 0.5 M_L will occur every year in the UK. It should be noted that 0.5M_L is the Red Light threshold in the Traffic Light System mitigation measure.

68. The 2.3M_L and 1.5M_L Preese Hall seismic events in April and May 2011 are within the range of natural seismicity in the UK. Compared to the regional seismicity of the UK, the seismic events induced by hydraulic fracturing at the Preese Hall well site are within the range of magnitudes commonly felt across the country. Typically the UK will get tens to hundreds of seismic events of a similar magnitude to those during the Preese Hall hydraulic fracturing each year.

12.6.5 Background seismic monitoring

69. In order to monitor the background seismicity, Cuadrilla installed a surface seismic monitoring system around the Becconsall drilling site, which is located approximately 15km south of Blackpool. The background monitoring system comprised four monitoring stations for which the monitoring was undertaken between 26th April 2012 and 1st October 2012. Background signals are commonly caused by vehicles, trains, farming activities and other human activities as well as wind and tides[319].

70. The variation in background seismicity over time is discussed in Section L6.7 of Appendix L and summarised as follows:

- It is apparent that there is a strong correlation of the background noise between day and night (and therefore related to human activities);
- Although there is a tight band of data between around 102 and 104nm/s (1.02×10^{-4} to 1.04×10^{-4} mm/s) there is a consistent and persistent higher band of data shown up to around 106nm/s (1.06×10^{-4} mm/s). This higher level of noise shows a variability that is dependent on geographical location;
- Two natural seismic events were recorded during the period between 01/06/2012 and 01/07/2012, which were also recorded by the BGS permanent monitoring network. The first event, a 2.8 M_L earthquake, occurred on 01/06/2012 near Ludlow with a hypocentral depth of around 7km and an epicentral distance of approximately 145km from the Becconsall-1 well. The second event, a 1.6 M_L earthquake, occurred on 04/06/2012 near Wigan with a hypocentral depth of around 8km and an epicentral distance of approximately 17km from the Becconsall-1 well. These observations demonstrate that natural seismicity occurs in the vicinity of the Fylde.

[318] Musson, R. (2006). British Earthquakes, s.l.: British Geological Survey.
[319] Department of Energy and Climate Change (2014). Fracking UK shale: understanding earthquake risk.

- Waveform recordings from these natural events were used to analyse the near surface amplitude amplification at the Becconsall site and the amplitude attenuation with distance.

71. To ensure the performance of the proposed real-time monitoring systems noise measurements were taken between the 6th and 13th November, 2013 by Q-con GmbH at the proposed seismic monitoring stations around the Preston New Road site[311]. The background noise level of a suitable station was determined by Q-con to be less that 2,000 nm/s in the vertical direction. The proposed number of 8 seismic stations and the array geometry is based on the site area and the proposed target volume.

72. The results of the background measurements indicate that the background noise level at all but one of the tested stations is less than the identified maximum noise level threshold of 2,000 nm/s. The station at I03 exceeded the threshold due most likely to the proximity of busy roads, urban noise and traffic.

73. At all station locations, the background noise level is dominated by local sources, in particular traffic, industry, farming and animals (cattle and sheep). However these noise contaminations usually occur only at one station at a time and therefore do not reduce the detection capabilities of the array. The surface array will be used to collect background seismic data prior to hydraulic fracturing taking place and will be used in the HFP that will be authorised by DECC before the hydraulic fracturing can commence.

12.6.6 Maximum magnitude estimates

74. The results from numerical modelling carried out by Baisch and Vörös (2011)[320] indicate that the maximum likely magnitude of induced seismic events in the Fylde area caused by fracture operations equivalent to those carried out at the Preese Hall well is 3.1 M_L if no mitigation measures are implemented. This is supported by the observation of maximum magnitudes of coal mining induced earthquakes in the UK (up to magnitude 3.0 M_L), which is considered to provide a realistic upper limit of induced seismicity[321].

75. An independent review of the assessment (discussed in detail within Section L6.8 of Appendix L) was carried out by Geomecon. They concluded that they agree with the conclusions of the Q-con modelling, that a maximum theoretical magnitude induced seismic event in the Fylde area caused by fracture operations equivalent to those carried out at the Preese Hall is 3.1 M_L given that no mitigation is in place and injection volumes are the same as those used during stage 2 of hydraulic fracturing at Preese Hall-1.

76. The above is based on injection volumes that will not be used in this well and as such the maximum magnitude that could be induced will be lower. A 3.1 M_L scenario has not been used within the main assessment of seismic events that are considered to be possible during the exploration stage at the Site (with implementation of mitigation measures). The likelihood of a 3.1 M_L event is considered to be very low (i.e. rarely encountered, never reported, or highly unlikely – see Table 12.2 for likelihood classification).

77. Nonetheless, an assessment of the effects of the ground motion hazard associated with a 3.1 M_L scenario has been considered and is presented separately within the 'Maximum magnitude 3.1 M_L seismic event' section within Section 12.7.4 for information.

[320] Baisch, S., Vörös, R. (2011). Geomechanical study of Blackpool seismicity. Report No. CUA001.
[321] Green, C.A., Styles, P., Babtie, B.J. (2012). Preese Hall shale gas fracturing: review and recommendations for induced seismic mitigation.

12.6.7 Seismic receptors

78. Potential seismic receptors have been identified within the Preston New Road site study area through a high level desk based review and subsequent walkover. The aim of this walkover was to identify and confirm general receptor types within the study area (5km radius of the well site). In addition, a brief comment was made on the general condition and construction of receptors.

79. Receptors types have been separated into the following types:

- Wells – including the Site exploration well and other wells;
- Infrastructure – including roads, railway, bridges, utilities, pipelines;
- Special buildings – including listed buildings, schools, hospitals, churches, monuments, stately homes, listening stations;
- Residential buildings; and
- Industrial/commercial buildings.

80. Specific receptor types are discussed in Section L6.10 of Appendix L.

12.7 Assessment

12.7.1 Construction of well pad and access

81. The construction phase of the project comprises the construction of the well pad, drilling cellars, access tracks and groundwater monitoring boreholes and there is no mechanism for induced seismicity. It is concluded that there will be no effects in the context of induced seismicity associated with the construction phase of the Project.

12.7.2 Installation of surface and buried arrays

82. The installation of the surface array will comprise surface construction activities at discrete locations within a few kilometres of the Site.

83. The installation of the buried array will comprise the drilling of shallow boreholes to depths of up to 100m below ground level at discrete locations within a few kilometres of the Site. These will be constructed using conventional rotary drilling techniques within the superficial deposits and shallow bedrock and there is no mechanism for induced seismicity.

84. It is considered that there will be no effects associated with induced seismicity for the installation of the surface or buried arrays.

12.7.3 Drilling

85. Drilling of the exploration well will be undertaken using conventional deep well drilling techniques.

86. Based on the review of the sub surface geology at the Site, it is not anticipated that the well will be drilled through any regional faults. Although no regional faults have been identified with the Project Area (red line) it is anticipated that the vertical well and the horizontal wells will be drilled through local faults such as the Fault-1 identified on the 3D geophysical (seismic) survey, see Figure 12.1 In addition it is noted that faults with

displacements below the resolution of the 3D geophysical (seismic) survey may be present and may be encountered during drilling.

87. Drilling will be undertaken using drilling fluid, however the volumes and pressures of fluid used during drilling will be negligible (compared to the volumes and pressure of fluid used for hydraulic fracturing). UKOOG[268], DECC[267] and a review of the mechanisms of induced seismicity by Davies et al (2013)[278] do not refer to drilling as a mechanism for inducing seismicity. A literature search also uncovered no evidence for drilling through faults as a mechanism for induced seismicity.

88. Nonetheless, during drilling when faults are encountered their presence will be noted and any fluid loss will be recorded (as is standard throughout the drilling process). If significant fluid loss occurs in combination with a recorded fault (following a review of geological conditions and borehole core) the hydraulic fracturing programme may be adjusted (i.e. section may be grouted to avoid further fluid loss).

89. It is considered that there will be no effects associated with induced seismicity for undertaking drilling activities.

12.7.4 Hydraulic fracturing

Mobilisation

90. It is considered that there will be no effects associated with induced seismicity for hydraulic fracturing mobilisation activities.

Hydraulic fracturing

91. It is well understood that hydraulic fracturing for the recovery of shale gas can cause induced seismicity. The mechanisms involved in causing induced seismic events are described in Section L3.4 of Appendix L. The following text describes the results of a seismic hazard assessment (in terms of peak ground velocity, PGV), which have subsequently been compared to ground motion criteria to assess the likely significant effects of a ground motion hazard associated with induced seismicity.

92. In addition to the assessment of the ground motion hazard, other seismic related effects such as liquefaction, slope stability and subsidence have been assessed.

Seismic hazard assessment

93. To assess the likely significant effects of a ground motion hazard associated with induced seismicity a deterministic seismic hazard assessment (DSHA) was undertaken. For this assessment, s*eismic hazard* refers to the expected levels of ground motion related to a seismic scenario in terms of peak ground velocity (PGV). A DSHA considers individual scenario events of a defined size and location. The seismic source scenarios considered for the purpose of this assessment are summarised within Table 12.6 and discussed in more detail within Section L8 of Appendix L.

94. Scenarios 1 and 2 (described in Table 12.6) have been chosen to represent seismic events that are considered to be possible during the exploration stage at the Site (with implementation of mitigation measures).

95. Scenario 1 (0.5 M_L) has been chosen as it represents the 0.5 M_L Red light threshold of the Traffic Light System, as recommended by DECC[267].

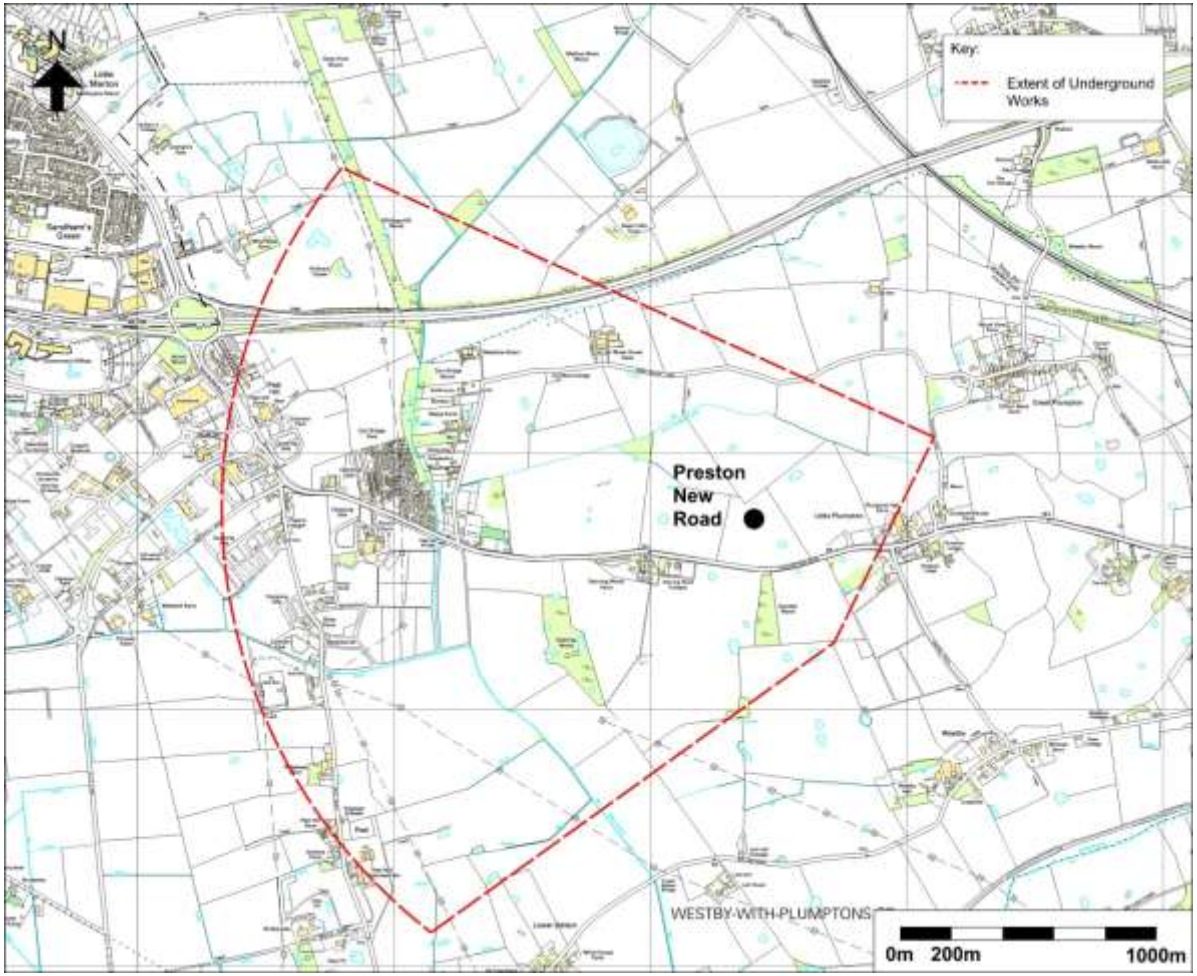
96. Scenario 2 (1.5 M_L) has been chosen as it represents the 0.5 M_L Red light threshold of the Traffic Light System plus a 1.0 magnitude unit trailing effect (post-injection magnitude increase). The 1.0 magnitude unit increase (trailing effect) has been chosen on the basis of a review of other post injection magnitude increases associated with injection related activities as discussed within the explanation of key terms (Section 12.1.1).

97. As recommended by DECC[267], a 1.5 M_L event is typically the limit of felt vibrations. Therefore, a Scenario 2 (1.5 M_L) event should limit vibrations to below that which may be felt at the ground surface.

Table 12.6 Seismic event scenarios considered for the purpose of the seismic hazard assessment and subsequent assessment of effects.

Seismic Event Scenario	Mag (ML)	Source Location	Depth (km)	Comments
With implementation of mitigation measures				
1	0.5	Area source – defined by 'Red Line' (see Figure 12.2).	1.5km	Depth based on the anticipated top of the Upper Bowland Shale which is assumed to be the highest level of hydraulic fracturing. Source based on 'Red Line'. Akkar et al (2013) GMPE used.
2	1.5			

Figure 12.2 Extent of underground works at the Preston New Road well site. The dashed 'Red Line' defines the planning boundary and the proposed extent of underground works. It is considered unlikely for induced seismic events to occur outside of this 'Red Line'.



Seismic hazard assessment results

98. The results of the seismic hazard assessment are discussed in detail, in terms of predicted peak ground velocity (PGV), within Section L8.3 of Appendix L and summarised in Table 12.7 for all scenarios. For conservatism, the results are presented in terms of the 95th percentile or upper bound PGV value (mean+2σ). The results are also presented in Figure 12.3 to Figure 12.4 as contours of predicted PGV in terms of the 95th percentile values (mean+2σ). These figures have been prepared to present the results for a seismic source location defined by the Red Line. This ensures that the PGVs predicted for all possible individual seismic source locations within the Red Line are encompassed within the same figure.

99. Within this section the following statistical terms and their definitions are used:

- 95th percentile (mean+2σ) = the probability of the PGV produced by a single induced seismic event exceeding the predicted 95th percentile value is 5%.
- 84th percentile (mean+1σ) = the probability of the PGV produced by a single induced seismic event exceeding the predicted 84th percentile value is 16%.
- 50th percentile (mean) = the probability of the PGV produced by a single induced seismic event exceeding the predicted 50th percentile value is 50%.
- 16th percentile (mean-1σ) = the probability of the PGV produced by a single induced seismic event exceeding the predicted 16th percentile value is 84%.
- 5th percentile (mean-2σ) = the probability of the PGV produced by a single induced seismic event exceeding the predicted 5th percentile value is 95%.

100. The colours of contour lines within Figure 12.3 to Figure 12.4 represent different effects in accordance with the criteria described in Table 12.8.

Table 12.7 Summary of peak ground velocity (PGV) (95th percentile or mean+2σ) estimated for all scenarios (0.5 and 1.5 M_L); depth H=1.5 km. The GMPE by Akkar et al. (2013) is used.

Epicentral Distance (km)	**Predicted ground motion (PGV) (95 percentile or +2σ) (mm/s)**	
	Scenario 1 – 0.5 M_L	**Scenario 2 – 1.5 M_L**
0km	0.21	1.88
3km	0.17	1.58
5km	0.13	1.22
10km	0.05	0.55

101. The results indicate that for a Scenario 2 (1.5 M_L) seismic event, which represents the worst case scenario that may occur with the implementation of mitigation measures (Red Light threshold of 0.5 M_L plus a post injection magnitude increase/trailing effect of 1.0 magnitude units), the predicted PGV attenuates with distance from the source. The predicted PGV for a Scenario 2 (1.5 M_L) are all below recommended thresholds for cosmetic damage and slightly exceed those for human perception. This is discussed further in the section on the significance of effects below.

102. A full condition survey of existing receptors within the study area was deemed unnecessary, as the results indicate that for a Scenario 2 (1.5M_L) seismic event that structural damage will not occur.

Figure 12.3: Peak ground velocity (PGV) (95th percentile or mean+2σ) estimated for an earthquake of $M_L = 0.5$ and depth H=1.5 km with a seismic source defined by the 'Red Line'. The use of the Red Line as the source ensures that all possible individual source locations within the Red Line are encompassed within the same figure. The GMPE by Akkar et al. (2013) is used.

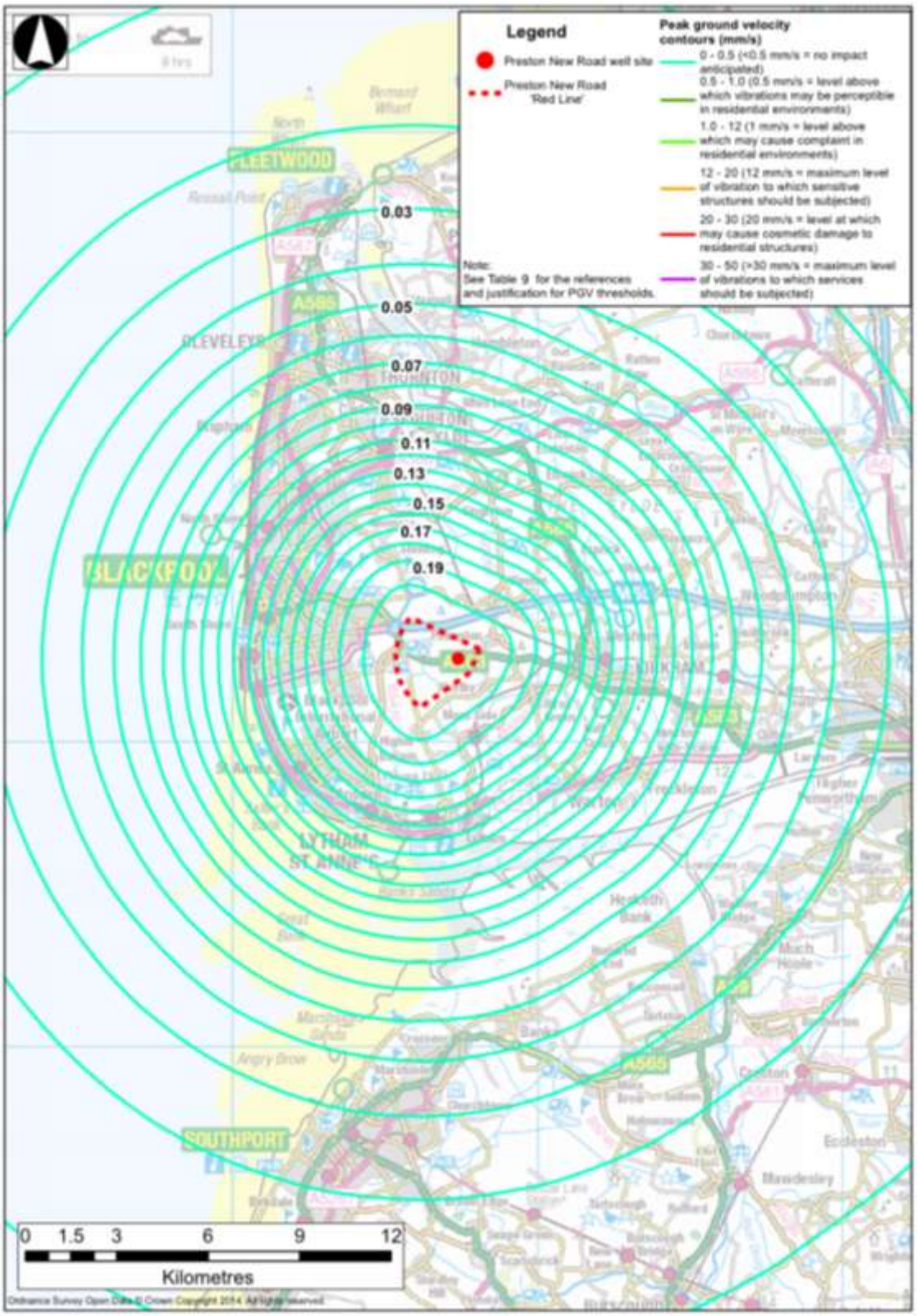
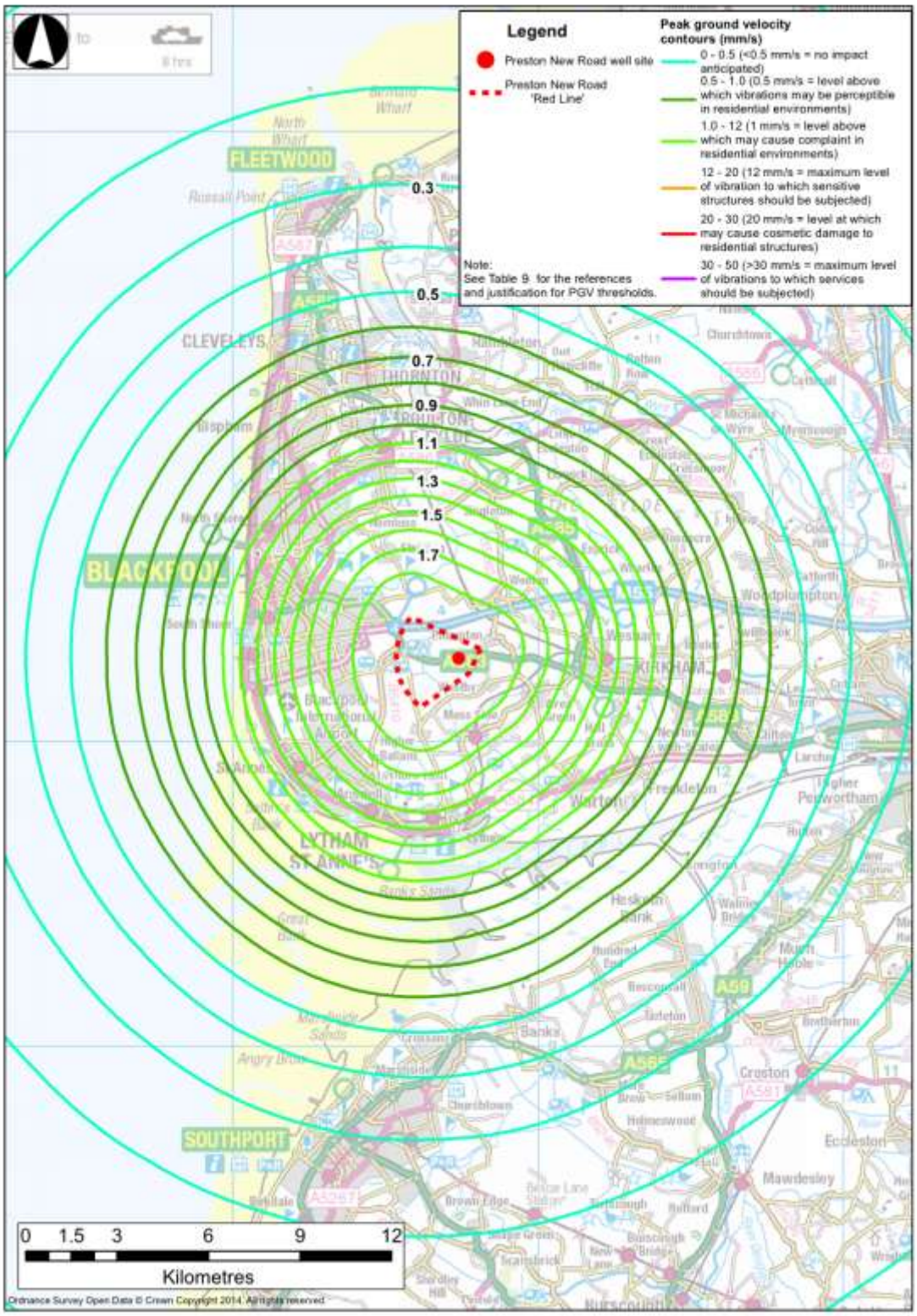


Figure 12.4: Peak ground velocity (PGV) (95th percentile or mean+2σ) estimated for an earthquake of M_L = 1.5 and depth H=1.5 km with a seismic source defined by the 'Red Line'. The use of the Red Line as the source ensures that all possible individual source locations within the Red Line are encompassed within the same figure. The GMPE by Akkar et al. (2013) is used.



Likely significant effects from induced seismicity

103. This section of the report provides a discussion on the assessment of the likely significant effects from induced seismicity. The effects of the ground motion hazard are considered the most important in terms of seismicity. The assessment is discussed in more detail within Section L9 of Appendix L and summarised here.

104. The quantification of the likely significant effects of the ground motion hazard has been undertaken through consideration of the location and vulnerability (or damage/nuisance potential) of particular identified receptors and the selected criteria for ground motion.

105. A detailed review of ground motion criteria was carried out and is presented within Section L7 of Appendix L. The findings of this review are summarised within Table 12.8 below in the context of damage to buildings, damage to infrastructure and human perception. As discussed in Section L7 of Appendix L sensitive equipment will have been installed mitigation measures to dampen and uncouple vibrations from background vibrations from sources such as traffic and trains. The ground motions produced by a maximum magnitude 1.5 M_L event will be within the range of maximum ground motions produced by other sources of ground motion, such as traffic and trains. In addition, the maximum magnitude of induced seismic events (0.5 to 1.5 M_L) will be well within the range of magnitudes experienced throughout the UK hundreds to thousands of times a year. It is therefore considered that there will be no additional effect of vibration on sensitive equipment/activities as a result of the Project and this has not been assessed further.

106. Receptors have been assigned sensitivity classes in accordance with their corresponding ground motion criteria.

107. These criteria presented below have subsequently been used to assess the likely significant effects of the ground motion hazard associated with induced seismicity in the context of these receptor types. The likely significant effects have then been quantified within the subsequent section using the significance criteria and the risk magnitude matrix which are presented within Section 12.4.

Table 12.8: Summary of ground motion criteria to be used for assessment of likely significant effects. See Tables 11 to 14 within Appendix L for specific references.

Sensitivity Class*	Receptor	Criteria	Comment
N/A	Sensitive equipment/activities	It is considered that there will be no additional effect of vibration on sensitive equipment/activities as a result of the Project and this has not been assessed further.	
Class IA	Human perception – residential environments.	0.5mm/s	Perceptible in residential environments.
Class IB	Human perception – residential environments	1.0mm/s	Level above which is likely to cause complaint.
Class II	Sensitive buildings.	12mm/s	Shall not exceed 12mm/s.
Class III	Unreinforced or light framed structure or residential or light commercial buildings.	20mm/s at 15Hz	Level above which is likely to cause cosmetic damage, i.e. cracking of plaster.
Class IV	Civil infrastructure	>30mm/s**	
	National grid high pressure pipeline and other pipelines.		Ground vibration to be limited to a maximum of 75mm/s.
	Utilities.		Maximum level of vibrations to which services should be subjected (30mm/s for transient vibrations).
	Bridges.		Above 51mm/s structures could be damaged under the category of threshold cracking
Class V	Reinforced or framed structure or industrial and heavy commercial buildings.	50mm/s	Level above which is likely to cause cosmetic damage, i.e. cracking of plaster.
*Sensitivity class assigned on the basis of selected ground motion criteria. **Criteria of >30mm/s assigned as a minimum. Criteria for individual features likely to be higher, i.e. National Grid pipeline recommend a maximum PPV of 50mm/s.			

108. The predicted ground motions presented as contours within Figure 12.3 to Figure 12.4 and are presented in graphical format in Figure 12.5 to Figure 12.6. These figures also illustrate the ground motion criteria for specific sensitivity classes (as defined within Table 12.8), and have subsequently been used to determine the likely significant effects of the ground motion hazard on receptors (as summarised within Table 12.9).

Figure 12.5: Peak ground velocity (PGV), 95 percentile (mean+2σ), 84 percentile (mean+1σ) and 50 percentile (mean), estimated for a seismic event of magnitude 0.5 M_L and depth (H) = 1.5 km. The GMPE by Akkar et al. (2013) is used. Ground motion criteria associated with various receptor sensitivity classes is also presented.

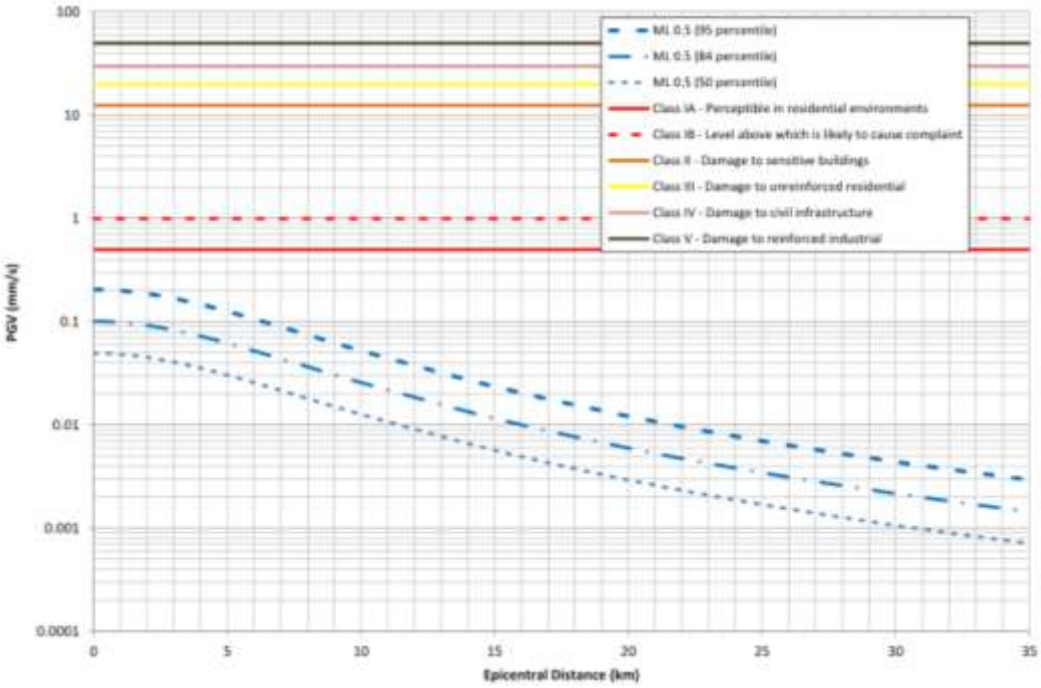


Figure 12.6: Peak ground velocity (PGV), 95 percentile (mean+2σ), 84 percentile (mean+1σ) and 50 percentile (mean), estimated for a seismic event of magnitude 1.5 M_L and depth (H) = 1.5 km. The GMPE by Akkar et al. (2013) is used. Ground motion criteria associated with various receptor sensitivity classes (Class 0 to V) is also presented.

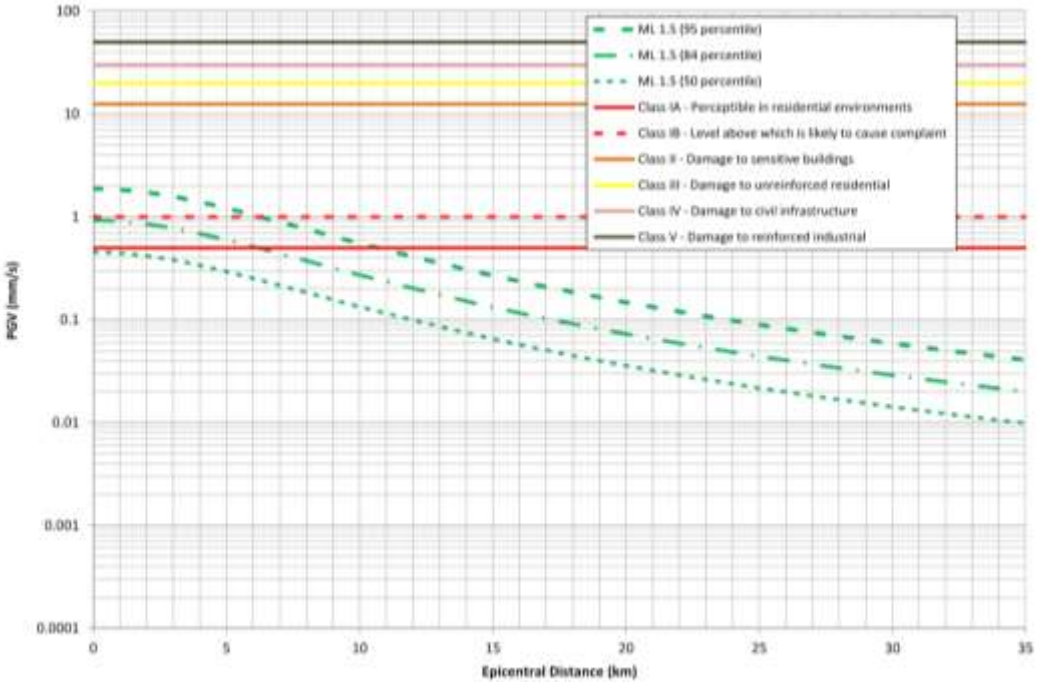


Table 12.9: Summary of the likely significant effects of induced seismicity (for a ground motion hazard) at the Site for specific seismic scenarios.

Seismic scenario	Mag (M_L)	Figure reference	Summary of the likely significant effects
With implementation of mitigation measures			
1	0.5	Figure 12.3 and Figure 12.5	Vibrations are not anticipated to be felt at the ground surface and will only be detected instrumentally. Damage to buildings or infrastructure is not anticipated. Locally intensities of up to I European Macroseismic Scale (EMS) (EMS I = not felt).
2	1.5	Figure 12.4 and Figure 12.6	Vibrations may be felt in the most sensitive situations local to the Preston New Road well site. Locally intensities of up to II European Macroseismic Scale Damage to buildings and infrastructure is not anticipated. (EMS) may be felt (EMS II = scarcely felt effects, only detected by very few individuals in the most sensitive situations, i.e. at rest indoors).

Significance of effects from induced seismicity

109. This section of the report provides a discussion on the assessment of the significance of effects of induced seismicity in the context of a ground motion hazard, but also considers other seismic related hazards that have been identified during the assessment and the consultation process. This is discussed in further detail within Section L9.4 of Appendix L.

Effects of a ground motion hazard

110. The assessment of the effects of a ground motion hazard indicates that no damage to structures is anticipated, however seismic events may be perceptible to some people in the most sensitive environments, but not in all cases. A summary of the assessment of the significance of effects of a ground motion hazard is summarised within Table 12.10.

111. It is noted here that the BGS co-ordinate a questionnaire which provides an online service for the public to record their experiences of seismic events on the 'Have you felt an earthquake?' page of their website[322] . This also allows for people to keep abreast of any seismic events in their locality and across the country.

Table 12.10: Summary of the significance of effects of a ground motion hazard at the Preston New Road well site for specific scenarios, with a description of the associated risk response (see Table 12.1 to Table 12.4 for reference to the Risk Assessment Framework).

Seismic scenario	Mag (M_L)	Significance of effects	Risk response
Implementation of mitigation measures			
1	0.5	Likelihood ***medium***. Consequence ***very low***. Risk magnitude ***minor*** and significance of effect **not significant**.	***Minor*** risks do not require mitigation measures above the embedded mitigation measures.
2	1.5	Likelihood ***low***. Consequence ***low***. Risk magnitude ***minor*** and significance of effect **not significant**.	***Minor*** risks do not require mitigation above the embedded mitigation measures.

[322] British Geological Survey. <URL: http://earthquakes.bgs.ac.uk/questionnaire/EqQuestIntro.html>

Effects of well integrity

112. The risk magnitude and significance of effects from induced seismicity on well integrity is has been assessed to be ***minor*** and **not significant**. The potential for well deformation associated with seismicity is discussed in Section 4.5 of Appendix K, Hydrogeology and Contamination.

Effects of liquefaction potential

113. The risk magnitude and significance of effects of induced seismicity causing liquefaction is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.2 of Appendix L.

Effects on slope instability

114. The risk magnitude and significance of effects of induced seismicity causing slope instability is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.3 of Appendix L.

Effects of settlement causing surface deflections from gas extraction

115. The risk magnitude and significance of effects of induced seismicity causing settlement and subsequent surface deflections from gas extraction is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.4 of Appendix L.

Effects of settlement from gas extraction causing earthquakes

116. The risk magnitude and significance of effect of settlement causing earthquakes is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.5 of Appendix L.

Effects of fluid migration and changes in the stress regime in the Bowland Basin inducing seismicity in deep basement faults

117. The risk magnitude and significance of effect of fluid migration inducing seismicity in deep basement faults is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.6 of Appendix L.

Effects of ground motion hazard causing salt cavern instability at the nearby proposed Preesall salt mine

118. The risk magnitude and significance of effect of induced seismicity causing salt cavern instability is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.4.7 of Appendix L.

Maximum considered magnitude 3.1 M_L earthquake scenario (without implementation of embedded mitigation measures)

119. The main assessment of the effects of induced seismicity focuses specifically on the scenarios that are considered possible during the Project (0.5 M_L and 1.5 M_L). This discussion on a 3.1 M_L event should not be considered part of the main assessment. It is considered useful for comparison to assess the effects of a theoretical maximum magnitude 3.1M_L induced seismic event for the Licence area (based on volumes of fracturing fluid used at Preese Hall-1 well) and to demonstrate the reduction in ground motion hazard achieved though implementation of the mitigation measures.

120. Although not considered part of the main assessment, because embedded mitigation measures are required to be implemented at all stages, it is of interest to note that for this scenario to occur, three very unlikely events are required to occur simultaneously, including: 1) The volume of pumping fluid per stage is similar to that used in the Preese Hall operations without minimisation; 2) The Traffic light System (described in Section 12.9) fails to fulfil its purpose; and 3) Fluid is transmitted into a critically stressed fault and it fails. Considering these points above, the likelihood of a 3.1 M_L seismic event is considered very low due to the effectiveness of the mitigation measures that have been implemented as part of the Project (see Section 12.9). The exploration activities will not take place without implementation of these mitigation measures.

121. For consistency the assessment of the seismic hazard of the 3.1M_L scenario the same source parameters and pathway parameters have been used to the main assessment (i.e. source depth 1.5km). The predicted ground motions have been derived for a point source (the Site) instead of using the Red Line.

122. The predicted ground motions indicate that if a 3.1 M_L seismic event occurred then the following effects may occur:

- Vibrations may be felt up to 65km from the Site;
- Some minor cosmetic damage, such as cracking plaster, to local sensitive structures and possibly some local unreinforced buildings;
- Rare minor damage to the most sensitive civil infrastructure;
- No damage anticipated to reinforced buildings.

123. Although not part of the main assessment, an assessment of the significance of the risk, in accordance with Table 12.1 to Table 12.4, is as follows:

- Likelihood of a 3.1M_L event occurring is considered *very low*;
- Consequence of a 3.1 M_L event is considered *medium;*
- The risk magnitude significance is ***minor*** and **not significant.**

12.7.5 Initial flow testing

124. Proposals are for up to 90 day period of flow testing following the completed hydraulic fracturing stages. This will comprise the flowback of natural gas, fracture fluid and hydrocarbons from the hydraulically fractured well. Flow testing was carried out following the first three stages of hydraulic fracturing at the Preese Hall-1 well for a period of approximately 6 weeks. During this period of flow testing three small seismic events were recorded, all of which were less than magnitude -0.5 M_L[276]. De Pater and Baisch (2011)[276] interpreted these events to be either aftershocks of the 2.3 M_L seismic events, or induced by the drawdown during flow testing.

125. There is no evidence to indicate that induced seismic events during initial flow testing will be greater than those induced by hydraulic fracturing. Additionally, any increase in pressure experienced during hydraulic fracturing will dissipate during flow testing due to the flowback of gas and fracture fluid to the surface. On this basis it is considered that there will be no direct impacts or effects associated with induced seismicity during initial flow testing. Residual seismic events may be experienced as a consequence of hydraulic fracturing, however, these events are anticipated to be well below magnitude 0 M_L. On the basis of the seismic hazard assessment results described within Section 12.7.4 any

induced seismicity during flow testing will not cause any damage to receptors and will not be felt at the surface. These events will only be detected instrumentally.

126. The significance of effect of seismic activity associated with the construction and operational activities for initial flow testing is therefore considered to be ***negligible*** and **not significant**.

12.7.6 Extended flow testing

127. Extended flow testing may be carried out following initial flow testing if production rates (during initial flow testing) are considered to be sufficient. It is considered that there will be no significant additional effects associated with induced seismicity for extended flow testing over the effects of initial flow testing during the hydraulic fracturing stage.

128. The significance of effect of seismic activity associated with the construction and operational activities for extended flow testing is therefore considered to be ***negligible*** and **not significant**.

12.7.7 Decommissioning and restoration

129. It is considered that there will be no effects associated with induced seismicity for the decommissioning and restoration of extended flow testing infrastructure, wells, well pad and access track.

12.8 Cumulative and interactive effects

130. The cumulative and interactive effects of induced seismicity have been discussed further within Section L9.5 of Appendix L, but have been described briefly below with their associated significance.

Cumulative and interactive effects Preston New Road and Roseacre Wood Works occurring together

131. The risk magnitude and significance of effect for the cumulative and interactive effects of the Preston New Road and Roseacre Wood works occurring together is considered to be the same as the risk magnitude and significance of effect for hydraulic fracturing at Preston New Road, therefore ***minor*** and **not significant**. This is discussed in Section L9.5.1 of Appendix L.

Cumulative and interactive effects of hydraulic fracturing and initial flow testing occurring together on the same well pad

132. The risk magnitude and significance of effect for the cumulative and interactive effects of hydraulic fracturing and initial flow testing occurring together on the same well pad is considered the same as the risk magnitude and significance of effect for hydraulic fracturing at Preston New Road, therefore ***minor*** and **not significant**. This is discussed in Section L9.5.2 in Appendix L.

Cumulative and interactive effects of initial flow testing and drilling occurring together at the same well pad

133. The risk magnitude and significance of effect for the cumulative and interactive effects of initial flow testing and drilling occurring together at the same well pad is considered the same as the risk magnitude and significance of effect for hydraulic fracturing at Preston

New Road, therefore ***minor*** and **not significant**. This is discussed in Section L9.5.3 in Appendix L.

Cumulative and interactive effects of Preston New Road occurring at the same time as other developments in the area

134. Whilst other above ground developments (i.e. typical construction activities such as housing and highway etc.) may occur within the area at the same time, there is no mechanism for these activities to induce seismicity. It is understood that the only other significant below ground project in the area, that may be capable of inducing seismicity, is the proposed gas storage project at the nearby abandoned salt mines at Preesall (situated approximately 12km north-west of the Site). The risk magnitude and significance of effect of seismic activity causing salt cavern instability is considered to be ***negligible*** and **not significant**. This is discussed in Section L9.5.4 in Appendix L.

12.9 Embedded mitigation measures

135. This section details a comprehensive list of recommendations that should be in place before future hydraulic fracturing operations should be recommenced in order to minimise the likelihood of felt induced seismic events from future hydraulic fracturing operations. These recommendations have been informed by a number of reports that were commissioned following the felt seismicity during hydraulic fracturing at the Preese Hall-1 well in 2011, but also from recommendations made by DECC[267], UKOOG[268] and the new controls announced by the Secretary of State for Energy and Climate Change issued as a written statement to the UK Parliament on the 13th December 2012[270]. These documents are the prevailing sources of recommendations for good industry practice.

136. In summary, the following principal embedded mitigation measures are recommended:

- Reviewing available information on geology, structure (including faults) and in situ stresses in the vicinity of the proposed Site to avoid hydraulically fracturing into, or close to, existing critically stressed faults;
- Carry out risk based geomechanical assessments of proposed hydraulic fracturing with regard to known faults (including maximum magnitude estimates);
- Monitoring background induced and natural seismicity before, during and after hydraulic fracturing;
- Applying an evolutionary approach to risk assessment and mitigation (operational mitigation) –. This stepped progressive approach to hydraulic fracturing will consist of an initial mini-fracture stage and modest initial pumped volumes building up to a maximum pump volume of 765m^3 per stage (less than half of the average volumes pumped per stage at Preese Hall). As this process continues, an understanding of the performance of the reservoir during hydraulic fracturing is developed;
- Monitor the extent of fracture growth during hydraulic fracturing using a buried microseismic array;
- Implementation of the Traffic Light System (via the surface seismic monitoring array); and
- Flowback in the case of Amber (0.0 M_L) or Red (0.5M_L) seismic events between hydraulic fracturing stages in accordance with the Traffic Light System.

137. The Project proposals include hydraulic fracturing and extended flow testing activities. In accordance with the DECC requirements[271], Cuadrilla will submit a description of the

controls described above to mitigate induced seismicity in the HFP. The HFP will be authorised by DECC prior to commencement of hydraulic fracturing activities.

138. Further details of the mitigation measures for induced seismicity are discussed in Section L10 of Appendix L including the implementation of the Traffic Light System.

139. There is no need for additional mitigation during any of the Project activities.

Mitigation measures – Site selection and site characterisation

140. Recommendations for hydraulic fracturing activities include a review of available geological and geophysical data for the Site and the surrounding area to characterise the stratigraphy and structural geology of the area. Cuadrilla commissioned a bespoke 3D geophysical (seismic) survey by CCG to investigate subsurface ground conditions. The interpretation of the 3D geophysical (seismic) survey was carried out by Cuadrilla geophysicists. An independent assessment of the data acquisition, processing and interpretation was carried out by Arup's sub consultant DMT GmbH (see Section L10.3 of Appendix L for further details of this review).

141. The 3D geophysical (seismic) survey covers an area of approximately 100km^2. The objective of this survey was to image the strata (particularly the Lower Carboniferous Bowland Shale) and the geological structures within the survey area.

142. The location of the site selected by Cuadrilla to construct the vertical and horizontal well has taken into account the geological and structural conditions in the region and the vertical well and the horizontal wells have been located in the most favourable ground conditions to minimise the risk felt induced seismicity from shale gas exploration operations.

Mitigation measures – Risk based geomechanical assessment

143. A risk based approach to the geomechanical assessment of proposed hydraulic fracturing activities is recommended by UKOOG[268]. This requires a detailed understanding of the geological structures within the vicinity of the Site at reservoir level, including fault geometry and activity. An understanding of the geomechanical properties of the rock is also required along with the regional stress regime. This information can be used to determine the risk magnitude and significance of a maximum magnitude of induced seismic event for a given injection volume

144. De Pater and Baisch (2011)[276] concluded that a 3.1 M_L induced seismic event is the largest that could occur for an injection volume similar to that used during the second stage at Preese Hall-1 well (i.e. 2,245m^3).

145. A review of the geological structures in the vicinity of the Site was also undertaken as part of this assessment on the basis of Cuadrilla's interpretation of the 3D geophysical (seismic) survey (and confirmed by Arup and DMT). This assessment also considered the existing stress regime, level of natural seismicity and the geomechanical properties of the rock to critically assess the study by De Pater and Baisch (2011)[276]. Arup and DMT concluded that the estimate of maximum magnitude of 3.1 M_L by De Pater and Baisch (2011)[276] is reasonable.

146. To assess the effects of induced seismicity, it was considered that all faults within the area are 'critically stressed'. This has been assumed for the assessment as it is the worst case scenario. However in reality not all faults will be critically stressed, therefore prior to the submission of the HFP work will be carried out to understand whether nearby faults are indeed critically stressed or not. The findings of this study will be presented within

the HFP that is required to be submitted and authorised by DECC before hydraulic fracturing can commence.

147. In view of the assumption above that all regional faults are critically stressed, it was considered that the approach to hydraulic fracturing would ensure that the offset distance from the location of a hydraulic fracture stage and a regional fault will be two times the anticipated fracture length (anticipated fracture length may vary during the lifetime of the Project depending on the Project phase and associated proposed injection volumes).

148. On this basis a 1.5 M_L induced seismic event is considered to be the maximum magnitude event that could occur given the embedded mitigation measures that will be in place.

Mitigation measures – Baseline seismic monitoring

149. Pre-fracturing monitoring is required to establish background levels of natural and induced seismicity and will be carried out for a period of at least 4 weeks prior to commencing hydraulic fracturing.

150. It is proposed that the seismic data collected during the 4 week monitoring period will be supplemented by the seismic data collected by the BGS network of seismographs. The BGS data is collected continuously and transmitted for real-time processing and analysis by the BGS. This will enhance the understanding of background seismicity.

151. Seismic monitoring will also occur during and after hydraulic fracturing activities in accordance with the description provided in the section on the 'Traffic Light System' and the 'Summary of instrumentation' below.

Mitigation measures - Fracture evolution and operational mitigation

152. The purpose of hydraulic fracturing is to create very closely spaced of network of fractures adjacent to the well over a distance of up to 200m in order to collect gas from the shale reservoir. The purpose of hydraulic fracturing is not to create a few large fractures that extend over long distances, vertically or horizontally.

153. In order to achieve these objectives and reduce the risk of felt seismicity Cuadrilla will monitor the location, orientation and extent of induced fractures to ensure that hydraulic fracturing does not occur within the vicinity of regional faults. The proposed offset distance from the location of a hydraulic fracture stage and a regional fault is two times the anticipated fracture length (anticipated fracture length may vary during the lifetime of the Project depending on the Project phase and associated proposed injection volumes).

154. The HFP, that will be authorised by DECC, will describe the methodology to be carried out during hydraulic fracturing to ensure that hydraulic fractures do not interact with regional faults. This methodology will consist of a stepped progressive process that uses various techniques such as mini-fractures, increasing pumped volumes of hydraulic fracturing fluids and microseismic monitoring to understand the performance of the reservoir during hydraulic fracturing (these operation mitigations are discussed further in the sections on 'Mini-fractures' and 'Reduced injection volumes' below). This will enable Cuadrilla to adjust the hydraulic fracturing operations to achieve the objectives described above and design future hydraulic fractures stages. This can be summarised by the following points:

    1. During initial drilling operations and mini-fractures Cuadrilla will collect data pertinent to informing the design of the hydraulic fracture model;

2. The model will be used to define the initial hydraulic fracture stage which will be designed to initiate a conservative hydraulic fracture growth approximately equal to one third to one half of the maximum stage size as authorised by DECC;
3. The orientation and extent of hydraulic fracturing will be monitored in real time during and after stages to evaluate the model and ensure the hydraulic fracture performance is within the design objectives;
4. This iterative process will allow the performance of the previous hydraulic fracture stage to be used to design the next hydraulic fracture stage to ensure the design objectives are maintained;

155. Fracture fluid volumes will gradually be increased to the maximum injection volume for each hydraulic fracture stage; 750m^3. Models indicate the likely predicted length of fracture growth from the well is anticipated to be between approximately 50m and 150m[301] (the variation is dependent on the geomechanical properties of the reservoir rock and the volume of fracture fluid injected).

156. Cuadrilla are anticipating that the horizontal well bore, or the area intended to be hydraulically stimulated, will encounter a number of small faults. Each hydraulic fracture stage will be monitored in real time during and after each hydraulic fracture stage to measure the location, orientation and extent of microseismic activity. If the monitoring indicates that a fault may be reacting to the hydraulic fracturing and showing signs of producing a seismic event greater than or equal to 0.5M_L, then the pumping parameters may be amended (these parameters are constantly monitored) or the hydraulic fracture stage will be terminated early.

Mitigation measures – Mini-fractures

157. The fracture behaviour of a particular formation is commonly characterised using a mini-fracture stage. A mini-fracture stage will be carried out prior to the initial main hydraulic fracturing stage (and as deemed necessary by Cuadrilla) to determine the geomechanical properties of the formation to inform the hydraulic fracture model. The mini-fracture stage will employ small volume stimulation of approximately 15m^3.

Mitigation measures – Reduced injection volumes

158. McGarr (1976)[323] and more recently McGarr (2014)[324] were able to demonstrate a relationship between injection volume and induced seismicity. Therefore one of the most significant mitigation measures against future induced seismic events is to reduce the volumes of hydraulic fracturing fluid injected for each hydraulic fracture stage compared to the volumes used at Cuadrilla's Preese Hall-1 well. This is discussed further in Section L10.5.2 of Appendix L.

159. It is estimated by Cuadrilla that up to 765m^3 (750m^3 per stage plus 15m^3 for mini-fracture) of fracturing fluid will be used for each hydraulic fracture stage at the Site. At the Preese Hall-1 well, a maximum injection volume of 2,245m^3 was used during the second hydraulic fracturing stage[276].

Mitigation measures – Microseismic monitoring of fracture growth

[323] McGarr, A. (1976). Seismic moments and volume changes. Journal of Geophysical Research. Vol 81, pp.1487-1494.
[324] McGarr, A. (2014). Maximum magnitude earthquakes induced by fluid injection. Journal of Geophysical Research: Solid Earth. Vol. 119.

160. Cuadrilla will monitor the location, orientation and extent of induced fracture growth to ensure that hydraulic fracturing does not occur within the vicinity of regional faults, near surface groundwater resources and other underground receptors.

161. The HFP that will be authorised by DECC, describes the methodology to be carried out during hydraulic fracturing, This consists of stepped progressive process that uses various techniques such as mini fractures, variable pumped volumes of hydraulic fracturing fluids and microseismic monitoring to understand the performance of the reservoir during hydraulic fracturing.

162. The progressive program of increasing pumped volumes will allow Cuadrilla to model fracture growth during successive stages. Monitoring of fracture growth will allow Cuadrilla to validate the model and manage fracture growth by adjusting future hydraulic fracturing operations to ensure hydraulic fractures do not propagate to within the vicinity of regional faults.

Mitigation measures – Traffic Light System during hydraulic injection (pumping)

163. A Traffic Light System (TLS) is the recommended tool to manage the potential for induced seismicity due to hydraulic fracturing during hydraulic injection (pumping). Cuadrilla will implement a TLS, using the trigger levels for green, amber and red events defined by DECC, see Figure 12.7.

164. Details of the equipment and methodology to implement the TLS in practice are presented in Section L10.7 of Appendix L.

165. The array responsible for the purposes of implementing the TLS consists of eight seismometer stations at ground surface. The instruments measure ground vibrations. All stations will be installed prior to the first hydraulic fracturing operation in order to allow for background noise monitoring over a period of 4 weeks and subsequent data interpretation.

166. Hydraulic fracturing monitoring will be implemented as part of the TLS under the regime defined by the Green, Amber and Red level triggers summarised below, see Figure 12.8 below.

Green level: <0 M_L

167. As long as the induced seismicity is <0M_L while pumping operations are carried out pumping will continue in line with the HFP. Cuadrilla will submit daily reports to DECC.

Amber level: 0 ML to < 0.5 ML

168. If an event occurs in the amber range while pumping the fracture stage, pumping can be completed for that stage. On completion of injection the flowback procedure will be initiated, see Table 12.11 for details. Cuadrilla will submit daily reports to DECC, including characterisation and location of seismic events.

169. Cuadrilla will assess the microseismic and hydraulic fracturing data and inform DECC on the following future operations:

- Post injection seismic monitoring period;
- Flowback period.

170. The original HFP may proceed with caution, possibly at reduced parameters.

Red level: >0.5 ML

171. If an event occurs in the red range while pumping the fracture stage the fracture stage will be aborted and the flowback procedure will be initiated, see Table 12.11 for details. Cuadrilla will submit daily reports to DECC, including characterisation and location of seismic events.

172. Cuadrilla will assess the microseismic and hydraulic fracturing data and recommend to DECC on the following future operations:

- Post injection seismic monitoring period;
- Flowback period;
- Cuadrilla will commence discussions with DECC regarding methodology for continuation or termination of hydraulic fracturing.

173. The TLS will be implemented for hydraulic fracturing monitoring of seismic activity. During hydraulic fracturing monitoring, data is transmitted in real-time to the data centre located at the Site. The Seismic Monitoring (TLS) Contractor will inform the operator's On-site Fracturing Supervisor immediately in the event that an Amber or Red TLS event has occurred. Seismic real-time monitoring will be documented in daily reports (during hydraulic fracturing activities) and submitted to DECC.

174. The daily reports will make up part of the End of Well report prepared by Cuadrilla and provided to DECC as agreed in the terms of the petroleum licence. Cuadrilla will also supply a daily update on the observed seismicity on their website. The result presented on the website will describe the number of amber and red events. Events within the Green traffic light are not required to be presented on the Cuadrilla's website.

Figure 12.7: DECC infographic showing the Traffic Light System[267]

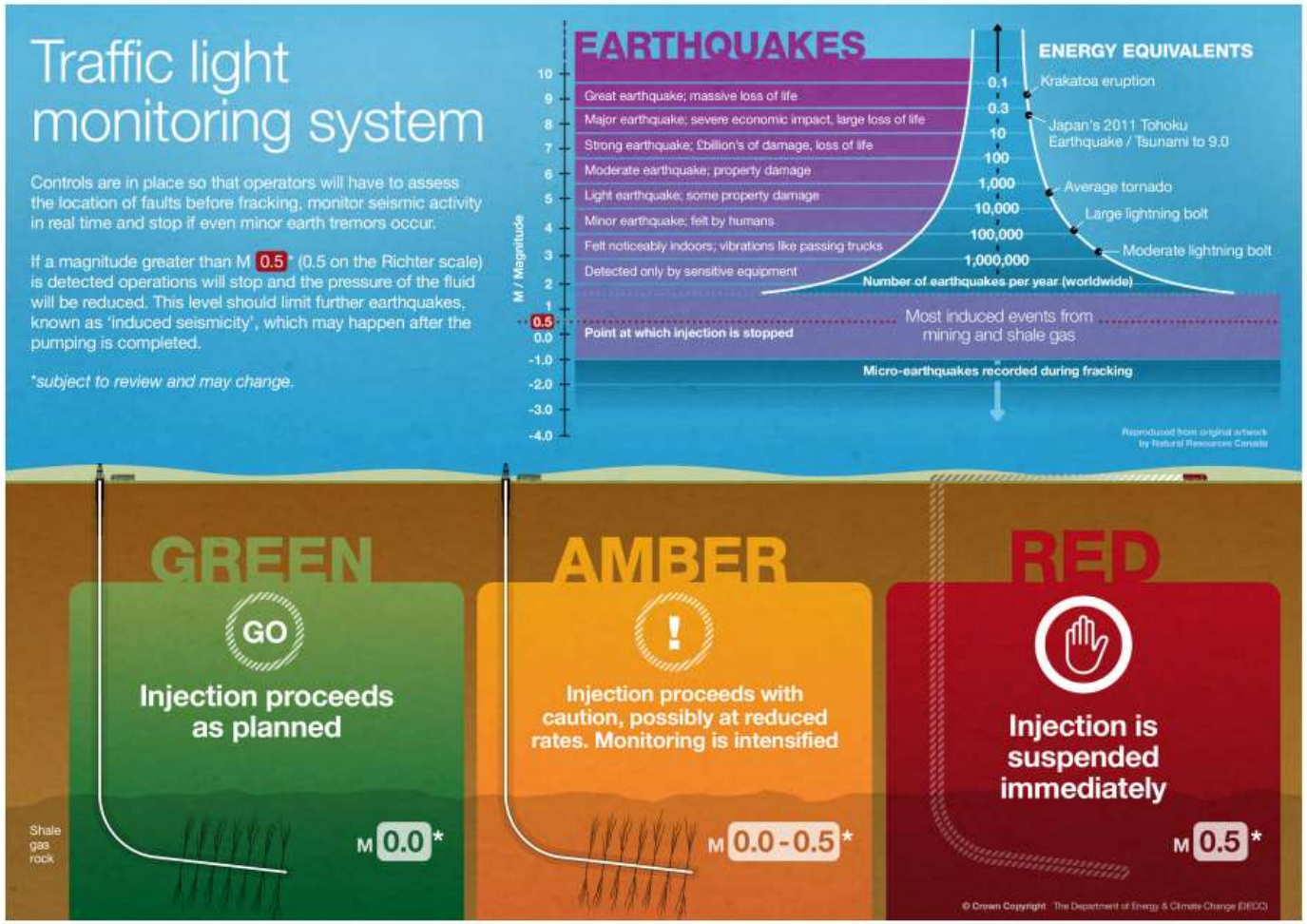
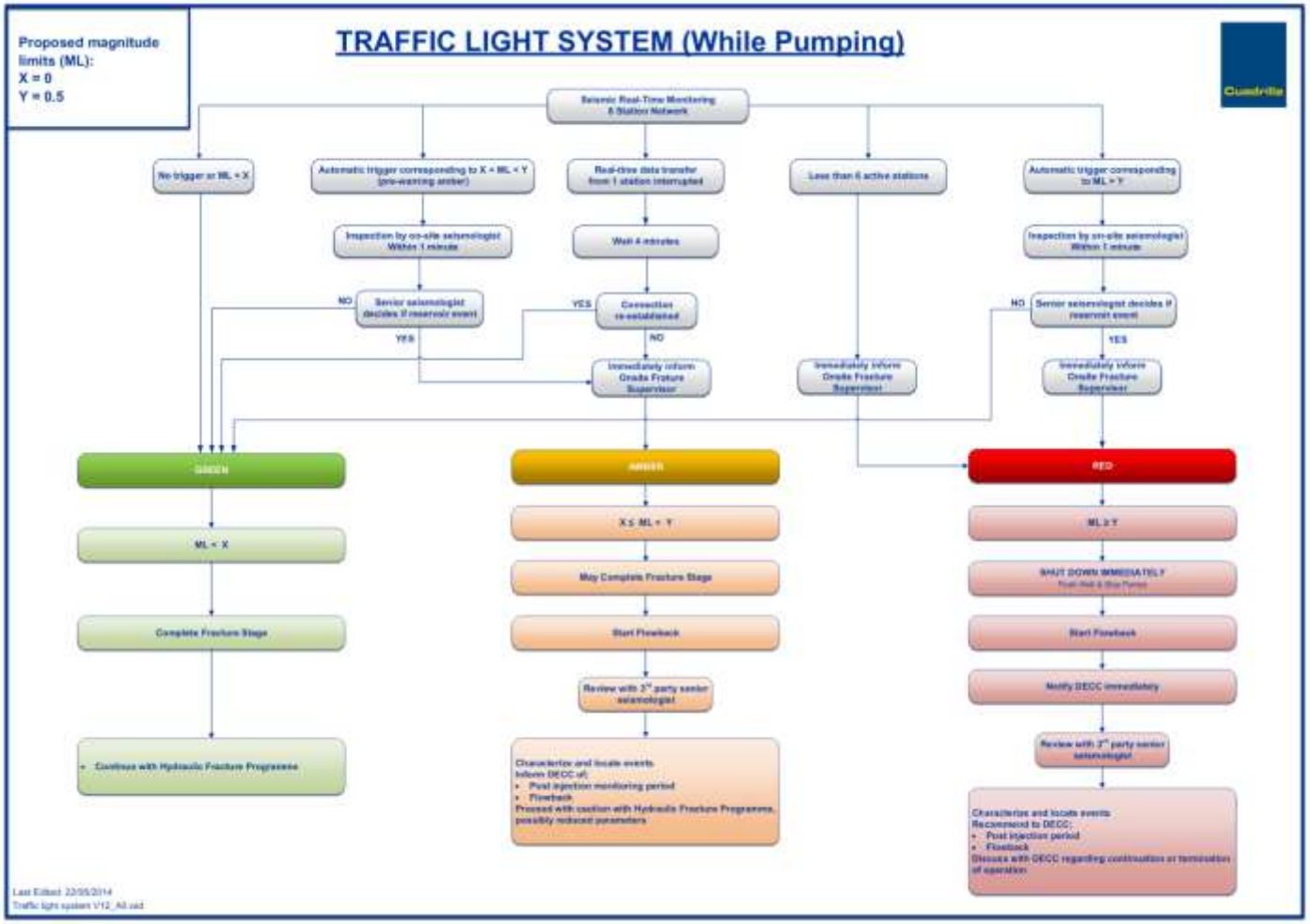


Figure 12.8 Traffic Light System summary flow chart



Flowback

175. A significant mitigation measure that will be employed at Preston New Road to mitigate future induced seismic events is to 'flowback' in the case of Amber or Red seismic events, between hydraulic fracturing stages. As recommended by DECC[267], flowback is the process whereby the hydraulic fracturing fluid is allowed to flowback up the well to the surface containment system after the hydraulic fracturing stage to minimise the build-up of fluid pressure within the formation. The disposal of flowback fluid is discussed in Chapter 17 Resources and Waste. It is estimated by Cuadrilla that 15-25% of hydraulic fracturing fluid returns to the surface during initial flowback. The quantity of flowback fluid returned during all testing is estimated at 40%

Table 12.11: Flowback procedure in the event of an Amber or Red TLS trigger.

If there is no proppant in the wellbore or in the near wellbore: • Stop pumping operations and switch over to flowback. It is estimated to take 5 minutes to initiate flow back. If there is proppant in the wellbore or in the near well bore: • Continue pumping with a non-proppant flush sufficient to over displace the well bore volume by $15m^3$ into the formation; and • Stop pumping operations and switch over to flowback. It is estimated to take 5 minutes to initiate flow back. The length of the flowback will be determined by the Operator and DECC

Summary of instrumentation

176. The 8 surface instruments in the surface array that facilitates the TLS will record induced and natural seismicity to provide a baseline of background seismicity for the site. The seismicity will be recorded for at least 4 weeks prior to commencement of hydraulic fracture operations and downloaded for analysis and interpretation. For further information on monitoring see Section L10.8 of Appendix L. The surface array will be installed just below the ground surface (approximately 0.8m).

177. Cuadrilla are also proposing to install a buried array composed of approximately 10 real time geophones linked to a central monitoring station on the site to monitor fracture growth during the hydraulic fracturing operations.

178. It should be noted that in addition to the 10 real time monitoring stations Cuadrilla will also install 70 store and harvest stations to monitor seismicity before, during and after the hydraulic stimulation. The data from the stations will be retrieved and analysed on a daily basis during hydraulic stimulation operations. This buried array will be installed in boreholes up 100m below ground level.

Summary of mitigation measires

179. Following the felt induced seismic event that was attributed to hydraulic fracturing of Cuadrilla's Preese Hall well, several measures have been incorporated into the Project as embedded mitigation. These measures are a requirement of the Department for Energy and Climate Change (DECC)[267], the United Kingdom Onshore Operators Group (UKOOG)[268] and were announced in Parliament as a written statement by Edward Davey on December 13th 2012[270]. These recommendations are included within Table 12.12 along with a comment on how Cuadrilla have implemented these recommendations.

Table 12.12: How Cuadrilla has implemented the key recommendations to mitigate induced seismicity.

Recommended Mitigation Measure	**Cuadrilla's Implementation Strategy**
Review available information on geology, structure and *in situ* stresses within the vicinity of the proposed Site to avoid hydraulically fracturing into, or close to, existing critically stressed faults[267,268,270,285,321].	Cuadrilla has carried out an extensive desk study to identify the faults in the vicinity of the Preston New Road site. This has been carried out through review of geological maps and memoirs, relevant peer reviewed published literature on the local and regional geology, in-house expertise and knowledge, interpretation of bespoke 3D geophysical (seismic) survey and end of well reports for the Grange Hill, Thistleton, Elswick and Preese Hall wells. This information has been used to locate the vertical well and horizontal wells in the most favourable ground conditions to avoid regional faults.
Carry out risk based geomechanical assessments of proposed hydraulic fracturing with regard to known faults (including maximum magnitude estimates)[268]	Cuadrilla have carried out a review of maximum magnitude induced seismic events within the Bowland Basin, which considers the location, geometry and activity of faults in combination with the geomechanical properties of the rock and the *in situ* stress regime. This has been reviewed by Arup and DMT and a maximum magnitude estimate of 3.1 M_L is considered reasonable (for injection volumes similar to Preese Hall-1). With embedded mitigation the maximum magnitude is considered to be 1.5 $M_{L.}$
Monitor background induced and natural seismicity before hydraulic fracturing[267,285,321]	Cuadrilla will monitor background induced and natural seismicity before hydraulic fracturing.
Monitor background induced and natural seismicity after the hydraulic fracturing[267,285]	Cuadrilla will monitor background induced and natural seismicity after hydraulic fracturing.
Monitor background induced and natural seismicity during the hydraulic fracturing[267,268,285,321]	Cuadrilla will monitor background induced and natural seismicity during hydraulic fracturing. This will include microseismic monitoring in order to manage the location and extent of fracture growth.
Evolutionary approach to risk assessment and mitigation (opertational mitigation) - i.e. fracture evolution and operational mitigation using a stepped progressive approach[268]	Cuadrilla will implement a stepped progressive approach that uses mini-fractures, increasing pumped volumes of hydraulic fracturing fluids and microseismic monitoring to understand the performance of the reservoir during hydraulic fracturing. This will enable Cuadrilla to adjust the hydraulic fracturing operations to ensure that hydraulic fractures are within the design objectives. This iterative process will allow the performance of the previous hydraulic fracture stage to be used to design the next hydraulic fracture stage to ensure the design objectives are maintained.
Carry out a mini-fracture stage[268,285,321]	A mini-fracture stage will be carried out prior to the initial main hydraulic fracturing stage to determine the geomechanical properties of the formation to inform the hydraulic fracture model. The mini-fracture stage will employ small volume stimulation of approximately 15m³.
Reduce volumes of hydraulic fracturing fluids[267,321]	Cuadrilla will reduce the volumes of hydraulic fluids to $15m^3$ for mini-fracture stimulations and $750m^3$ for full stimulations per hydraulic fracture stage.
Monitor the extent of fracture growth during hydraulic fracturing[267,268,285,321]	Cuadrilla will use a buried microseismic array to monitor the extent and orientation of hydraulic fractures to ensure fractures are within the design objectives and to ensure that fractures do not extend to regional faults.
Implementation of a Traffic Light System[267,268,285,321]	Cuadrilla will implement the Traffic Light System as agreed by DECC in order to locate the hypocentre of the seismicity and determine the magnitude of each event in real time during the

Recommended Mitigation Measure	Cuadrilla's Implementation Strategy
	hydraulic fracturing stages. Cuadrilla have committed to the dissemination of the status of the TLS at the end of each hydraulic fracture stage.
Flowback of hydraulic fracturing fluids[267,321]	Cuadrilla will flowback, in the case of Amber or Red threshold (TLS) seismic events, between hydraulic fracturing stages.
Develop a Hydraulic Fracturing Programme (HFP)[268,271]	The Project proposals include hydraulic fracturing and extended well testing activities. Therefore, Cuadrilla is required to submit a description of the controls described in the Section 12.9 to mitigate induced seismicity in the HFP. The HFP will be authorised by DECC prior to commencement of hydraulic fracturing activities.

12.10 Residual effects

180. The mitigation measures discussed within Section 12.9 are all embedded mitigation measures. With these mitigation measures in place, all effects identified within Section 12.7 were assessed as being *not significant*. No significant residual effects therefore remain.

12.11 Assessment summary matrix

181. The risk magnitude or significance of effect associated with the likely significant effects has been evaluated according to the methodology described within Section 12.4. The results of this risk assessment have been described with preceding text and summarised in Table 12.13 below.

182. In summary, the risk magnitude associated with each likely effect has been assessed as ***minor*** or ***negligible***. As a consequence, the predicted significance of all likely effects is **not significant**. This assessment has been made on the basis of the mitigation measures described within Section 12.5 being implemented as embedded mitigation measures, i.e. form part of the proposed Project. Therefore no additional mitigation measures are considered necessary and the significance of residual effects are therefore also **not significant**.

183. The location of the site selected by Cuadrilla to construct the vertical and horizontal well has taken into account the geological and structural conditions in the region and the vertical well and the horizontal wells have been located in the most favourable ground conditions to minimise induced seismicity from shale gas exploration operations.

Table 12.13: Induced seismicity assessment summary matrix for exploration activities.

Description of effect	Risk magnitude (and significance)	Mitigation	Residual effect
Construction of the Well Pad and Access			
No anticipated effects			
Installation of the Surface and Buried arrays			
No anticipated effects			
Drilling			
No anticipated effects			
Hydraulic fracturing, initial flow testing and extended well testing			
Ground motion hazard from induced seismicity associated with hydraulic fracturing (Scenario 1 – 0.5 ML seismic event).	***Minor* (not significant)**	Mitigation measures embedded, including: • Reviewing available information on geology, structure (including faults) and in situ stresses in the vicinity of the proposed Site to avoid hydraulically fracturing into, or close to, existing critically stressed faults; • Carry out risk based geomechanical assessments of proposed hydraulic fracturing with regard to known faults (including maximum magnitude estimates); • Monitoring background induced and natural seismicity before, during and after hydraulic fracturing; • Evolutionary approach to risk assessment and mitigation – Fracture evolution and operational mitigation including a mini-fracture stage prior to the initial main hydraulic fracturing stage and reduced per stage volumes of hydraulic fracturing fluids compared to those used at Preese Hall. This stepped progressive approach to hydraulic fracturing will consist of an initial mini-fracture stage and modest initial pumped volumes building up to a maximum pump volume of 765m^3 per stage (less than half of	***Minor* (not significant)**
Ground motion hazard from induced seismicity associated with hydraulic fracturing (Scenario 2 – 1.5 ML seismic event).	***Minor* (not significant)**		***Minor* (not significant)**
Effects on well integrity	***Minor* (not significant)**		***Minor* (not significant)**
Effects on liquefaction potential	***Negligible* (not significant)**		***Negligible* (not significant)**
Effects on slope instability	***Negligible* (not significant)**		***Negligible* (not significant)**
Effects of settlement causing surface deflections from gas extraction	***Negligible* (not significant)**		***Negligible* (not significant)**

Description of effect	Risk magnitude (and significance)	Mitigation	Residual effect
Effects of settlement from gas extraction causing earthquakes	***Negligible* (not significant)**	the average volumes pumped per stage at Preese Hall). As this process continues, an understanding of the performance of the reservoir during hydraulic fracturing is developed; • Monitor the extent of fracture growth during hydraulic fracturing using a buried microseismic array; • Implementation of the Traffic Light System (via the surface seismic monitoring array); and • Flowback in the case of Amber (0.0 M_L) or Red (0.5M_L) seismic events between hydraulic fracturing stages in accordance with the Traffic Light System.	***Negligible* (not significant)**
Effects of fluid migration and changes in the stress regime due to hydraulic fracturing in the Bowland Basin inducing seismicity in deep basement faults.	***Negligible* (not significant)**		***Negligible* (not significant)**
Effects of ground motion hazard causing salt cavern instability at the nearby Preesall Saltfield Underground Storage Project.	***Negligible* (not significant)**		***Negligible* (not significant)**
Decommissioning and Restoration			
No anticipated effects			
Cumulative and interactive effects			
Cumulative and interactive effects of the Preston New Road and Roseacre Wood works occurring together	**Not significant (Minor)**	As above.	**Not significant (Minor)**
Cumulative effects of hydraulic fracturing and initial flow testing occurring together on the same well pad	**Not significant (Minor)**		**Not significant (Minor)**
Cumulative effects of initial flow testing and drilling occurring together at the same well pad	**Not significant (Minor)**		**Not significant (Minor)**
Cumulative effect of Preston New Road occurring at the same time as other developments in the area	**Not significant (Minor)**		**Not significant (Minor)**

13 Land Use

Chapter Summary- Land Use

This chapter assesses the potential for the Project to impact on the agricultural land uses in and around the Site. The effects of all aspects of the Project have been considered. However, the detailed assessment has focussed on the construction, use and decommissioning of the well pad and access track (the Site) as the main source of potential impacts because of the nature of the construction works (earthworks) and the duration that the Site will be in use (up to 6 years).

The majority of the land that will be occupied by the Site has been assessed as moderate in terms of its agricultural land quality. However due to clay content in the soil there is the potential for an adverse significant effect on soil resources from compaction and smearing during the construction of the access track and wellpad. Effect on farming operations are assessed as not significant.

The significant effect will be mitigated by implementing best practice measures for the excavation and handling of soils during construction. As a consequence the residual effects are not significant.

The Roseacre Wood and Preston New Road Sites are not within the same ownership so there is no scope for cumulative impact on the same landowner from both projects.

13.1 Introduction

1. This Chapter assesses the effect of the Project on agricultural land and the uses of that land. In particular it considers the quality of the affected land and the potential consequential loss of or damage to the land, and the effects of the loss of agricultural land to the Project on the agricultural businesses occupying the Site.

13.2 Key development issues

2. Aspects of the Project of relevance to agriculture are the temporary reduction in the farmable area for the farm holding; the management of soils excavated, stored and replaced on site; and the potential for damage to soils which remain in-situ at the Site, for example through tracking by heavy machinery to construct the well pad.

13.3 Scoping and consultation

3. The Scoping Opinion issued by Lancashire County Council required that the ES include:

"an assessment of the impact of the development on agricultural land based upon an agricultural land quality survey. The impact of the proposed operations on the use of this field for any of the agricultural purposes to which it may be used should be examined. The effects of the development area on the viability of existing farm holdings should also be assessed including any potential impacts on the use of the surrounding land for agricultural purposes resulting from any contamination, noise or other indirect impacts, either as part of any day to day operation of the facility or as a result of any accidents occurring on the site. The impact on adjacent agricultural holdings should also be considered."

4. The scope of these requirements has been addressed by means of site observation, a soil survey of the Site, and the collection of data from the main affected farming interest. The subject matter does not require any formal consultation to be undertaken. Statutory consultation procedures in the Town and Country Planning (Development Management Procedure) Order 2010 require reference to Natural England only of proposals for development not allocated in a development plan which individually or cumulatively involve the loss of more than 20ha of best and most versatile agricultural land.

13.4 Methodology

13.4.1 Introduction

5. A detailed soil resources survey was undertaken on land at the Site in November 2013, in order to derive the likely baseline land quality of the area to be disturbed by the Project, as well as that of the land immediately surrounding it. These data and other physical parameters of topography and land drainage conditions were observed, and the data collected assessed in accordance with the Ministry of Agriculture, Fisheries and Food (MAFF) revised guidelines for classifying agricultural land in the context of the national Agricultural Land Classification (ALC)[325].

6. Information on the land use and farming circumstances was obtained in an interview with the sole farming interest affected at the Site. This has provided information on the area of land occupied; the type and scale of farming undertaken; the nature, scale and location of the farm items of farm capital; and the scale and nature of effects of the Project on agricultural activities.

13.4.2 Baseline methodology

7. In order to make an assessment of the agricultural land quality of the Site, a baseline survey of soil resources was undertaken. This comprised the examination of seven full soil profiles using an Edelman (Dutch) auger and spade. The locations of profiles examined are shown in Figure 1: Observations. At each observation point, the following characteristics were assessed for each soil horizon, up to a maximum depth of 120cm or any impenetrable layer:

- Soil texture;
- Significant stoniness;
- Colour (including local gley and mottle colours);
- Consistency;
- Structural condition;
- Free carbonate; and
- Depth.

13.4.3 Assessment methodology

8. The assessment of likely significant effects as a result of the Project has taken into account the site preparation, earthworks, construction phase and decommissioning. The significance level attributed to each effect has been assessed based on the magnitude of change due to the Project and the sensitivity of the affected receptor/receiving

[325] MAFF (1988) Agricultural Land Classification of England and Wales : Revised guidelines and criteria for grading the quality of agricultural land

environment to change. Magnitude of change and the sensitivity of the affected receptor/receiving environment are both assessed on a scale of high, medium, low and negligible.

9. The following terms have been used to define the significance of the effects identified:

- Major effect: where the Project could be expected to have a very significant effect (either positive or negative) on agricultural receptors;
- Moderate effect: where the Project could be expected to have a noticeable effect (either positive or negative) on agricultural receptors;
- Minor effect: where the Project could be expected to result in a small, barely noticeable effect (either positive or negative) on agricultural receptors; and
- Negligible: where no discernible effect is expected as a result of the Project on agricultural receptors.

10. The criteria for assessing the sensitivity of the agricultural land resource are set out in Table 13.1.

Table 13.1. Criteria for assessing the sensitivity of land resources.

Sensitivity	Land Resource
High	Grade 1, excellent quality agricultural land
Medium	Grade 2 and Subgrade 3a, very good to good quality agricultural land
Low	Subgrade 3b and Grade 4, moderate to poor quality agricultural land
Negligible	Grade 5, very poor quality agricultural land

11. The sensitivity of the soil resource reflects its textural characteristics and its susceptibility to smearing and compaction. The least sensitive soils are those with a high sand fraction (sands, loamy sands and sandy loams); the most sensitive are those with a high clay and silt fraction (clay, silty clays, heavy clay loams and heavy silty clay loams); with medium textured clay loams being of medium sensitivity.

12. Table 13.2 sets out the criteria for the consideration of the magnitude of change for agricultural land and soil resources.

13. The magnitude of change to the soil resource is assessed according to the degree to which soils can continue to fulfil their primary functions other than food and fibre production, which is encapsulated within the ALC. These other functions comprise:

- the storage, filtration and transformation of many substances and elements, including water, carbon and nitrogen;
- support of ecological habitats and biodiversity;
- support for the landscape;
- protection of cultural heritage;
- providing raw materials; and
- providing a platform for human activities, such as construction and recreation.

Table 13.2. Magnitude of change for land and soil resources.

Magnitude	Criterion	Criterion
High	50ha or more of agricultural land is affected by the Project	The Project would directly lead to the loss of soil such that it can no longer perform its principal social, economic or environmental service

Magnitude	Criterion	Criterion
Medium	Between 20ha and 50ha of agricultural land is affected by the Project	The Project would lead to the inappropriate re-use of a soil such that its principal social, economic or environmental service is diminished
Low	Between 5ha and 20ha of agricultural land is affected by the Project	The Project would lead to the re-use of a soil in a way that does not affect its principal social, economic or environmental service
Negligible	Less than 5ha of agricultural land is affected by the Project	The soil resource remains unaffected

14. The sensitivity of agricultural operations and enterprises to change is determined primarily by their size and more particularly their nature. In general terms, larger farms will have a greater capacity to absorb the impacts of developments and will be less sensitive to change. However, a simple assessment based solely on size could be misleading as some agricultural operations are more sensitive to change than others, irrespective of the size of holding with which they are associated. This is reflected in the following criteria for assessing the sensitivity of the agricultural receptors set out in Table 13.3.

Table 13.3. Criteria for assessing the sensitivity of agricultural receptors.

Receptor Sensitivity	Receptor definition
High	Farm types in which the operation of the enterprise is dependent on the spatial relationship of land to key infrastructure, and where there is a requirement for frequent and regular access between the two, or dependent on the existence of the infrastructure itself, e.g. Dairying, irrigated arable or field scale horticulture, and intensive livestock or horticultural production undertaken in buildings.
Medium	Farm types in which there is a degree of flexibility in the normal course of operations e.g. combinable arable and grazing livestock farms.
Low	Farm types and land uses undertaken on a non-commercial basis.

The effects on farm holdings relate primarily to the loss of land and other key farm infrastructure (dwellings, buildings and other structures such as irrigation reservoirs and slurry pits), the severance and fragmentation of land and disruption to operations arising from construction effects such as noise, dust and water pollution. Guideline criteria for determining the magnitude of change are presented in Table 13.4.

Table 13.4. Magnitude of change to farm holdings.

Magnitude	Loss of agricultural land	Loss of farm infrastructure	Severance
High	Loss of 20% or more of all land farmed	Direct loss of farm dwelling, building or structure	No access available to severed land
Medium	Between 10% and less than 20% of all land farmed	Loss of or damage to infrastructure affecting land use	Access to severed land via public highway
Low	Between 5% and less than 10% of all land farmed	Infrastructure loss/damage does not affect land use	Access to severed land via private way
Negligible	Less than 5% of all land farmed	No impact on farm infrastructure	No new severance

15. The significance of effects is then assessed based on the magnitude of change and the sensitivity of the receptor or resources, as shown in Table 13.5. An effect of moderate or greater magnitude has been assessed as a significant effect in terms of the EIA regulations.

Table 13.5. Criteria for assessing the significance of effects.

Sensitivity	Magnitude of Change			
	High	Medium	Low	Negligible
High	Major **Significant**	Major – Moderate **Significant**	Moderate **Significant**	Minor **Not Significant**
Medium	Major – Moderate **Significant**	Moderate **Significant**	Minor **Not Significant**	Negligible **Not Significant**
Low	Moderate **Significant**	Minor **Not Significant**	Negligible **Not Significant**	Negligible **Not Significant**
Negligible	Minor **Not Significant**	Negligible **Not Significant**	Negligible **Not Significant**	Negligible **Not Significant**

13.4.4 Buried and surface arrays and EFT gas grid pipeline

16. The works to construct the arrays and EFT gas grid pipeline will result in a temporary and short term impact a given site or area of farm land (see Appendix B for durations). The duration and scale of the works are such that magnitude of the potential impact is considered to be negligible and therefore not likely to give rise to a significant effect.

13.5 Baseline

13.5.1 Landform

17. The Site sits within a parcel of agricultural land of around 7.2ha. The complete parcel of land is bounded to the west, north and east by other agricultural land and to the south of the Site. The Project also makes provision for a potential gas pipeline connection to an existing pipeline to the west and crossing two additional field units.

18. The site is largely level and sits at around 12.5m above Ordnance Datum (AOD). A small pond is situated to the south east of the Site.

13.5.2 Agro-Climatic Conditions

19. Agro-climatic data has been interpolated from the Meteorological Office's standard 5km grid point data set at a representative altitude of 15m AOD. The data are given in Table 13.6. The Site is wet and moderately warm, with moderate to moderately small crop moisture deficits. The number of Field Capacity Days is greater than is typical for lowland England and is considered unfavourable for providing opportunities for agricultural field work.

Table 13.6. Local climatic factors.

Criterion	Measurement
Average annual rainfall	918mm
Accumulated temperature >0°C*	1423 day°
Field Capacity Days*	205 days
Average moisture deficit, wheat*	81mm
Average moisture deficit, potatoes*	67mm

Note: * see the Glossary of terms and abbreviations for definitions of these terms.

13.5.3 Soil Parent Material and Soil Type

20. The principal underlying geology is that of the Sidmouth Mudstone Formation which consists predominantly of structureless mudstone and siltstone. This is overlain by superficial deposits of Devensian Till, which comprises poorly- or unsorted material ranging in size from clay to boulders.

21. The Soil Survey of England and Wales soil association map (1:250,000 scale) shows two associations to be present at the Site Preston New Road Site. Across most of the area is the Salop association, which is characterised by fine loamy topsoils which overlie poorly permeable clayey subsoils. Where the Field Capacity Day regime exceeds 200 days, as is the case at the Site, Salop soils remain severely waterlogged even where under-drainage is installed. Such soils are typically of Wetness Class (WC) IV.

22. In the east of the Site is an intrusion of the Flint association, which has similar characteristics to the Salop association. Topsoil typically has a fine loamy texture and subsoils are clayey, although better draining than the Salop soils. The Flint association is therefore more commonly of WC III.

13.5.4 Agricultural Land Quality

23. The detailed survey of soil characteristics on the land surrounding the Site show the land quality to be limited by soil wetness.

24. Topsoil predominantly comprises organic medium clay loam, although clay and sandy clay loam textures are also present, which has an average thickness of 34cm. There is slight variation in the subsoil with most being of clay but several observations of sandy clay loam were made. The most south-westerly observation also showed sandy loam in the profile. This area is of WC II and is the best drained area of the site.

25. The remainder of the profiles are of WC III or IV, depending on the presence of or depth to a poorly permeable layer. Those profiles which are not poorly permeable remain to be of WC III due to the great number of Field Capacity Days applicable to the site.

    With medium clay loam topsoil textures, profiles of WC II or III are of Subgrade 3a and those of WC IV are of Subgrade 3b. The distribution of land quality in the study area is shown in Figure 2, and the areas of land affected by the Project in Table 13.7.

Table 13.7. ALC Areas affected by Project.

Grade	Description	Area (ha)	Area (% of agric. land)
3a	Good quality	1.5	58
3b	Moderate quality	1.1	42
	Total Agricultural	2.6	100

13.5.5 Farming Circumstances

26. There is a single farming interest associated with the land affected by the Project. This is a large, family based interest whose land holding extends to some 162 ha. This occupies a continuous block of land located between the M55 motorway and Preston New Road and largely to the west of the settlement of Great Plumpton. 65% of the holding is owner-occupied, including that part affected by the proposed exploration site. The holding is essentially a grassland unit and engaged in dairying.

27. The grassland provides grazing and conserved forage to support a milking herd of 140 animals. It is also produces hay and haylage crops for sale. In addition to the milking cows the farm retains female progeny as dairy replacements and produces finished beef and/or store cattle from the remainder. Land is also made available for the winter grazing of sheep.

28. The farm is concentrated at the main farmstead, Plumpton Hall Farm, adjacent to Preston New Road on the western edge of the settlement of Little Plumpton. Here there is a substantial range of mainly modern agricultural buildings accommodating the dairy unit and winter stock housing.

29. The holding is shortly to expand through access to an additional 8 ha of rented land.

13.6 Assessment

13.6.1 Construction, drilling, hydraulic fracturing, initial and extended flow testing, decommissioning and restoration

13.6.1.1 Agricultural Land Resource

30. The area required for the construction of the Site is presently in agricultural use. This assessment assumes that the remainder of the field unit primarily, in which the Site is located, would remain in agricultural use post-construction.

31. The main factor affecting land quality at the Site is soil wetness, which limits most of the Site to no better than Subgrade 3b In accordance with Table 13.1, the land is therefore a resource of *medium to low* sensitivity. The scale of change is small and, in accordance with Table 13.2, is assessed as being of *negligible* magnitude.

32. It is therefore determined that the impact of the loss of agricultural land to the Project is **not significant**.

13.6.1.2 Soil Resources

33. The principal attribute of the soils on Site are their productive capability, as expressed in the ALC. The other main attribute of the soil is as a carbon and water store. The soil contains a significant proportion of clay and silt which have a high capacity for water and

nutrient retention. Furthermore, these textures are also most susceptible to damage by smearing and compaction and hence the sensitivity of the soil in this respect is *high*.

34. Prior to any mitigation measures, the vulnerability of clay soils is such that they could be irreparably damaged and rendered unable to fulfil their current agricultural and ecological functions, which would be an effect of *high* magnitude.

35. It is therefore determined that the temporary impact on soil resources is *moderate to major* and a **significant** effect.

13.6.1.3 Farm Holding

36. The land requirement of the Site represents about 1.5% of the total area farmed by the agricultural interest. There is a limited area of severance of land associated with the proposed development, except during the period of the potential pipeline connection. There is, however, disruption to operational movement between the field unit occupied by the site and those units to its east and west. This is mitigated within the Project by the provision of new accesses across the western field boundary and the proposed access road to the Site, and by the inclusion of a cattle grid to preclude livestock gaining access to Preston New Road.

37. The Project incorporates protection and mitigation measures for field and surface drainage. The Project provides for the conservation of soil resources removed to form the exploration site which will, if necessary, enable the restoration of the site to its current agricultural condition.

38. The existing land use, namely dairying, is a receptor of *high* sensitivity to change due to the close operational relationship between grazing land and buildings. However, the land requirements of the Project are small and, in the absence of any additional adverse operational effects, represent a *negligible* degree of change. The farming interest considers that any change in circumstances will be more than offset by the recently agreed access to a further 8ha of land. The impact of the Project on the farming interest will therefore be one of *minor* magnitude and **not significant**.

13.7 Cumulative and Interactive Effects

39. The Project will only effect the landowner of the Site. Different landowners are involved with Preston New Road and Roseacre Wood so there will not be a cumulative effect from both this Project and Roseacre Wood.

13.8 Mitigation measures

13.8.1 Construction, drilling, hydraulic fracturing, initial and extended flow testing, decommissioning and restoration

13.8.1.1 Agricultural Land Resource

40. No significant effects have been predicted and as such mitigation measures are not required.

13.8.1.2 Soil Resources

41. To avoid significant effects on soil resources Defra's "Construction Code of Practice for the Sustainable Use of Soils on Construction Sites"[326]. will be applied. Relevant soil management and construction management measures will also be included in the EOS (Appendix E). The soil that is excavated during construction of the well pad and access track will be used during the restoration and reinstatement of the Site. .

13.8.1.3 Farm holding

42. No significant effects have been predicted and as such mitigation measures are not required.

13.9 Residual effects

13.9.1 Construction, drilling, hydraulic fracturing, initial and extended flow testing

43. The main operational effect of the Project will be the removal of agricultural land from production. Both in terms of the main site and the monitoring arrays, this effect is negligible and **not significant**.

44. In terms of the displacement of soil resources, these will be safeguarded with a requirement to reinstate them in the event of the cessation of operational activities.

45. The temporary loss of farmland will have an impact of minor significance on the affected farming interest. The expectation is that the land will be returned to agricultural use.

46. It is concluded that the residual effects are **not significant**.

13.10 Assessment summary matrix

Table 13.8. Agriculture assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction, drilling, hydraulic fracturing, initial and extended flow testing decommissioning and restoration.			
Temporary displacement of soil resources	Moderate / Major **Significant**	Stripped and stored according to Defra best practice.	Negligible **Not Significant**
Temporary loss of productive agricultural land	Negligible **Not Significant**	Reinstatement requirement	Negligible **Not Significant**
Loss of farmable area to the holding affected	Minor **Not**	Reinstatement requirement	Negligible **Not Significant**

[326] Defra (2009). Construction Code of Practice for the Sustainable Use of Soils on Construction Sites. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69308/pb13298-code-of-practice-090910.pdf

Description of effect	Significance	Mitigation	Residual effect
	Significant		
None – subject to appropriate reinstatement and aftercare of land	Not Applicable.		Negligible **Not Significant**

14 Landscape and visual amenity

Chapter Summary- Landscape and Visual Amenity

This chapter assesses the potential change in landscape character, setting of heritage assets and the visual nature of the landscape experienced by people as a result of the Project. The landscape and visual components of The Fylde landscape that have been assessed lie within the study area of a 5km radius. The methodology follows the best practice set out in the Guidelines for Landscape and Visual Impact Assessment 3rd Edition (GLVIA3).

Consultation has been undertaken with Lancashire County Council's Landscape officer as well as through public consultation events. The study area has been characterised into seven landscape character areas at the local level. Sixteen principal viewpoints have been identified from which four were selected to produce photomontage representations in support of the assessment. In visual terms especially, the phased activities from well pad construction through to appearance of the drilling rig on the Site to decommissioning have an important bearing on the visual effects.

In summary the landscape assessment findings reveal that for all phases of the Project activity there are no significant landscape effects. There would be very localised direct change due to development proposals temporarily altering a very small proportion of one local character area during construction of the well pad but no effect during other phases.

In summary the visual assessment findings reveal that there would be significant adverse visual effects arising during the drilling, hydraulic fracturing and flow testing phases. Seven of the principal viewpoints would experience significant adverse visual effects. Six of these are residential receptors within and one a recreational viewpoint, the fishing pond on Moss House Lane. No significant adverse visual effects were judged to occur on any receptor more than 930m distance from the Site during any phase of the Project.

The following summary of mitigation proposed for respective phases of activity includes:

- Construction of well pad and access - 4m high bunds created around the well pad; a tree survey would be carried out to B.S. 5837 and root protection plan produced; proposed planting of native tree and shrubs immediately around the well pad to help filter views from PRoW and the residential properties; existing specific hedgerows would be allowed to grow taller in agreement with the landowner; minimisation of light spill and direct upward light from temporary task lighting required for operation and ideally designed to meet Environmental Zone E2 and where practical, hours of working would be arranged to minimise potential intrusive effects on the countryside from lighting; targeted hedgerow, and hedgerow tree planting to gaps in hedgerows to filter views to the Site.
- Surface network and buried array - involves an iterative design / micro-siting process to select the least visually intrusive location for arrays, especially in respect of the significant adverse visual effects for PRoW receptors
- Drilling, Hydraulic Fracturing and Flow Testing – mitigation for this phase is similar to that for the construction of the well pad and access phase comprising specific hedgerows allowed to grow taller; minimisation of light spill and targeted offsite hedgerow, and hedgerow tree planting.
- Extended Well Testing – mitigation as earlier phases
- Decommissioning - mitigation focussed on minimal working area to well pad and access road restoration using appropriate materials with management and maintenance strategy.

Since there are judged to be no significant effects on the landscape resource for any phase of the development any further mitigation would have no bearing on the significance of effect and therefore the non-significant residual effects would remain the same. The only significant visual effects would occur during the Drilling, Hydraulic Fracturing and Flow Testing phases over a period of twenty nine months. It is considered that any mitigation in the form of offsite screening for example is not possible to markedly reduce these effects since vegetation is unlikely to grow sufficiently in that time to fully mitigate any adverse effects.

In terms of cumulative landscape and visual effects there are no known proposed or committed developments of an appropriate scale or nature that would generate significant cumulative effects on the landscape character or visual amenity along with the Project development.

The majority of the land that will be occupied by the Site has been assessed as moderate in terms of its agricultural land quality. However due to clay content in the soil there is the potential for an adverse significant effect on soil resources from compaction and smearing during the construction of the access track and wellpad. Effect on farming operations are assessed as not significant.

14.1 Introduction

1. This chapter addresses the potential landscape and visual effects from the Project. The assessment considers the existing landscape and visual resource, the key landscape and visual effects associated with the activities outlined above, together with proposed mitigation measures and residual and cumulative effects.

14.2 Key Development Issues

2. For the Landscape and Visual chapter of this ES the following development issues are relevant to the assessment;

- All development proposals are of a temporary nature;
- Landscape and Visual effects would arise primarily from the following components; construction of the pad including 4m high security fencing and bunding; drilling rig up to 53m maximum height; workover rig 30m in height, two sand storage silos, each of 15m in height, well services rig of 36m and two flare stacks of approximately 10m in height including an unpainted metal casing / shroud around the flame; and
- Decommissioning would involve the restoration of the Site to its former condition and would be limited in its extent to the development area. The decommissioning of each array would be limited in its extent and also seek to restore each localised site to its former condition.

14.3 Scoping and Consultation

3. The Scoping Report (Appendix C) outlined that the Landscape and Visual Impact Assessment (LVIA) would be carried out in accordance with the Guidelines for Landscape and Visual Impact Assessment GLVIA 3rd Edition and other current best practice. The Scoping Report also stated that the LVIA will consider the effects on the landscape resource (both direct effects and effects on the setting of the landscape resource) and visual amenity (views). Potential landscape and visual effects associated with the Project were considered to be:

- Change in landscape character due to the proposed development, in particular the decommissioning of the Site; and
- Visual effects on receptors from the Project including any required night time illumination during the operational period.

4. A 5km radius study area from the Site was proposed in the Scoping Report with a digital ZTV (Zone of Theoretical Visibility – see section 14.4.2 below for definition) produced to explore an equivalent visual study area of 5km.

5. Initial verbal response from Lancashire County Council was that ZTVs would not be required for this development. Table 14.1 below summarises the details of consultation to date with Lancashire County Council.

Table 14.1: Landscape and Visual Assessment scoping and consultation overview.

Consultee	Comment	Response
Lancashire County Council	Scoping responses received 14/2/14 via email	Summary of LCC scoping responses includes: Baseline should include landscape amenity/cultural heritage receptors and those that lie on or just beyond the edge of 5km Queried 5km study area in relation to scale of drilling equipment Include TPO's Provide details of how landscape and visual susceptibility to development is judged Production of Photomontages were requested that adhere to LCC and best practice methodology Include reference to specific landscape documents in baseline and likely effects against the key tests of landscape policy
Lancashire County Council	Meeting with LCC 7/3/14	Meeting held between Arup Landscape Architect / Cultural Heritage and Steve Brererton (Landscape Architect) and Doug Moir (Archaeology and Heritage) from LCC
Natural England	Scoping responses received 18/2/14 via email	NE comments have been addressed in this LVIA chapter

14.4 Methodology

14.4.1 Introduction

6. The methodology adopted for the LVIA has been informed by current thinking and industry best-practice guidance, in particular:

- Guidelines for Landscape and Visual Impact Assessment 3rd Edition[327] (GLVIA3);
- Landscape Character Assessment – Guidance for England and Scotland [328]; and

[327] Landscape Institute and Institute of Environmental Management and Assessment (2013) Guidelines for Landscape and Visual Impact Assessment Third Edition (GLVIA3)

- Advice Note 01/11 Photography and Photomontages in Landscape and Visual Impact Assessment[329].

7. A study area for the LVIA extending to a 5km radius from the development is considered appropriate for the scale and nature of the proposed development. Refer to Appendix N4 Figure 1 for the Site location and study area.

14.4.2 Baseline methodology

8. The existing landscape and visual baseline has been informed by an initial desktop study, including a review of relevant publications, Ordnance Survey (OS) data and aerial mapping. The findings of the preliminary desktop study have been verified in the field during October, 2013.

Landscape baseline

9. The assessment of the landscape baseline within the study area considers the following:

- The existing situation – including a factual description of the existing landscape and its condition;
- The existing landscape character –through desk study informed by existing published landscape character assessments followed by verification in the field; and
- The value of the existing landscape – including reference to relevant statutory and non-statutory designations.

Visual baseline

10. The assessment of the visual baseline within the study area considers the following:

- The area within which the development proposals may be visible – by use of a Zone of Theoretical Visibility plan prepared for the proposed development;
- The different groups of people within the study area who may experience views of the development proposal;
- The identification of specific viewpoints – informed by the ZTV; and
- The nature of the views at the viewpoints.

11. All viewpoints used for the assessment of visual effects are in publicly accessible locations, with the exception of Thistleton Lodge and Ribby Hall as requested by LCC and have been chosen to reflect a representative range of the visual receptors within the surrounding area. The area around each broad viewpoint location was explored to find the most suitable (i.e. unscreened and representative) and safely accessible location for the view to be recorded.

12. Baseline photographs have been taken for each of the viewpoints in accordance with best practice guidance. A description of the visual composition of the existing view from each viewpoint has been provided.

Zone of Theoretical Visibility

[328] The Countryside Agency and Scottish Natural Heritage (2002) Landscape Character Assessment – Guidance for England and Scotland
[329] Landscape Institute (2001) Advice Note 01/11 Photography and Photomontages in Landscape and Visual Impact Assessment

13. Three Zones of Theoretical Visibility (ZTV) plans have been produced to illustrate the theoretical area over which the Project would be visible. These have been generated to represent the respective heights of the drilling and workover rigs, at up to 53m and 30m (when fully elevated). See Figures for ZTV's. . These were chosen as representative of a worst-case' of the potential visual extent of development for the preparation of the ZTV as, due to their scale and height, they are the elements of the development proposal that have potential to be visible over the greatest area. In addition to the two rigs there would be two sand storage silos, each approximately 15m in height and flare stacks of 10m in height including an unpainted metal casing / shroud around the flame. A ZTV plan has been generated assuming the height of the 15m storage silos representative of the most prominent for these components. See Figure's for ZTV's.

14. An important assumption when considering the mapped results of the ZTV is that it has been generated using topographical digital data (OS 5m DTM data) which does not allow for the filtering or screening of views by natural components in the actual landscape such as trees, hedgerows and woodland or of built forms such as buildings, walls and boundary fences from certain locations.

15. In addition the ZTV assumes that climatic visibility is 100%. Together the combination of landscape components with climatic visibility can potentially reduce visibility to a considerable extent. The ZTV therefore represents the maximum theoretical potential visibility i.e. the worst-case scenario.

Baseline photography

16. Baseline photographs have been taken for each of the viewpoints in December 2013 using a Canon EOS 350D Digital SLR with a full frame sensor (36x24mm) using a 50mm equivalent fixed focal length lens. The photographs were taken in accordance with best practice guidance and were merged together using Adobe Photoshop to form panoramic views. The location for each of the viewpoints was recorded using an on-site GPS. The time at which the photographs were taken and details about the weather were recorded for each viewpoint

14.4.3 Assessment methodology for the effects from construction

17. The assessment of landscape and visual effects are separate, although linked procedures. Landscape effects derive from alterations to the physical landscape as a resource, which may give rise to changes in the landscape character, while visual effects relate to the changes that arise in the composition of available views and visual amenity, as experienced by people, as a result of changes to the landscape. The landscape baseline, its analysis and the assessment of landscape effects all contribute to the assessment of visual effects.

18. The two principal criteria which have been used to determine the significance of an effect, whether a landscape or visual effect, are:

- the ***sensitivity*** of the receptor; and
- the ***magnitude*** of change (impact).

19. The determination of the significance of an effect within the LVIA is a qualitative assessment and requires the application of professional judgement to weigh the findings of the sensitivity of receptor and the magnitude of the impact experienced by the receptor. Effects are described according to their nature, which may be beneficial or adverse.

14.4.3.1 Landscape effects

20. The assessment of landscape effects considers the potential effect of the development proposals on the landscape within the study area, with particular reference to effects on landscape designations and landscape character.

Landscape sensitivity

21. An assessment has been made of the sensitivity of the landscape resource by combining judgements about the value attached to the landscape and the susceptibility of the landscape to the nature of change arising from the type of development proposed.

22. The criteria which have been used to guide the assessment of landscape sensitivity are summarised in Table 14.2.

Table 14.2 Landscape sensitivity

Sensitivity	Typical descriptors
High	A landscape valued at the international, national, regional or borough/district level; A vulnerable landscape likely to be fragile and susceptible to change; A landscape which is well maintained and in a good condition and contains rare and distinctive elements; A landscape with a limited tolerance of change; No, or limited, scope for substitution or positive enhancement.
Medium	A landscape that is valued at the local level; A landscape that is of a fair condition with some degraded elements; A landscape which is fairly tolerant of change; Some scope for substitution or positive enhancement.
Low	A landscape of limited value; A landscape which is in a poor condition with few or no distinctive components; A landscape which is tolerant of change; Scope for substitution or positive enhancement.

Landscape magnitude

23. The likely nature of effect (magnitude of change) that would be experienced by landscape receptors has been described. The factors that are considered in assessing the nature of effect include the:

- Extent to which the removal or addition of landscape features alters the existing landscape character;
- Geographical extent of the area over which the effect is evident;
- Duration of the effect (short/medium/long term, permanent/temporary); and
- Effectiveness of any mitigation proposed.

24. The criteria which have been used to guide the assessment of the magnitude of change that would be experienced by landscape receptors as a result of the Project are set out in Table 14.3.

Table 14.3 Criteria for the assessment of the magnitude of landscape change

Magnitude of change	Typical Descriptors
Large	Major alteration to resource, key characteristics, features or elements, and/or quality and integrity of resource.
Medium	Moderate benefit to/loss of resource, key characteristics, features or elements; improvement/degradation of attributes quality.
Small	Some measurable change in attributes, quality or vulnerability; minor benefit/loss of, or positive/detrimental alteration to, one (maybe more) key characteristics, features or elements.
Negligible	Very minor benefit/loss of or positive/detrimental alteration to one or more characteristics, features or elements.
No Change	The Project would result in no alteration of characteristics, features or elements.

Significance of landscape effects

25. The assessment criteria that have been used for the determination of the significance of landscape effects are set out in Table 14.4.

Table 14.4 Significance criteria for landscape effects

Significance	The Project would result in effects that potentially would :
Major Adverse	• be at considerable variance with the existing landscape character, degrading its integrity; and/or • completely degrade, diminish or destroy the integrity of valued characteristic features, elements and / or their setting.
Moderate Adverse	• be at variance with the existing landscape character; and/or • substantially degrade or diminish the integrity of valued characteristic features, elements and / or their setting.
Minor Adverse	• be slightly at variance with the existing landscape character; and/or • slightly degrade or diminish the integrity of valued characteristic features, elements and / or their setting.
Negligible	• be compatible with the existing landscape character; and/or • be compatible with the integrity of valued characteristic features, elements and / or their setting.
Minor Beneficial	• improve and enhance the existing landscape character; and/or • restore valued characteristic features partially lost through other land uses.
Moderate Beneficial	• markedly improve and enhance the existing landscape character; and/or • restore valued characteristic features largely lost through other land uses.
Major Beneficial	• substantially improve and enhance the existing landscape character; and/or • restore or reinstate valued characteristic features of the area lost through other land uses

26. In addition a significance category of ‘No Effect’ would be used where the Project would result in ‘No Change’ in terms of magnitude of impact on the landscape.

27. For this assessment landscape effects identified as being Moderate or above are considered to be significant.

14.4.3.2 Visual effects

28. The assessment of visual effects considers the potential effect of the Project on the visual amenity as experienced by people within the study area. The effects on visual amenity have been assessed through the consideration of potential effects on the identified viewpoints.

Visual sensitivity

29. An assessment has been made of the sensitivity of the visual amenity by combining judgements about the value attached to a particular view and the susceptibility of the visual receptor to changes in the view.

30. As identified within GLVIA3, susceptibility is mainly a function of:

- The occupation or activity of people experiencing the view at particular locations; and
- The extent to which their attention or interest may be focussed on views and the visual amenity they experience at particular locations.

31. The visual receptors most susceptible to changes in their view generally include;

- Residential receptors and those engaged in outdoor recreation including public rights of way (PRoW), where interest is focused on the landscape and on particular views;
- Visitors to heritage assets; and
- Communities where views contribute to the landscape setting enjoyed by residents in the area

32. People travelling on road, rail or other transport routes tend to have a moderate susceptibility to change, although whilst travelling on scenic routes the awareness of views can be high.

33. The visual receptors least susceptible to changes in their view generally include;

- People engaged in outdoor sports or recreation which does not involve or depend on an appreciation of views of the landscape;and
- People at their place of work, whose attention is likely to be focused on their activity rather than the surrounding landscape and where the setting is not important to the quality of working life.

The criteria which have been used to inform the assessment of visual sensitivity are outlined in Table 14.5.

Table 14.5 Visual sensitivity.

Sensitivity	Typical descriptors
High	People with a key interest in the view such as residents at home, and people engaged in outdoor recreation where the view is a key reason for the activity e.g. users of PRoW and visitors to attractions where views of their surrounding area are an important contributor to the experience.
Medium	People with a moderate interest in the landscape such as travellers on road, rail and

	other transport routes.
Low	People with little or passing interest in the landscape, for example, those in the work place and people taking part in outdoor sport or recreation.

Visual magnitude

34. The nature of effect (magnitude of visual change) experienced by visual receptors as a result of the development proposals has been described by reference to the:

- Scale of change in the view in respect of the loss or addition of features and changes in the visual composition;
- Degree of contrast or integration of any changes in the existing or remaining landscape components – form, mass, height, colour and texture;
- Orientation, angle and extent of the view in relation to the main activity of the receptor;
- Distance from the viewpoint to the proposed development;
- Duration of the effect (temporary/permanent, intermittent/continuous etc.); and
- Effectiveness of any mitigation proposed.

35. The criteria which have been used to guide the assessment of the nature of effect that would be experienced by visual receptors as a result of the development proposals are outlined in Table 14.6.

Table 14.6 Criteria for the assessment of visual magnitude

Magnitude of change	Typical descriptors
Large	Changes to the view that would completely alter the overall perception and key characteristics of the view
Medium	Changes to the view that would be readily noticeable and would alter the general perception or key characteristics of the view
Small	Some measurable, small scale visual changes to the overall perception and key characteristics of the view.
Negligible	Very minor changes to the overall perception and key characteristics of the view that would be barely noticeable with the naked eye
No change	No alteration to the view.

Significance of visual effects

36. The assessment criteria for the determination of the significance of visual effects are set out in Table 14.7.

Table 14.7 Significance criteria for visual effects.

Significance	The Project would result in:
Major Adverse	a substantial deterioration in the existing view
Moderate Adverse	a distinct deterioration in the existing view
Minor Adverse	a discernible deterioration in the existing view

Significance	The Project would result in:
Negligible	A barely perceptible deterioration or improvement in the existing view
Minor Beneficial	a discernible improvement in the existing view
Moderate Beneficial	a distinct improvement in the existing view
Major Beneficial	a substantial improvement in the existing view

37. In addition a significance category of 'Not visible' would be used where there is 'No Change' in the magnitude of impact on the visual resource arising from the proposed development. As with landscape effects, visual effects identified as being Moderate or above are considered to be significant.

Visual representation/ photomontages as illustrative tools

38. Consultation was undertaken with Lancashire County Council's Landscape officer with regard to the location of viewpoints and those for which photomontages would be produced.

39. The use of illustrative material / photomontages to assist in the presentation and assessment of proposals is considered to be good practice. There are a number of limitations which are important to understand when using the illustrative material:

- A visualisation can never show exactly what the drilling rig will look like in reality due to the differing lighting, weather and seasonal conditions which vary throughout the year;
- The images provided give a technically robust impression of the scale of the drilling rig and the distance from the viewer but can never be 100% accurate;
- To form the best impression of the impact of the drilling rig proposal, these images are best viewed at their viewpoint location;
- Photomontage images must be printed at the correct size stated on the images and viewed at the correct distances stipulated on the images.

40. The photography was undertaken in accordance with accepted good practice and the Landscape Institute's Practice Advice Note on the subject (Photography and photomontage in landscape and visual impact assessment – Advice Note 01/11).

41. The photography for the three photomontages taken in May 2014 used a Canon EOS 350D Digital SLR with a full frame sensor (36x24mm) using a 50mm equivalent fixed focal length lens mounted on a level panoramic head tripod.

42. For each montage a perspective match is achieved between the computer generated wireframe and the photographs by iteratively adjusting the perspective parameters until all the major features in the image are aligned satisfactorily. The coordinate positions of known points appearing in the photographic view are plotted in the computer model and appear in the wireline which allows the photograph to be aligned with the wireline view and a match achieved. Each photomontage is then rendered using TOPOS visualisation software and Photoshop. In this assessment the photomontages have been presented at A3 size with a viewing distance of 300 mm.

14.4.4 Assessment methodology for the effects from installation of surface network and buried array

43. The landscape and visual assessment methodology for the effects of the installation of surface network and buried array features would be identical to the assessment methodology for the effects from construction described in 1.4.1 above.

14.4.4.1 Assessment methodology for operational effects

44. The landscape and visual assessment methodology for the effects of operations, including drilling, hydraulic fracturing, initial flow testing and extended flow testing would mirror the assessment methodology for the effects from construction described in 1.4.1 above.

14.4.5 Assessment methodology for suspension, decommissioning and restoration effects

45. The landscape and visual assessment methodology for the suspension, decommissioning and restoration effects would mirror the assessment methodology for the effects from construction described in 1.4.1 above.

14.5 Assumptions and limitations

46. The visual assessment undertaken in December 2013 and March 2014 represents the 'worst case' in terms of visibility due to deciduous vegetation being bare in winter and as such representing maximum visual permeability.

47. It has been assumed that the installation of the arrays could proceed in parallel with the construction of the Site. This is based on a monitoring capability needing to be in place before hydraulic fracturing. Such a situation would have no cumulative, direct implications for the Landscape resource. The worst case situation has, however, been considered for the visual resource (both development activities taking place concurrently) for those viewpoints where the Site operation activities could be viewed in conjunction with the seismic arrays (in particular the Traffic Light System) and so potentially might be visible within the same view.

    The visible elements of the completed array stations (as described in section 4.4) will not have a significant effect on landscape designations, landscape character areas or principal viewpoints. This has been achieved by an iterative design and micro-siting process that will ensure minimal existing vegetation is removed to gain access for installation or siting of monitoring arrays especially in relation to the routes of PRoW. Therefore this is not assessed any further by this chapter.

14.6 Baseline

48. This section defines the baseline landscape and visual conditions relating to the study area for this development.

14.6.1 Landscape baseline

49. The constituent elements and character of the landscape, its condition, the way it is experienced and the value attached to it are described as follows:

14.6.1.1 Topography and drainage

50. The topography around the Site is generally gently undulating and slopes towards the Carr Bridge Brook shallow valley which lies just to the north of the Site. At a height of approximately 14m Above Ordnance Datum (AOD) the site is on sloping ground between the A583 Preston New Road and Carr Bridge Brook to the north.

51. The land rises to the east and northeast either side of the shallow valley to approximately 25m AOD at Little Plumpton and 35m AOD at Great Plumpton. The land does not rise any higher than this within the 5km radius study area.

52. Numerous field ponds and inconspicuous drainage ditches following field boundaries are also evident in this area.

53. The extensive, relatively low, gently undulating ground extending south west and north of the Site typifies the Carr Bridge Brook Floodplain landscape character area. The area is generally wet and field boundaries are often accompanied by ditches and watercourses many of which eventually feed into the Main Drain (leading into the Main Dyke further north) to the southwest of the site.

14.6.1.2 Land use and Vegetation

54. The Site is surrounded by a combination of cow and sheep pasture and arable fields. Field boundaries to the general large sized field parcels are marked by a combination of well-managed or poorly managed, gappy native hedgerows and timber and wire fencing. Hedgerow trees are largely absent in the proximity of the Site, but mature trees are found in association with farmsteads, individual properties and along transport routes. The main deciduous woodland blocks visually prominent in the surrounding landscape are Staining Wood and Humber Wood to the south of the A583 Preston New Road, the woodland block to the southwest of Mossfield, Great Plumpton and the small triangular woodland block approximately 400m northwest of the Site adjacent to Carr Bridge Brook.

55. Hedgerows line the local roads and are generally 1.5m to 1.8m in height and well managed, though not tapered for ecological benefit.

14.6.1.3 Settlement Pattern and Transport Links

56. The closest settlement to the Site is Little Plumpton at a distance of approximately 0.5 km immediately to the east. The settlement is dominated by Plumpton Hall Farm which occupies a prominent position on higher ground overlooking the Carr Bridge Brook valley and the agricultural/industrial buildings at Plumpton Lodge to the south. The A583 Preston New Road passes through the settlement from east to west and connects with Plumpton Lane leading to Great Plumpton to the northeast and with Westby Road to the south. The larger village of Great Plumpton can be found 2km to the northeast and Westby 2km to the southeast. The urban edge of Blackpool lies 2km to the west.

57. The M55 motorway runs east – west at an approximate distance of 1km north of the Site and the A583 Preston New Road runs east – west past the Site to the south. The fields adjacent to the Site are surrounded by Moss House Lane to the north and west, and Plumpton Lane to the east.

58. The nearest residential properties are those located along Preston New Road to the south, Moss House Lane to the north, and west and Plumpton Lane to the east.

59. The Preston to Blackpool railway line passes the Site approximately 2km to the northeast but is not visible from the Site.

60. The A583 Preston New Road from which the Site will be accessed is a wide, busy road with dedicated cycle lanes to each side.

14.6.1.4 Landscape Designations

61. There are no National Parks and Areas of Outstanding Natural Beauty within the 5km radius study area. However, there are two Registered Historic Parks and Gardens which lie just on the edge of the 5km radius study. Lytham Hall and park 5km to the south of the development site and Stanley Park 5.5km to the northwest. In addition to these there are two locally listed unregistered historic designed landscapes. Ribby Hall at 4km west of the development site and Thistleton Lodge at just beyond the 5km study area to the north east. LCC have requested that these parks and gardens are considered in this assessment. Descriptions of these landscapes are as follows:

- Ribby Hall – Grade II listed mansion house built for Joseph Hornby in the 1790's but now converted into private suites as part of the 5 star luxury holiday park & village. Not publically accessible.
- Thistleton Lodge – A manor house created as a private residence in the late-19th century but now converted to a care home. It is set in grounds including a walled, kitchen garden and parkland bordered with tree belts.
- Lytham Hall - A fine grade 1 listed 18th century manor house situated in 80 acres of mature parkland, and was built for Thomas Clifton by John Carr of York between 1752-1764 on the Site of an earlier manor house and Priory settled by Benedictine monks from Durham
- Stanley Park - A public park designed by Thomas Mawson & Sons in 1922. The 104ha site is bordered by residential development on all but the eastern side which is adjacent to Blackpool Zoo and open green space. Stanley Park is characterised by a strongly formal central core connecting with areas which become less formal towards the edges of the park. The north part of the Site is a golf course, to the east is a large lake, and playing fields and sports facilities are concentrated in the south and west. There is perimeter planting on all but the north side of the Site.

14.6.1.5 Access and Rights of Way

62. There are no National Trails or Long Distance Paths within the 5km study area.

14.6.1.6 Public Rights of Way and Recreational Routes

63. The study area has a reasonable level of provision of public rights of way (PRoW) throughout although connectivity of the network in the vicinity of the Site is limited.

64. There are no PRoW within 1km of the Site with the nearest being FP7 approximately 1.5km to the north. The visual assessment includes a viewpoint from this PRoW.

14.6.1.7 National / Regional Cycle Routes

65. The National Cycle Route 90 known as the Northern Loop passes through the village of Great Plumpton at a distance of 1km from the Site.

14.6.1.8 Open Access and Registered Common Land

66. There are no areas of Open Access or Registered Common Land within the 5km radius study area.

14.6.1.9 Green Belt Land

67. There are four areas of Green Belt that fall within the 5km study area which includes: two to the west on the eastern edge of Blackpool, one located east of Blackpool airport at Lytham Moss the other just north of the village of Staining. A further two areas of Green Belt land lie to the east associated with the southern edge of Kirkham and an area of land between Lytham and Warton. Green Belt land is referred to in the Planning Chapter and each area captured in the baseline descriptions of the local landscape character areas in paragraphs 93-102 below.

14.6.1.10 Conservation Areas

68. Six conservation areas lie within or just outside the 5km study area and they are listed below. These areas are administered by Fylde Council. Any development proposals within Conservation Areas will be considered against Local Plan Policies. Currently there are no Conservation Area Appraisals or Policy Statements intended as supplementary planning guidance for these Conservation Areas. When prepared, development proposals will also be considered in relation to their effect on the character and appearance of the area as identified in the supplementary planning guidance.

- Singleton Conservation Area – administered by Fylde Council this conservation area comprises the entire village boundary of Singleton and includes mature trees and woodland.
- Thistleton Conservation Area - administered by Fylde Council this conservation area comprises the entire extent of the village of Thistleton.
- Kirkham Conservation Area – This conservation area lies to the west of the development site on the edge of the 5km radius study area and is administered by Fylde Council. This conservation area is centred around the junction of Church Street and Preston Street in Kirkham.
- Wrea Green Conservation Area – within the 5km radius study area 2.5km to the southeast of the development site this conservation area is administered by Fylde Council and is centred on The Green public open space at the heart of this village.
- St. Anne's Road East Conservation Area – with just its north eastern tip falling within the 5km radius study area this conservation area extends for approximately another 1.5km southwest to the coast at St Anne's. The conservation area is administered by Fylde Council and is defined by the buildings and environment along St.Annes Road East in the St.Annes district of Blackpool.
- Stanley Conservation Area - administered by Blackpool District Council this conservation area comprises the entire extent of Stanley Park. The park has been registered Grade II on the National Register of Historical Parks and Gardens as well as been nominated a National Green Flag Award. Blackpool District Council commissioned its design to renowned architects T.H. Mawson and Sons. The park was officially opened in 1926 by the 17th Earl of Derby and Sir George Edward Villiers Stanley, in whose honour it was named.

14.6.1.11 Listed Buildings

69. The following listed buildings have been identified within the 5km radius study area.–

No	Name	Grade
1	STANLEY COTTAGE	II
2	WILLOW COTTAGE	II
3	ROMAN CATHOLIC CHURCH OF ST ANNE	II
4	BY THE WAY	II
5	RAILWAY HOTEL	II
6	CHRIST CHURCH	II
7	CHURCH OF ST NICHOLAS	II
8	THE OLD COTTAGE	II
9	CHURCH OF ST JOHN THE EVANGELIST	II
10	WAR MEMORIAL WITH SURROUNDING RAILINGS	II
11	RIBBY HALL	II
12	HAWTHORN HOUSE	II
13	CHURCH OF ST MICHAEL	II
14	GARAGE CIRCA 20 METRES WEST OF WESTBY HOUSE	II
15	FOX LANE ENDS CROSS	II
16	ATTACHED WALL TO NORTH BLOWING SANDS AND ATTACHED WALL TO NORTH	II
17	1 AND 2, FISHERS LANE	II
18	LITTLE MARTON MILL	II
19	WALKERS HILL FARMHOUSE AND ATTACHED BARN AND SHIPPON	II
20	1-2, REGENT AVENUE	II
21	BARN CIRCA 50 METRES WEST OF CHURCH ROAD END FARMHOUSE	II
22	GRAMMAR SCHOOL (FRONT RANGE ONLY)	II
23	CHURCHYARD WALL AND GATEWAY SOUTH OF THE CHURCH OF ST JOHN THE EVANGELIST	II
24	BRADKIRK HALL FARMHOUSE	II
25	CHURCH GROVE HOUSE	II
26	STAINING WINDMILL	II
27	KNOWSLEY FARMHOUSE	II
28	WHITE HOUSE	II

70. The listed building which is located closest to the development site at a distance of approximately 1.5km is the thatched garage near Westby House (14 above).

71. None of the listed buildings set out above have any inter-visibility with the development site due to a combination of distance, topography and intervening vegetation and buildings. Therefore it is judged that the listed buildings should be scoped out of the landscape and visual assessment because there will be no direct or indirect effects on the setting of them as a result of the proposed development.

14.6.1.12 TPOs

72. Tree Preservation Orders have been identified within the 5km radius study area. The closest TPOs are located approximately 700m from the development site to either side of the A583 Preston New Road at the junction with Plumpton Lane. However, because the TPOs identified throughout the study area are not present on the development site or on proposed haul routes and as such there will be no direct effects. Therefore it is judged that TPOs should be scoped out of the assessment.

14.6.2 Landscape Character

14.6.2.1 National Character Areas

73. At a national level the Character of England Landscape, Wildlife and Cultural Features Map[330] divides England into 159 National Character Areas (NCAs). Natural England is in the process of updating the NCA descriptions and revised profiles for all 159 character areas and these are due to be updated soon.

74. National Character Area guidance has been included as being relevant to this assessment since it is referenced in the Draft Lancashire Green Infrastructure Strategy – Consultation Draft, 2007. This guidance is designed to remain in operation for at least ten years – and provides the following as a Vision for the evolution of Green Infrastructure in Lancashire over that time frame:

    "The Vision for Lancashire's Green Infrastructure is for the development of a network of multifunctional green spaces and places, connecting urban areas to rural hinterlands, and ensuring that the countryside continues to contribute towards the economic, social and environmental well-being of the sub region. This sub regional effort will in turn contribute towards the city regional objective of creating the 'the city with room to breathe'.

75. National Character Area guidance may be used by Local Planning Authorities to help to inform likely sensitivity and the assessment of any landscape effects.

76. The study area lies entirely within the single National Landscape Character area known as No. 32 the Lancashire and Amounderness Plain (defined by Natural England). Although the classification has slightly less relevance at this scale of site there are land cover features and characteristics that are typical of the area and which are represented on this site.

77. Some common characteristics include; a large scale agricultural landscape with a patchwork of pasture and blocks of wind sculpted mixed woodland; a high density of field ponds; a rectilinear network of lanes and tracks and clipped hedgerows and drainage ditches.

78. The Character Plan for this area reports that there has been loss of hedgerows and hedgerow trees and field ponds through the increase in field size and poor management of remaining hedgerows. Recommendations from the plan include; improving hedgerow management and the restoration of wetland habitats especially field ponds; enhancement of drainage channels and the introduction of buffer planting strips.

[330] Natural England with support from English Heritage (2005) The Character of England Landscape, Wildlife and Cultural Features Map

14.6.2.2 Regional Landscape Character

79. A Landscape Strategy for Lancashire was published on 22 May 2001 and forms Supplementary Planning Guidance on landscape and developments for the Joint Structure Plan.

~~80.~~ Landscape Character Types drawn from Lancashire County Council's Mario (Maps And Related Information Online) web site include; Coastal Plain, Mosslands; Open Coastal Marsh and Suburban.

~~81.~~ In the Landscape Character Assessment for Lancashire the Coastal Plain landscape type occurs in six distinct areas within the lowland landscape of western Lancashire. The development site lies within one of these six areas known as Landscape Sub Character area 15d. The Fylde. (Refer to Appendix N4 Figure 2).

~~82.~~ The Site is located in the western extent of The Fylde character area. The gently undulating farmland of The Fylde extends between Blackpool and the M6 corridor to the east and envelopes the River Wyre estuary. It has been formed of boulder clay deposits which lie on soft Triassic sandstones and mudstones and is naturally poorly drained. Field ponds are a particularly characteristic feature of this area and provide important wildlife habitats. The predominant land use is dairy farming on improved pasture, and lowland sheep farming with a small amount of arable on the more freely draining soils. Red brick nineteenth century two storey farmsteads with slate roofs and red brick barns are dominant built features of this landscape character area; occasional windmills also reflect the historic importance of the area for corn milling. Field size is large and field boundaries are low clipped hawthorn hedges, although hedgerow loss is extensive. Blocks of woodland are characteristic, frequently planted for shelter and/or shooting and views of the Bowland Fells to the east are frequent between the blocks. There are many man-made elements; electricity pylons, communication masts and road traffic that are all visually prominent in the flat landscape. In addition, views of Blackpool Tower, the Pleasure Beach rides and industry outside Blackpool are visible on a clear day to the west

14.6.2.3 Local Landscape Character

83. In response to the nature and scale of this development it was judged that the baseline for the assessment should take account of the local level of landscape character. This allows a baseline description to be established for the differing local landscape susceptibility to change, its value and sensitivity. From desktop and field work the study area can be characterised into seven local character areas shown on Appendix N4 Figure 3 that are named and described as follows:

Main Dyke Floodplain and South Fylde Mosses

84. To the west of the Singleton to Weeton, north-south ridgeline, this character area mirrors the Thistleton Brook / Medlar Brook floodplain in the east. It is less tranquil than its eastern counterpart because of its proximity to Blackpool and the railway line. There are large areas not crossed by lanes so some areas, especially along PRoW, are more tranquil. In places it is difficult to visually distinguish the area as a floodplain because the watercourse can be hidden from view by hedgerows and also the hummocky nature of the Mosses in the south. As Main Dyke heads north east of Staining it is centred in a broad and very shallow valley with sloping valley sides capped by woodland blocks such as Long, Knowle, Carr and Avenham Woods. Field patterns are medium to large and rectilinear with long axes orientated east – west mostly laid to pasture.

Susceptibility: A landscape that is of a fair condition with some degraded elements and has some scope for substitution and positive enhancement.

Value: Although this landscape is of a fair condition with some degraded elements it is likely to be valued at a local level.

Sensitivity: Medium

Fylde Drift Farmland

85. This extensive local character area is primarily defined by areas of relatively more elevated topography, between 10-30m AOD in contrast to the less well, drained lower lying areas marked by the drainage catchments of the Thistleton Brook. Woodplumpton Brook and New Draught to the east. Glacial boulder clay deposits have created this gently undulating topography which although it provides open horizon views also, from certain locations, offers concealment of near and middle distance views.

86. Open, often expansive, long distance views are possible from some eastern locations across the agricultural landscape towards the Bowland Fells further to the east. Similar views can be experienced to the south, west and north. Urbanising influences of power lines and telecommunication aerials with their associated lattice pylon structures are visible across a wide area from the eastern part so this character area. There is no visual connection with the main urban fringe of Blackpool.

87. Other characteristics include medium to large field patterns, mostly pasture, intermixed with arable and frequent woodland blocks that follow ridgelines and high points. Field ponds are frequent and associated with the woodland together providing a local resource and cover for gamebird shooting. There is an absence of any large settlements, though the tops of village church towers and spires such as St. Anne's at Singleton, United Reformed Church at Elswick and Copp can be seen above woodland from across the area. Where grouped or individual properties exist they occupy high points in The Fylde as dispersed farmsteads. The A586 Garstang New Road and A585 Fleetwood Road are busy highways generally following high ground but largely obscured by hedgerows, roadside trees and woodland blocks. The M55 motorway corridor, Lancaster Canal and railway line between Blackpool and Preston are all transport corridors that contribute to the character and pass through this area. Hedgerows are generally well managed in places but gappy and absent in others with few hedgerow trees. Away from the main roads the area has a relatively high level of tranquillity although the M55, railway line, telecommunication towers and power lines introduce localised urbanising influences. This character area encompasses two proportionally small areas of Green Belt land towards the south and identified in the Local Development Framework. They are associated respectively with the southern edge of the town of Kirkham and an area of land between Lytham and Warton.

Susceptibility: This is a landscape that is fairly tolerant of change and has some scope for substitution and positive enhancement.

Value: This landscape is of a fair condition with some degraded elements and is likely to be valued at a local level.

Sensitivity: Medium

Greenhalgh & Esprick Tunsteads

88. This area, reflecting the historic land use and farming practices of The Fylde, is distinct from the surrounding areas of the Fylde Drift Farmland due its characteristic small,

rectilinear field patterns that are prevalent where land holding or agricultural practices have resisted agglomeration of field parcels and subsequent hedgerow loss along with fewer arable fields, more hedgerow trees with smaller woodland blocks. The area lies between 21-29m AOD and offers filtered views across the more elevated Fylde landscape in all directions with glimpses of Bleasdale Moors from certain locations to the east. The only settlement focus is Esprick clustered along the A585 Fleetwood Road separate from this locally distinctive land use and pattern. Away from the A585 Fleetwood Road the area has a heightened level of tranquillity with only narrow lanes, bounded by high sided hedges.

Susceptibility: This is a landscape that is fairly tolerant of change and has some scope for substitution and positive enhancement.

Value: This landscape is of a good condition with only a few degraded elements and is likely to be valued at a local level.

Sensitivity: Medium

Mythop Hall Farmlands

89. This character area is defined by a knoll of high ground similar to, but separate from, the Fylde Drift Farmland also found on higher ground to the east. Historically this 'island' within the South Fylde Mosses was occupied and farmed to avoid the poorly drained peat soils. Today's field patterns are medium to large and rectilinear with well managed hedgerows and small copses. The area is less tranquil than other character areas by proximity to the urban edge of Blackpool, the railway line just to the east and M55 audible to the south.

Susceptibility: A landscape which is fairly tolerant of change and with some scope for substitution or positive enhancement.

Value: This landscape is generally of a good condition with only a few degraded elements and is likely to be valued at a local level.

Sensitivity: Medium

Staining South Fylde Mosses

90. This local character area is within the regional character area of the South Fylde Mosses and is distinct at the local level by virtue of the urban related land uses west of the village of Staining including; the visually prominent Herons Reach Golf Course; former peat extraction water bodies such as Marton Mere and the recreational attraction of Stanley Park, Zoo and Hotel. There are views of at least one windmill which is testament to the area's former agricultural heritage.

91. The area is very low lying and although well-used PRoW cross the area, the tranquillity is lowered by the other activities that take place in the landscape. Hedgerows and woodland are less frequent than other character areas and traditional field boundaries have been lost to development of the Mosses. This character area encompasses a proportionally small area of Green Belt land identified in the Local Development Framework. It is associated with the area of land separating the village of Staining from the urban edge of Blackpool.

Susceptibility: A landscape which is fairly tolerant of change and with some scope for

substitution or positive enhancement.

Value: This landscape is of generally well-managed, good condition with a few degraded elements but is likely to be valued at a local level.

Sensitivity: Medium

Carr Bridge Brook Floodplain and South Fylde Mosses

92. South of the 'island' of raised topography occupied by the hamlet of Mythop with its Hall and Grange there is a low lying area drained by Carr Bridge Brook, split in two by the M55 and whose southern extent is marked by the A583 Preston New Road following a subtle ridgeline ascending from around 5m AOD at Peel Hill eastwards to 31m AOD just east of Little Plumpton. The area is characterised by landscape components typical of the areas mossland landscape type with shelter belts, woodland copses such as Wildings Hill Wood. The few properties that exist occupy contained high points in the landscape linked by narrow winding lanes. The area lacks tranquillity of other floodplain areas by virtue of the motorway, cable ski centre, urbanising features such as electricity pylons and proximity to Blackpool. The Site lies within this character area. This character area encompasses a proportionally small area of Green Belt land to the west of the area and identified in the Local Development Framework. It is associated with the land separating St.Annes and Blackpool covering the undeveloped area of Lytham Moss.

Susceptibility: A landscape which is fairly tolerant of change and with some scope for substitution or positive enhancement.

Value: This landscape is generally of a fair condition with a few degraded elements but is likely to be valued at a local level.

Sensitivity: Medium

Urban/settlement

93. This character area is extensive and forms a continuous north-south urban edge to The Fylde national landscape character area marking the eastern limit of Blackpool. Visually the urban edge is indistinct and often filtered and from some locations almost totally screened from The Fylde hinterland by the rural and agricultural land uses and intervening landscape components especially hedgerows, woodland blocks and the subtle changes in topography. Very tall townscape elements can be glimpsed but are not prominent in the wider landscape such as; the top of Blackpool Tower; telecommunication masts and occasional views of the distinctive architecture of the National Savings building near Little Marton. The village of Staining stands out as an outlying satellite of this urban edge on high ground just to the east. Elsewhere, across The Fylde, farmsteads, villages and settlements occupy areas of higher ground although these are not visually interconnected except for church spires and towers. At night there is a background glow of light from the Blackpool urban centre in the wider landscape.

Susceptibility: A landscape that is of good condition with only some degraded elements but one that fairly tolerant of change.

Value: An urban landscape that is valued at the local level.

Sensitivity: Medium

14.6.3 Visual baseline

94. The principal visual receptors identified for Site include existing residential areas, publicly accessible routes and transport corridors. Table 8 lists the visual receptors, their location and distance from the development site, a short description and identifies the viewpoint sensitivity.

95. A study area-wide visual baseline survey has been undertaken. The main viewpoint and photo locations showing the general context and public viewpoints are indicated in Appendix N4 Figure 4. Viewpoint photographs are in Appendix N4 Figures 1-6.

14.6.3.1 Views within and around the Site

96. The terrain surrounding the Site is undulating and the field sizes generally large and open, however, the visual containment is judged to be relatively high from most locations beyond 1km. Localised topography along the A583 forms a ridge of higher ground which curtails potential expansive and long distance views from the south and east. Similarly a ridge of higher ground at Great Plumpton curtails longer distance views from the northeast. The edge of Blackpool's conurbation starts at Moss House Lane to the east and the built up areas restrict views from this direction. There are several residential properties nearby which have relatively unrestricted views of the Site and these are all within 1km.

97. Visual receptors include those people who live and work locally, those who travel through the area of the Site and those who visit and use the recreational facilities and landscape within the area affected by the proposed development.

98. As stated in paragraph 27 of the methodology, a digitally mapped ZTV has been prepared to define the area within which the Project could potentially be visible and on which an initial viewpoint selection was made. Site visits confirmed that from a number of initial ZTV- derived potential viewpoints there would in reality be no potential views of the proposed development. These were scoped out of the assessment leaving 16 principal viewpoints identified within the visual study area and ZTV. Views from these principal viewpoints have been recorded in a consistent manner, capturing the sensitivity of the viewpoint and the key characteristics of the existing view (see Table 14.8). Following consultation with Lancashire County Councils Landscape Officer photomontages have been produced for viewpoint no's 3, 6, and 10. Refer to Appendix N4 Figures 7-9.

Table 14.8 Schedule of principal viewpoints

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
V1	FP7 Between Westfield Cottages and Ream Hills Farm looking south SD37603,34387 1634m	Receptor type: Recreational PRoW **Susceptibility:** People using this public right of way (PRoW) have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
		• Representative view from the footpath FP3 as it crosses slightly elevated arable fields between Westfield Cottages on Mythop Road and Ream Hills Farm • Expansive horizon line and open landscape marked by low hedgerows in the foreground. The M55 is mostly obscured by intervening topography and vegetation in the middle ground and there are groups of trees and blocks of woodland in the background	
V2	View from the caravan site at Clifton Bank Farm, Great Plumpton looking southwest SD38315,33209 1021m	**Receptor type:** Recreational **Susceptibility:** People living in the residential properties and those using the caravan site have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High
		• Representative of views from both the caravan site and residential properties at Clifton Bank Farm on the edge of the settlement at Great Plumpton • Wide angle view which is punctuated by telegraph poles in the foreground and curtailed by mature trees and woodland to the right. The landscape is gently undulating and slopes towards the shallow Carr Bridge Brook valley in the middle ground. The small settlement of Little Plumpton including Plumpton Hall Farm is visible in the left of the view • The A583 Preston New Road and blocks of woodland and mature trees are in the background of the view	
V3	View from Plumpton Lane looking southwest SD38089,33139 788m	**Receptor type:** Transport **Susceptibility:** People travelling along Plumpton Lane have a moderate susceptibility to change in their views across the landscape **Value:** This view is not likely to be valued locally.	Low

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
	Photomontage produced for this viewpoint	• Representative view from the gateway on the bend in Plumpton Lane as it leaves Great Plumpton • A panoramic view across the open landscape marked by low hedgerows in the middle ground. The horizon consists of blocks of woodland and mature trees with pylons and overhead powerlines • Plumpton Hall Farm is in the left of the view	
V4	View from Plumpton Lane adjacent to the Morar bungalow looking west SD38137,32839 745m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally. • Representative view from Plumpton Lane adjacent to residential property with views west towards the Site • View partially obscured by hedges and topography • Plumpton Hall Farm is partially visible in the left of the view	High
V5	View from the footway on Preston New Road adjacent to the cottage at Plumpton Hall Farm looking west SD37960,32655 575m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally. • Representative view from the residential property on Preston New Road looking west towards the Site • The view is across an open paddock in the foreground with views of Blackpool in the distance framed by trees on the left and residential properties on the right	High
V6	View from the entrance to Plumpton Hall Farm off Preston New Road representative of views from the houses overlooking the Site to the west SD37871,32651	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
	489m *Photomontage produced for this viewpoint*	• View from the footpath along the A583 Preston New Road which is representative of the view from the residential properties with windows and conservatory facing west at Plumpton Hall Farm • Broad uninterrupted sky views with a flat horizon line towards Blackpool. The view is of open pasture marked by low hedgerows and fences in the foreground and middle ground and punctuated by pylons and overhead powerlines in the background. • The A583 Preston New Road with associated lighting columns and signage is in the left of the view	
V7	View from Preston New Road in front of Staining Wood Cottages at Knights K9 Kare kennels looking northeast SD37085,32592 356m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally • Representative of the oblique view from the residential properties looking across the A583 Preston New Road • The A583 is bounded by a deciduous hedgerow and mature trees partially obscuring views of the fields in the middleground as they gently slopes away towards Carr Bridge Brook . Lighting columns line the road at regular intervals • The horizon line is relatively flat with Great Plumpton visible in the background and Plumpton Hall Farm in the right of the view	High
V8	View on Preston New Road from the residential development on Foxwood Chase at Staining Wood Farm looking northeast SD36992,32606 434m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
		• Representative of the oblique view from the residential properties looking across the A583 Preston New Road • The foreground is dominated by the A583 which is bounded by a deciduous hedgerow partially obscuring views of the fields in the middle ground as they gently slopes away towards Carr Bridge Brook. Lighting columns line the road at regular intervals • The horizon line is relatively flat with Great Plumpton visible in the background and Plumpton Hall Farm in the right of the view	
V9	View from the house at Penny Farm Horse Recovery and Rehabilitation Centre looking east SD35920,32724 1476m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally. • Representative view from the residential property at the farm overlooking horse pasture in the foreground • The bungalows in Carr Bridge Park, Maple Farm Nursery Gardens and A583 New Preston Road are in the middle ground but distant views beyond are obscured by mature trees and woodland • Overhead powerlines cross the view in the foreground and lighting columns along the A583 punctuate the view	High
V10	View from field entrance off Moss House Lane adjacent to Moss Cottages looking southeast SD36650,33323 930m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
	Photomontage produced for this viewpoint	• Representative of the oblique view from the residential property on Moss House Lane • Open view across arable fields in the foreground and middle ground with the A583 Preston New Road running along the horizon from Stainings Wood on the right to Little Plumpton to the left • The topography in the middle ground falls away towards Carr Bridge Brook in its shallow valley and telegraph poles punctuate the view	
V11	View from Moss Meadows near Moss House Farm looking southeast SD36826,33342 810m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High
	View from Moss Meadows near Moss House Farm looking southeast SD36826,33342 810m View from the fishing pond off Moss House Lane looking southeast SD36939,33324 721m	• Representative of the view from the residential property on Moss House Lane near Moss House Farm • Open view across arable fields in the foreground and middle ground. The A583 Preston New Road crosses the view from Maple Farm Nursery Gardens on the right, past Stainings Wood and Foxwood Chase to Plumpton Hall Farm and Little Plumpton to the left • The topography in the middle ground falls away towards Carr Bridge Brook in its shallow valley and telegraph poles punctuate the view • Distant views are frequently filtered and obscured by intervening vegetation	High Medium
V12	View from the fishing pond off Moss House Lane looking southeast SD36939,33324 721m	**Receptor type:** Recreational **Susceptibility:** People using the fishing ponds have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	Medium

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
		• Representative of the views from the fishing ponds on Moss House Lane • Views out are across open arable and pasture fields in the foreground and middle ground • The A583 Preston New Road is in the background and distant views are frequently filtered and obscured by intervening woodland blocks and vegetation • There is a small isolated block of woodland in the middle ground and the topography in the middle ground falls away towards Carr Bridge Brook in its shallow valley	
V13	View from Ballam Road PRoW FP6 looking north west SD 339024,432128 1730m	**Receptor type:** Recreational PRoW **Susceptibility:** People using this public right of way (PRoW) have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High
		• Representative view from the public right of way FP6 north west across pasture fields rising gently to a low ridgeline marked by the A583 Preston New Road but not visible. • Expansive horizon line and open landscape exhibiting telegraph poles crossing view in the near distance. The Hill residential property enclosed by woodland is visible on the horizon through scrubby hedgerows. Other woodland blocks punctuate the horizon and Mere Farm can be distinguished right of view by the large agricultural sheds and silo.	
V14	View from rear of properties just off Westby Road looking north west (representative of rear view from residential properties) SD338333,431918 1240m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
		• Representative view from rear of properties just off Westby Road looking north west to a featureless ridgeline across arable fields. The low ridgeline marked by the A583 Preston New Road is not visible. • Expansive horizon line with glimpses of small woodland blocks and hedgerow trees lining Westby Road that screen views north and east.	
V15	View from Ballam Road nr Lark Hall looking north (representative of view from Lark Hall) SD 337254,431423 1325m	**Receptor type:** Residential **Susceptibility:** People living in the residential properties have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High
		• Representative view from Ballam Road nr Lark Hall looking north (representative of view from Lark Hall). View to low ridgeline marked by the A583 Preston New Road with lamp columns just visible but not road itself. • Expansive horizon line across an open landscape but broken up by Staining and Humber Wood and other smaller woodland blocks and well managed hedgerows but few hedgerow trees. Electricity pylons cross the view in the near distance. Staining Wood Farm can be seen on the horizon.	
V16	View from Anna's Road (track) Bridleway 16 from western end of Public Right of Way looking north east SD 334911,430938 3080m	**Receptor type:** Recreational PRoW **Susceptibility:** People using this public right of way (PRoW) have a high susceptibility to change, where their interest is focused on views across the landscape. **Value:** This view is likely to be valued locally.	High

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Receptor type, susceptibility to change and value and description	Sensitivity
		• Representative view from the Bridleway 16 as it crosses low lying ground across Lytham Moss through pasture fields between the B5410 Northhouses Lane and Peel Road • Expansive horizon line and open landscape exhibiting pylons. View distinguished by an absence of hedgerows in the foreground. The Anna's Road Cuadrilla owned site and bunding is visible in middle distance due east. Staining Wood can be seen centre view on the horizon as can housing on the SE edge of Blackpool left of view.	

14.7 Assessment

99. For the full sequence of the proposed exploration activity with the periods when each activity would take place refer to the relevant description in Appendix A and section 4.3.2.

100. Of particular relevance to the landscape and visual topic area are the drilling, hydraulic fracturing and flow testing phases. During the drilling, hydraulic fracturing and flow testing phases differing heights of rig would be potentially visible on the Site. The overall duration for all four wells when rigs would be present is twenty nine months. For the duration of each rig type on each well refer to Table 14.11. Program of rig deployment showing the maximum heights in metres for each well and rig type.

14.7.1 Construction of Well Pad and Access

14.7.1.1 Effects on Landscape Designations

Ribby Hall

101. No intervisibility between Ribby Hall and the Site construction activities. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Thistleton Lodge

102. No intervisibility between Thistleton Lodge and the Site construction activities. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Lytham Hall

103. No intervisibility between Lytham Hall and the Site construction activities. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Stanley Park

104. No intervisibility between Stanley Park and the Site construction activities. No direct or indirect effects on setting or landscape character of the park.

Conservation Areas

105. The two designated conservation areas within the study area are: Wrea Green and St Anne's Road East. There is no intervisibility between these areas and construction activities.

14.7.1.2 Effects on Landscape Character Areas

106. The following section describes and assesses the landscape effects arising from the Project on the Local Landscape Character Areas during the construction phase of the well pad for Preston New Road.

Table 14.9. Effects on Local Landscape Character Areas during construction of well pad.

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During construction of well pad
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		
LCA06	Carr Bridge Brook Floodplain	Medium	Localised direct change would occur due to the introduction of the development proposals to a very small proportion of the total character area in addition to indirect effects on landscape character setting and tranquillity within 1km. This would result in a Negligible magnitude of change.	Negligible – **Not significant**
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

107. The construction of the well pad would lead to some direct physical change but this would be limited to the Site itself and only affect a very small proportion of the total Carr Bridge Brook Floodplain character area. There would be some indirect effects on this single landscape character area's setting and tranquillity but would be limited to 1km around the Site. This would result in a negligible magnitude of change and Negligible significance of effect on landscape character. **Effect on landscape is judged to be non-significant.**

14.7.1.3 Effects on Principal Viewpoints

108. There are no significant visual effects during the construction phase of the well pad. Refer to Appendix N1 Table 1 for a schedule of assessment effects of all the visual effects for this phase of the development.

14.7.2 Installation of Surface and Buried Arrays

14.7.2.1 Effects on Landscape Designations

109. Landscape Designations and Assessed Effects Arising from Installation of Surface and Buried Arrays

Ribby Hall

110. No intervisibility between Ribby Hall and the Installation of Surface and Buried Arrays. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Thistleton Lodge

111. No intervisibility between Thistleton Lodge and the Installation of Surface and Buried Arrays. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Lytham Hall

112. No intervisibility between Lytham Hall and the Installation of Surface and Buried Arrays. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Stanley Park

113. No intervisibility between Stanley Park and the Installation of Surface and Buried Arrays. No direct or indirect effects on setting or landscape character of the park.

Conservation Areas

114. The two designated conservation areas within the study area are: Wrea Green and St Anne's Road East. There is no intervisibility between these areas and installation of surface and buried arrays.

Landscape Character Areas and Assessed Effects during installation of Surface and Buried Arrays

Table 14.10. Effects on Local Landscape Character Areas during Installation of Surface and Buried Arrays.

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During installation
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During installation
LCA06	Carr Bridge Brook Floodplain	Medium	Extremely localised direct change would occur due to the introduction of the development proposals. There would be no indirect effects on tranquillity and landscape setting. This would result in a 'No change' in magnitude.	No effect
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

115. The construction of the Surface and Buried Arrays would lead to only extremely localised direct physical change and in turn this change would only affect a very small proportion of the total Carr Bridge Brook Floodplain, Main Dyke Floodplain, Fylde Drift Farmland, Mythop Hall Farmlands, Elswick and Great Eccelston Tunsteads and Staining South Fylde Mosses local character areas. There would be indiscernible indirect effects on landscape character setting and tranquillity. This would result in No change to magnitude and 'No effect' on landscape character. **Effect on all landscape character areas is judged to be non-significant.**

14.7.2.2 Effects on Principal Viewpoints

116. Due to the extremely localised, minor and short-term effects, it is considered that there would be no magnitude of change and therefore no effect on the visual resource associated with the installation of the surface and buried arrays associated with the Preston New Road well pad. There are no significant visual effects during this phase of the development.

14.7.3 Drilling, Hydraulic Fracturing and Initial Flow Testing

14.7.3.1 Timescales

Of particular relevance to the Landscape and Visual resource are any effects arising from the presence of the rigs on the Site. The drilling (up to 53m high rig) and hydraulic fracturing (up to 36m high rig) of the four wells at the site would be for a period of approximately 29 months. During this time the well services rig (up to 36m high) of wells 1, 2 and 3 would also be visible. The initial flow testing of well 4 and extended flow testing of wells 1,2 and 3 would then continue for a further 3 months. This program is set out in the Table 14.11 below.

Table 14.11 Program of rig deployment with maximum heights in metres.

14.7.3.2 Mobilisation

117. Approximately a 30m long section of hedgerow and individual trees along the north side A583 Preston New Road would be removed and replanted as part of the mobilisation activity and formation of the proposed access route to the Site. In addition to this 245m of hedgerow will also be lowered on either side of the access for visibility. Another 10m section of hedgerow will also be removed and another 100m of hedgerow lowered to provide access to the western most connection to the gas grid. Any direct effect on landscape would be very localised and removal of the hedgerow and a limited number of individual trees would not alter the local landscape character.

14.7.3.3 Effects on Landscape Designations

Ribby Hall

118. No intervisibility between Ribby Hall and the Drilling, Hydraulic Fracturing and Flow Testing rigs. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Thistleton Lodge

119. No intervisibility between Thistleton Lodge and the Drilling, Hydraulic Fracturing and Flow Testing rigs. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Lytham Hall

120. No intervisibility between Lytham Hall and the Drilling, Hydraulic Fracturing and Flow Testing rigs. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Stanley Park

121. No intervisibility between Stanley Park and the Drilling, Hydraulic Fracturing and Flow Testing rigs. No direct or indirect effects on setting or landscape character of the park.

Conservation Areas

122. The two designated conservation areas within the study area are: Wrea Green and St Anne's Road East. There is no intervisibility between these areas and Drilling, Hydraulic Fracturing and Flow Testing rigs.

14.7.3.4 Effects on Landscape Character Areas

123. The following section describes and assesses the landscape effects arising from the Project on the Local Landscape Character Areas during the drilling, hydraulic fracturing and flow testing phases for Preston New Road.

Table 14.12 Effects on Local Landscape Character Areas during drilling, hydraulic fracturing and flow testing phases.

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		
LCA06	Carr Bridge Brook Floodplain	Medium	Extremely localised direct change would occur due to the introduction of the development proposals. There would be no indirect effects on tranquillity and landscape setting. This would result in a 'No change' in magnitude.	No effect
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

124. The drilling, hydraulic fracturing and flow testing phases of the development would not result in any direct physical change to the immediate landscape character area or any other of the local landscape character areas beyond the small change during construction of the pad already experienced in that phase. There would be no indirect effects on landscape character setting and tranquillity. This would result in 'No change' in magnitude of change and 'No effect' on landscape character. **Effect on landscape is judged to be non-significant.**

14.7.3.5 Effects on Principal Viewpoint

125. The following section describes and assesses the visual effects arising from the proposed drilling, hydraulic fracturing and flow testing phases for Preston New Road on the principal viewpoints identified in the baseline. Table 14.13 schedules the magnitude of change and significant effects on each visual receptor.

Table 14.13. Effects on visual receptors during drilling, hydraulic fracturing and flow testing.

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Sensitivity	Magnitude of Change	Significance of Effect
V5	View from the footway on Preston New Road adjacent to the cottage at Plumpton Hall Farm looking west SD37960,32655 575m	Residential High Sensitivity	The drilling, hydraulic fracturing and flow testing rigs and associated plant would be clearly visible above the intervening vegetation and a prominent vertical feature in the open landscape view. It is therefore judged that the changes would completely alter the overall perception and key characteristics of the view and give rise to a Large magnitude of change.	The High sensitivity in conjunction with the Large magnitude of change is judged to result in a substantial deterioration in the existing view and therefore a **Major Adverse** effect.
V6	View from the entrance to Plumpton Hall Farm off Preston New Road representative of views from the houses overlooking the Site to the west SD37871,32651 489m	Residential High Sensitivity		
V7	View from Preston New Road in front of the house at Knights K9 Kare Kennels looking northeast SD37085,32592 356m	Residential High Sensitivity		
V8	View on Preston New Road from the residential development on Foxwood Chase at Staining Wood Farm looking northeast SD36992,32606 434m	Residential High Sensitivity		

Ref No.	Location / Grid Ref / Distance to Preston New Road site (m)	Sensitivity	Magnitude of Change	Significance of Effect
V10	View from field entrance off Moss House Lane adjacent to cottage property looking southeast SD36650,33323 930m	Residential High Sensitivity	The drilling, hydraulic fracturing and flow testing rigs and associated plant would be clearly visible above the intervening vegetation and a prominent vertical feature in the open landscape view. It is therefore judged that there would be readily noticeable changes which would alter the general perception and key characteristics of the view and give rise to a Medium magnitude of change.	The High sensitivity in conjunction with the Medium magnitude of change is judged to result in a distinct deterioration in the existing view and therefore a **Moderate Adverse** effect.
V11	View from Moss Meadows near Moss House Farm looking southeast SD36826,33342 810m	Residential High Sensitivity		
V12	View from the fishing pond off Moss House Lane looking southeast SD36939,33324 721m	Recreational Medium Sensitivity	The drilling, hydraulic fracturing and flow testing rigs and associated plant would be clearly visible above the intervening vegetation and a prominent vertical feature in the open landscape view. It is therefore judged that there would be readily noticeable changes which would alter the general perception and key characteristics of the view and give rise to a Medium magnitude of change.	The Medium sensitivity in conjunction with the Medium magnitude of change is judged to result in a distinct deterioration in the existing view and therefore a **Moderate Adverse** effect.

126. There are seven significant adverse visual effects acting on the principal visual receptors during the drilling, hydraulic fracturing and flow testing phases. Six of these are on residential properties and one at a fishing pond on Moss House Lane. Refer to Appendix N1 Table 2 for a schedule of assessment effects of all the visual effects for this phase of the development. Photomontages have been produced for viewpoints 3, 6 and 10 for this phase of the development and are included in Appendix N4 Figures 7-9.

14.7.4 Extended Flow Testing

14.7.4.1 Mobilisation

127. There are no mobilisation activities that would directly or indirectly affect the landscape resource.

14.7.4.2 Effects on Landscape Designations

Ribby Hall

128. No intervisibility between Ribby Hall and the extended flow testing construction works. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Thistleton Lodge

129. No intervisibility between Thistleton Lodge and the extended flow testing construction works. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Lytham Hall

130. No intervisibility between Lytham Hall and the extended flow testing construction works. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Stanley Park

131. No intervisibility between Stanley Park and the extended flow testing construction works. No direct or indirect effects on setting or landscape character of the park.

Conservation Areas

132. The two designated conservation areas within the study area are: Wrea Green and St Anne's Road East. There is no intervisibility between these areas and the extended flow testing construction works.

14.7.4.3 Effects on Landscape Character

133. The following section describes and assesses the landscape effects arising from the Project on the Local Landscape Character Areas during the construction phase for extended well testing construction works for the Project.

Table 14.14. Effects on Local Landscape Character Areas during the construction phase for extended flow testing.

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During Extended Well Testing
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		
LCA06	Carr Bridge Brook Floodplain	Medium	No direct change would occur due to the development proposals only lead to imperceptible indirect effects on tranquillity and landscape setting. This would result in a No Change to magnitude.	No effect

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During Extended Well Testing
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

134. During flow testing there would be no direct physical change to the immediate landscape character area or any other of the local landscape character areas. There would be only imperceptible indirect effects on the landscape character setting and tranquillity of Carr Bridge Brook Floodplain and to the other landscape character areas. This would result in a No Change to magnitude and 'No effect' on landscape character. **Effect on landscape is judged to be non-significant.**

14.7.4.4 Effects on Principal Viewpoints

135. There are no significant visual effects during this phase of the development. Refer to Appendix N1 Tables 3 and 4 for schedules of assessment effects of all the visual effects for this phase of the development..

14.7.5 Decommissioning and Restoration

14.7.5.1 Effects on Landscape Designations

Ribby Hall

136. No intervisibility between Ribby Hall and decommissioning and restoration activity. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Thistleton Lodge

137. No intervisibility between Thistleton Lodge and decommissioning and restoration activity. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Lytham Hall

138. No intervisibility between Lytham Hall and the decommissioning and restoration activity. No direct or indirect effects on setting or landscape character of the building or immediate grounds.

Stanley Park

139. No intervisibility between Stanley Park and decommissioning and restoration activity. No direct or indirect effects on setting or landscape character of the park.

Conservation Areas

140. The two designated conservation areas within the study area are: Wrea Green and St Anne's Road East. There is no intervisibility between these areas and the decommissioning and restoration activity.

14.7.5.2 Effects on Landscape Character Areas

141. The following section describes and assesses the landscape effects arising from the Project on the Local Landscape Character Areas during the Decommissioning and Restoration phase of the extended well testing infrastructure for Preston New Road.

Table 14.15. Effects on Local Landscape Character Areas during Decommissioning and Restoration phase of the extended well testing infrastructur**e.**

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect During the Decommissioning and Restoration phase of extended well testing infrastructure
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		
LCA06	Carr Bridge Brook Floodplain	Medium	No direct physical change would occur due to the decommissioning and restoration of extended well testing infrastructure with limited indirect effects on tranquillity and landscape setting. This would result in No Change to magnitude	No effect
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

142. There would be no direct change as a result of restoration and decommissioning of the extended well testing infrastructure. There would be very limited indirect adverse effects of short term duration on tranquillity and landscape setting through site plant carrying out the restoration. This would result in No Change to magnitude and overall 'No effect' in terms of significance. **This is judged to be non-significant**.

14.7.5.3 Effects on Principal Viewpoints

There are no significant visual effects during the restoration and decommissioning of the extended well testing infrastructure phase of the development. Refer to Appendix N1 Table 6 for a schedule of assessment effects of all the visual effects for this phase of the development.

14.7.5.4 Effects on Landscape Character Areas

143. The following section describes and assesses the landscape effects arising from the Project on the Local Landscape Character Areas during the Decommissioning and Restoration phase of the exploration well, pad and access track at Preston New Road.

Table 14.16. Effects on Local Landscape Character Areas during the Decommissioning and Restoration phase of the exploration well, pad and access track at Preston New Road.

Ref No.	Local Landscape Character Area	Sensitivity	Magnitude of Change	Significance of Effect during Decommissioning and Restoration phase of Exploration well, pad and access track
LCA01	Main Dyke Floodplain	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect
LCA02	Fylde Drift Farmland	Medium		
LCA03	Greenhalgh & Esprick Tunsteads	Medium		
LCA04	Mythop Hall Farmlands	Medium		
LCA05	Staining South Fylde Mosses	Medium		
LCA06	Carr Bridge Brook Floodplain	Medium	Localised direct change would occur due to the restoration of the development Site with short lived limited indirect effects on tranquillity and landscape setting. This would result in a localised Negligible magnitude of change.	Negligible adverse effect
LCA07	Urban / Settlement	Medium	No direct physical change and no indirect change to the visual component and landscape setting.	No effect

144. There would be very localised, direct change as a result of restoration of the Site's landscape components, returning it to agricultural pasture, removing earth bunds and security fencing and reinstating hedgerows along Preston New Road. There would be very limited indirect adverse effects of short term duration on tranquillity and landscape setting through site plant carrying out the restoration. This would result in a localised Negligible magnitude of change and a localised Negligible Adverse significance of effect on the Carr Bridge Brook Floodplain character area only. **This is judged to be non-significant**.

14.7.5.5 Effects on Principal Viewpoints

145. There are no significant visual effects during the restoration and decommissioning of the extended well testing infrastructure phase of the development. Refer to Appendix N1 Table 7 for a schedule of assessment effects of all the visual effects for this phase of the development.

14.8 Cumulative and Interactive Effects

146. Cumulative landscape and visual effects are unlikely to arise from the development and operation of this site with other similar developments in the area, due to distance between locations and individual site contexts. In addition, there are no known proposed or committed developments of an appropriate scale or nature that would generate significant cumulative effects on landscape character or visual amenity. All known planning applications with approval or lodged are summarised in Chapter 21 and Appendix T of the ES. Each development has been assessed as being relevant to the Landscape and Visual topic. If a development is considered as not being relevant it is assumed to be scoped out with no cumulative effect arising from the development taking place with/without the Preston New Road development.

147. For the purposes of this assessment the drilling, hydraulic fracturing and flow testing activities have been grouped together into one phase with the worst case scenario being the drilling rig, up to 53m high being visible for periods over this 29 month long phase.

148. Concurrent development of Preston New Road and Roseacre Wood across same period of activity is highly unlikely to give rise to cumulative landscape or visual effects because drilling (up to 53m rig) is only likely to take place on one site at a time. Although the cumulative ZTV for the two sites in combination indicates that there is theoretical visibility of both sites at once, in fact in the field there are substantial blocks of existing intervening vegetation and development which obscure views. Therefore it is judged that there are no cumulative effects from the two developments.

14.9 Mitigation Measures

14.9.1 Construction of Well Pad and Access

149. Landscape resource - during the Construction of Well Pad and Access phase there would be removal and storage of site subsoil and topsoil into 2-3m high bunds surrounding the well pad; these would be contoured asymmetrically where appropriate to offer a limited degree of localised visual screening of the pad and plant. The access road would require removal of hedgerow and a small number of trees on the northern edge of Preston New Road. A tree survey would be carried out to B.S. 5837 and root protection areas identified before works commence to inform any tree removal.

150. Views and visual amenity - During this operational phase there would be no significant adverse effects on visual receptors due to the limited scale of construction works. Due to the scale and temporary nature of the development it is considered that the following measures would provide adequate mitigation of potential effects:

- The Site has been selected for its effective lack of visual intrusion which is supported by the findings of this assessment. Minimal intervention is proposed for this construction phase. It is not considered necessary to undertake extensive visual screening of the development from the wider area although it is proposed to plant native tree and shrubs immediately around the well pad to help filter views from PRoW and the residential properties nearby at this early stage.
- Existing hedgerows would be allowed to grow taller in agreement with the landowner in advance of this initial phase of works.
- Since the area is intrinsically a dark area there should be minimisation of light spill and direct upward light from temporary task lighting required for operation should be

minimised and ideally designed to meet Environmental Zone E2. Where practical, hours of working would be arranged to minimise potential intrusive effects on the countryside from lighting.

- Where adverse visual effects occur to receptors adjacent to the Site it is suggested that targeted hedgerow, and hedgerow tree planting is undertaken to fill in gaps that allow views to the Site. This would have limited short-term mitigative effects but would contribute to screening over several years and would enhance landscape and ecological value of the area.

14.9.2 Surface and Buried array

151. Landscape resource - During the construction of arrays there would be only minor and very localised, low key physical change to landscape character in discrete areas. No further mitigation is judged to be necessary.

152. Views and visual amenity - During the construction of monitoring arrays there would only be temporary, very localised and negligible effects on visual receptors accessible by the public confined to routes followed by PRoW. Therefore no further mitigation is judged to be necessary.

14.9.3 Drilling, Hydraulic Fracturing and Initial Flow Testing

14.9.3.1 Mobilisation and Drilling

153. Landscape resource – as a result of the relatively short-term duration of drilling, hydraulic fracturing and flow testing activity there would be no physical alteration to the existing landscape and only very minor changes to the perceptual baseline character arising from the development. No mitigation is considered to be required.

154. Visual resource - Due to the scale and temporary nature of the development it is judged that the following mitigation measures would be appropriate:

- The Site has been selected for its effective lack of visual intrusion which is supported by the findings of this assessment. Minimal intervention is proposed for this phase. It is not considered necessary to undertake extensive visual screening of the development from the wider area.
- Existing hedgerows would be allowed to grow taller in agreement with the landowner in advance of this initial phase of works.
- Since the area is intrinsically a dark area the mitigation measures set out in Chapter 15 will be implemented..
- Where adverse visual effects occur to receptors adjacent to the Site it is suggested that targeted hedgerow, and hedgerow tree planting is undertaken to fill in gaps that allow views to the Site. This would have limited short-term mitigative effects but would contribute to screening over several years and would enhance landscape and ecological value of the area.

14.9.4 Extended Well Testing

14.9.4.1 Construction and Operation

155. The embedded landscape and visual mitigation for this phase would replicate that proposed for the previous phases of Project activity.

14.9.5 Decommissioning and Restoration

14.9.5.1 Extended Well Testing Infrastructure

156. Landscape and visual resource - During the removal of the Extended Well Testing Infrastructure phase there are no appropriate mitigation measures judged to be necessary beyond those already in place for earlier phases of the development.

14.9.5.2 Exploration well, pad and access track

157. The following mitigation measures are recommended to optimise the beneficial effects of restoring the Preston New Road Site and array sites to their original condition;

- Restricted minimal working area to well pad and access road, appropriate materials management methodology to be followed ensuring no mixing of sub soil with topsoil as Site itself is restored. All necessary drainage connections checked and restored along with decompaction, reseeding of areas and restoration of hedgerows. Hedgerow to Preston New Road to be restored.
- Works activity restricted to day light hours.
- Array sites – least intrusive site access to be used and any necessary decompaction of existing soils where construction plant has passed.

158. Views and visual amenity - During the decommissioning phase it is judged that the mitigation recommended for the landscape restoration would be appropriate and there would be no additional benefits to the visual resource.

14.10 Residual Effects

159. Following mitigation measures outlined above for all development activity phases it is judged that all non-significant and significant landscape and visual effects identified in section 14.7 would remain the same for the duration of the development.

160. There are no significant effects on the landscape resource for any phase of the development and any further mitigation, beyond that described, would have no bearing on the significance of effect.

161. The only significant visual effects would occur during the Drilling, Hydraulic Fracturing and Flow Testing phases and arise as a result of the drilling rig (between 30 and 53m high), hydraulic fracturing rig and well services rig (up to 36m high) which would be in use for approximately two and half years.

162. It is considered that any mitigation in the form of offsite screening for example is not possible to markedly reduce these effects. Considering the temporary duration of the visual effects it is also considered to be unnecessary.

14.11 Assessment Summary Matrix

Table 14.17. Landscape assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad and Access			
Only localised direct change would occur in addition to indirect effects on landscape character setting and tranquillity within 1km. This would result in a Negligible magnitude of effect	**Not Significant**	Removal and storage of site subsoil and topsoil into 2-3m high bunds surrounding the well pad, contoured asymmetrically where appropriate, to provide a degree of localised visual screening. Undertake tree survey to B.S. 5837 and implement root protection plans. Minimal intervention is proposed alongside planting of native tree and shrubs immediately around the Site. Existing hedgerows allowed to grow taller. Task lighting required for construction designed to meet Environmental Zone E2. Targeted offsite hedgerow and hedgerow tree planting undertaken between PRoW's and Site.	**Not Significant**
Installation of the Surface and Buried arrays			
Extremely localised direct change would occur due to the introduction of the development proposals. There would be no indirect effects on tranquillity and landscape setting. This would result in a 'No change' in magnitude.	**Not Significant**	None required.	**Not Significant**
Drilling, Hydraulic fracturing and Flow testing			
N/A	N/A	N/A	N/A
Extended Well Testing			
N/A	N/A	N/A	N/A
Suspension			
N/A	N/A	N/A	N/A
Decommissioning and Restoration			
Localised direct change would occur due to the restoration of the development Site with short lived limited indirect effects on tranquillity and landscape setting. This would result in a localised Negligible magnitude of change and Negligible Adverse significance of effect.	**Not significant**	Minimal working area.	**Not Significant**

163. Table 17 below provides a summary of only the significant visual effects arising from the assessment. Refer to Appendix N1 for the schedules of all visual effects on all visual receptors.

Table 17. Visual assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad and Access			

Description of effect	Significance	Mitigation	Residual effect
N/A	N/A	N/A	N/A
Installation of the Surface and Buried arrays			
N/A	N/A	N/A	N/A
Drilling, Hydraulic fracturing and Flow testing			
Viewpoint 5	**Significant**	As above	**Significant**
Viewpoint 6	**Significant**	As above	**Significant**
Viewpoint 7	**Significant**	As above	**Significant**
Viewpoint 8	**Significant**	As above	**Significant**
Viewpoint 10	**Significant**	As above	**Significant**
Viewpoint 11	**Significant**	As above	**Significant**
Viewpoint 12	**Significant**	As above	**Significant**
Extended Well Testing			
N/A	N/A	N/A	N/A
Suspension			
N/A	N/A	N/A	N/A
Decommissioning and Restoration			
N/A	N/A	N/A	N/A

164. It is only at the construction of well pad, installation of arrays and decommissioning and restoration phases where localised, direct, adverse landscape effects are considered likely to occur. For the well pad construction and arrays the effects are not significant and appropriate localised mitigation will ensure that changes to the landscape would be restricted to a very localised area.

165. During the restoration phase a negligible adverse significance of effect is likely to occur with the replacement of local landscape components and characteristics. Overall there are no significant effects on landscape character at any stage of the development. Appropriate best practice landscape and environmental design will minimise any non-significant adverse effects.

166. The main significant visual effects would occur during the Drilling, Hydraulic Fracturing and Flow Testing phases as a result of the height of the drilling rig, hydraulic fracturing work-over rig, well services rig and the flare stacks. Overall sixteen representative principal viewpoints have been assessed. Of these only seven are judged to be significantly adversely affected. These all lie within a 1km radius of the Site. Such significant effects would be temporary and the worst case would not occur continually over the twenty nine months for the drilling, hydraulic fracturing and flow testing of the four wells.

167. The recommended mitigation of gapping up and supplementing existing hedgerows and tree planting where visual intrusion would be experienced would minimise intervisibility with the Site. However, the main significant visual effects are difficult to mitigate against in the wider landscape, through offsite planting for example, even though the extent of visual effects is limited geographically to about one kilometre.

168. Due to the short term nature of these effects it is considered that these temporary adverse visual effects on a limited number of receptors across a small area are significant but temporarily so.

15 Lighting

Chapter Summary- Lighting

This chapter assesses the potential night time light obtrusion from the Project. The Site is in a rural location away from built up areas (such as Blackpool and Preston) where there is little in the way of existing night time lighting.

The Project will involve 24 hour operations during drilling and hydraulic fracturing. Lighting of working areas will also be necessary during winter when standard working hours overlap with the hours of darkness. Low-level security lighting will also be required so that the Site operatives and security staff can carry out their monitoring activities during night time hours.

Due to the combination of relatively few sources of night time lighting in the vicinity of the Site the use of lighting during the Project, without mitigation, would result in a significant effect is predicted for drilling, hydraulic fracturing, initial flow testing and extended flow testing.

All of the potentially significant effects will be mitigated by:

- Following lighting industry best practice for the arrangement of lighting on Site,
- Using covers to prevent light spilling outside of the areas requiring illumination; and
- Using low powered lighting to illuminate other areas of the Site that require lighting.

By implementing these measures the lighting used by the Project can be kept below lighting limits for light into windows and overall light intensity. As a consequence the residual effects are not significant. The mitigation measures described above also reduce the magnitude of the Project's impact on sky glow and building luminance levels from the equipment at the Site and the surface of the well pad. However, because of the low levels of night time light sources around the Site these two lighting effects will remain significant.

The Roseacre Wood and Preston New Road Sites are sufficiently distant from one another that there will not be a combined or cumulative lighting impacts on receptors from both sites.

15.1 Introduction

1. This chapter describes the assessment of potential night time light obtrusion from the Project. It considers the baseline situation in the locality, and visual effects that the Project may have on the nocturnal landscape in terms of relevant light obtrusion guidance.

2. All of the aspects of the Project are likely to require lighting and have been assessed as part of this chapter.

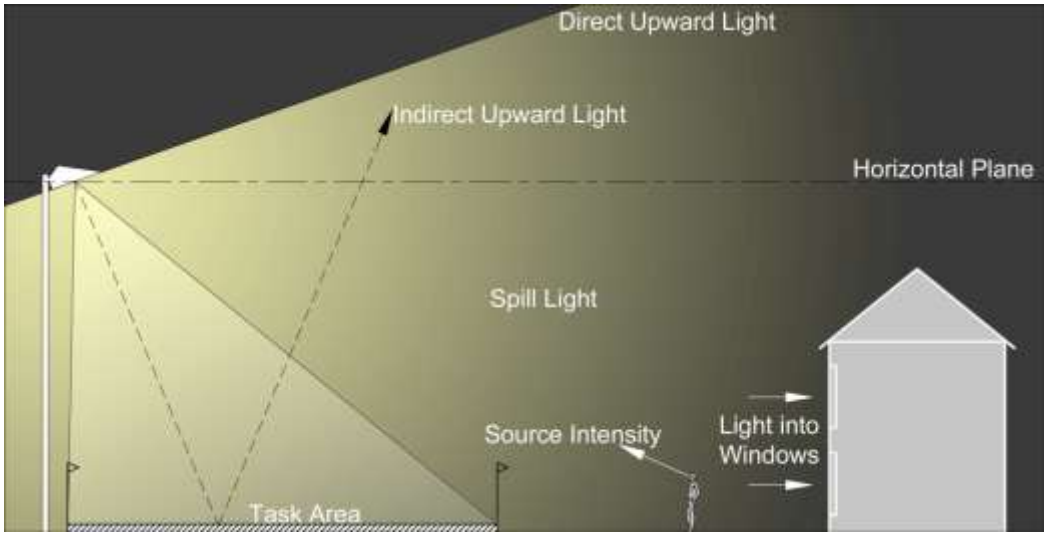
3. The consequences of light obtrusion are more commonly associated with the loss of dark night skies, loss of visibility of stars, perception of an unsatisfactory nocturnal environment and the harming of wildlife habitats. In some cases, light obtrusion has also been shown to have detrimental effects on human health and can present physiological and ecological problems. Furthermore, light obtrusion manifests itself as unnecessary energy waste and, in that sense, may be a contributor to climate change.

4. Light Obtrusion is illustrated in **Error! Reference source not found.**. It has four associated characteristics:

   - Skyglow - a combination of direct upward light and indirect upward light. This effect is often seen as an orange glow in the night sky;

- Spill Light - i.e. this includes the spill of light from a badly aimed floodlight straying beyond the task area such as light into windows or a neighbouring property;
- Source Intensity - how bright the source appears to an observer; and
- Façade or Building Luminance - i.e. the 'brightness' of a façade or excessive lighting on a building façade (not shown in Figure 15.1).

Figure 15.1 Light obtrusion characteristics as defined by the Institution of Lighting Professionals (ILP)[331].



6. Ideally, any light should only be directed onto the task area and not beyond. In many cases, light obtrusion can be significantly reduced without detriment to lighting of the task by correctly aiming floodlights, selecting more efficient floodlight optics or simply switching off any unnecessary external lighting.

15.2 Key Development Issues

7. Drilling and hydraulic fracturing (preparation and flowback) are the main activities that could give rise to significant effects because they are 24 hour operations and require lighting to ensure that tasks can be carried out safely. Additionally, during drilling some elevated parts of the drilling rig also require illumination and as a result there is less opportunity for the local landscape and vegetation to provide screening.

8. For security over-door low powered bulkhead luminaires will present on site cabins and stores throughout the duration of the Project. These will be similar to domestic lights.

15.3 Scoping and Consultation

9. The information provided in the Environmental Scoping Report summarised the scope of the Light Obtrusion assessment. This specified baseline data acquisition and assessment including:

- Nocturnal site and neighbourhood visits to record baseline lighting scene;

[331] The Institution of Lighting Professionals (2011). GN01: Guidance Notes for the Reduction of Obtrusive Light.

- Analysis of digital photographs to determine the existing lighting scene at selected viewpoints (included in Appendix O); and
- Review of relevant local planning guidance with reference to light obtrusion.

10. During the scoping phase, consultations were made with the following local authorities as listed in Table 15.1. Roseacre scoping and consultation overview..

Table 15.1. Roseacre scoping and consultation overview.

Consultee	Nature of request	Response received
Lancashire County Council	Need to assess the effects from lighting.	Effects on human beings are assessed within this chapter. Where relevant the impacts of lighting on wildlife have also been assessed in Ecology (Chapter 10) in terms of lighting arrangement principles.

15.4 Methodology

15.4.1 Introduction

11. This section outlines the methodology used in this assessment. Appropriate planning policy and light obtrusion guidance used to guide this assessment is also summarised.

12. Local authorities have powers through legislation to consider obtrusive artificial light as a Statutory Nuisance. Specific legislation includes the following:

13. **Environmental Protection Act 1990, Clean Neighbourhoods and Environment Act 2005:** The Clean Neighbourhoods and Environment Act renders 'exterior light emitted from premises so as to be prejudicial to health or a nuisance', a statutory nuisance.

14. **National Planning Policy Framework (NPPF):** National planning policy relating to the impact of external lighting proposals is contained within Section 11; Conserving and enhancing the natural environment. Specifically, this assessment has had regard to paragraph 109, which states that the planning system should contribute to and enhance the natural and local environment. In addition, this assessment has considered paragraph 125 which states: By encouraging good design, planning policies and decisions should limit the impact of light pollution from artificial light on local amenity, intrinsically dark landscapes and nature conservation.

15. **Blackpool Local Plan 2001/2016, (Adopted June 2006):** BH4: Public Health and Safety states that *Developments which are considered likely to be detrimental to public health and safety will not be permitted: […] (c) Light pollution should be minimised and not harm residential amenities*.

16. The assessment of visual effects on the surrounding countryside has been taken into consideration with the following documentation:

    - The Landscape Institute and Institute of Environmental Assessment: Guidelines for Landscape and Visual Impact Assessment, 3rd edition, 2013
    - DEFRA: Statutory Nuisance from Insects and Artificial Light. Guidance on Sections 101 to 103 of the Clean Neighbourhoods and Environment Act 2005.

17. Reference to the following design documents was used in preparation of the assessment:

- Institute of Lighting Professionals (ILP) Guidance Note for the Reduction of Obtrusive Light (GN01):2011;
- Commission Internationale de I'Eclairage (CIE) 150: Guide on The Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations;
- CIE 126: Guidelines for Minimising Sky Glow;
- CIE 136: Guide To The Lighting Of Urban Areas;
- The Chartered Institution of Building Services Engineers (CIBSE) LG6 The Exterior Environment;
- BS EN 12464 Part 2 Outdoor Lighting;
- CIBSE Environmental Considerations for Exterior Lighting (Factfile No.7: 2003); and
- CIBSE Lighting Guide 6: Outdoor Environment.

18. These guides provide design advice for the appropriate illumination of external spaces and design limits for obtrusive light. The ILP GN01 document summarises the CIE 150 document and offers guidance for designers to ensure their lighting schemes honour the need to reduce light obtrusion. Lighting design limits are defined in Environmental Zones designated E0 to E4, relative to the Site location and are described in Table 15.2.

Table 15.2 - Environmental Zones.

Zone	Description
E0	UNESCO Starlight Reserves, IDA Dark Sky Parks
E1	Intrinsically dark areas – National parks and areas of outstanding natural beauty
E2	Low district brightness areas – Rural or small village locations
E3	Medium district brightness areas – Small town centres or urban locations
E4	High district brightness areas – Town or city centres

19. Zone E2 is considered appropriate for the Site and the relative distance between it and other existing sources of lighting such as the urban fringes of Blackpool.

20. To determine the magnitude of the effect obtrusive light criteria are described in Table 15.3 below.

Table 15.3 - ILP guidance for limiting obtrusive light

Environmental Zones	Sky Glow UWLR[332] (Max %)	Light into Windows Ev[333] (lux) Pre/Post Curfew	Source Intensity I[334] (kcd) Pre/Post Curfew	Average Building Luminance L[335] (cd/m²) Pre-curfew
E0	0	0	0	0
E1	0.0	2.0 / 1.0	2.5 / 0.0	0.0
E2	2.5	5.0 / 1.0	7.5 / 0.5	5.0
E3	5.0	10.0 / 2.0	10.0 / 1.0	10.0
E4	15.0	25.0 / 5.0	25.0 / 2.5	15.0

21. A curfew is defined as the time after which stricter requirements (for the control of obtrusive light) would apply; often a condition of use of lighting applied by the local planning authority.

[332] UWLR = Upward Light Ratio: max permitted % of luminaire flux emitted directly up into the sky.
[333] Ev = vertical illuminance (lux): measure of light reaching neighbouring facades.
[334] I = light intensity (kilo-candelas, kcd): measure of intensity of the light source.
[335] L = luminance (candelas per sq. metre): measure of how bright a surface appears

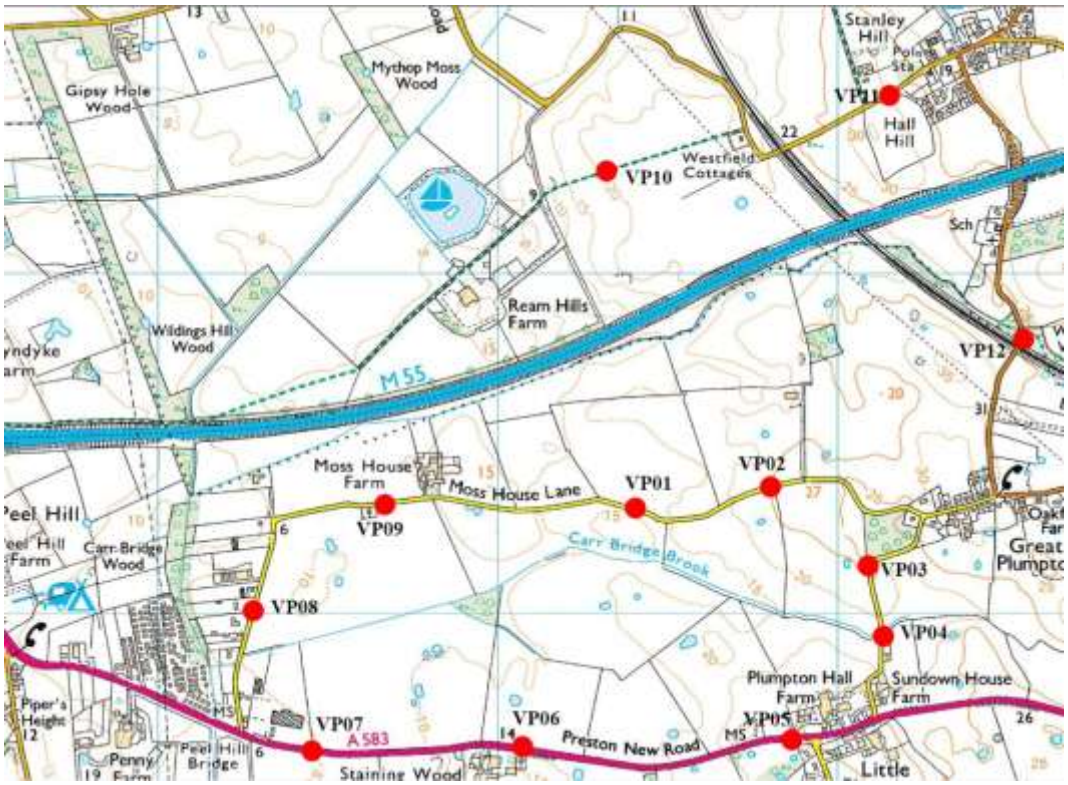
22. If not otherwise stated 2300hrs is adopted as the time when superfluous lighting (i.e. not required for late night working and/or street lighting) would be extinguished for the benefit of local dwellings and nocturnal wildlife. This is based on experience on other projects and from working with planning authorities.

15.4.2 Baseline methodology

23. The following section summarises the methodology used to assess baseline nocturnal lighting conditions around the Site. The ILP guidance note does not include a methodology for the measurement of illuminance data, however a method is provided in CIE 150[336] and the survey was completed in accordance with this guidance.

24. The receptors bordering the Site, or with a view towards the Site, are the villages of Little Plumpton and Great Plumpton. In addition to these receptors the potential effects of lighting adjacent habitats and species have been assessed by the Ecology chapter of this ES (Chapter 10).

Figure 15.2 – The Site and local receptors.



25. Baseline nocturnal lighting measurements were taken at selected viewpoints identified during the landscape and visual impact assessment reported in Chapter 14 of this ES, in order to provide a comprehensive nocturnal baseline study around the Site (Figure 15.2). These viewpoints have been used as the basis for the light assessment. The quantitative and visual baseline survey of the existing lighting in the locality of the Site and surrounding landscape was undertaken on 6/7 November 2013 after dusk, from 19:00 to 01:30 hours. Light measurements were taken using the following calibrated test equipment:

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- ATP DT-8809A illuminance meter; and
- Minolta LS100 luminance meter

26. Light readings were taken at selected viewpoints around the Site. The ambient conditions were: temperature 10°C, clear skies with scattered high level cloud. It should be noted that the atmospheric conditions may have marginally reduced the recorded measurements made but the effects are considered to be insignificant.

27. There is no light presently emanating from the Site and therefore the survey generally comprises luminance measurements and digital photographs which are analysed and calibrated using the luminance measurements to provide a quantitative interpretation of the scene. Luminance measurements were recorded in the direction of the Site.

15.4.3 Assessment methodology for all Project stages

28. The measure of significance relates to the deviation from the environmental Zone E2 limits for obtrusive light (see Table 15.3). A summary of the methodology for assessing significance of effects is provided below (Table 15.4). The same criteria have been used for the assessment of all Project stages.

Table 15.4- Evaluation of significance.

Effect Significance	Evaluation Criteria
Minor adverse Not Significant	Compared to the baseline data, predicted/measured obtrusive light levels remain within the designated limits for that Zone
Moderate adverse Significant	Compared to the baseline data, predicted/measured obtrusive light levels exceed the Post-Curfew limits for that Zone
Major adverse Significant	Compared to the baseline data, predicted/measured obtrusive light levels exceed the limits for that Zone

Note: text in bold sets out which effects are deemed significant or not significant under the EIA Regulations.

29. Any effect that results in an effect of moderate or greater magnitude is deemed a significant effect as defined in the EIA Regulations (2011).

15.4.4 Assumptions and limitations

30. For the purposes of the EIA the initial assessment has assumed that no mitigation measures are in place.

15.5 Baseline

Lighting data was gathered during the nocturnal survey in the form of luminance data and illuminance data. Luminance data is in the form of calibrated digital photographs, which can be found in Appendix O. The following illuminance measurements were also recorded (Table 15.5).

Table 15.5. Illuminance measurements.

Viewpoint	Vertical Plane Illuminance
VP02 VP05 VP06	<1 lux

Viewpoint	Vertical Plane Illuminance
VP07 VP08 VP09 VP10 VP11	

31. The following luminance data was recorded at the viewpoints (Table 15.6).

Table 15.6 - Luminance Measurements

Viewpoint	Vertical Plane Illuminance
VP02	0.11cd/m² (peak sky luminance)
VP05	0.10cd/m²(peak sky luminance)
VP06	0.12cd/m² (peak sky luminance)
VP07	0.07cd/m² (peak sky luminance)
VP08	0.07cd/m² (peak sky luminance)
VP09	0.05cd/m² (peak sky luminance)
VP10	0.03cd/m² (peak sky luminance) 0.45cd/m² (transmitter)
VP11	0.11cd/m² (peak sky luminance)

32. It can be observed in the luminance images (Appendix O) that there is no significant lighting located at the Site or in the vicinity.

33. The most significant forms of obtrusive light visible in the neighbourhood are in the form of street lighting on the A583 which borders the south of the Site. This lighting scheme can be seen from many viewpoints (VP05, VP06 and VP07). There are two farms; Plumpton Hall and Sundown House (to the south-east of the Project) with floodlights which produce high levels of luminance as can be seen in VP01 and VP02. Blackpool and Fylde Industrial Estate and Blackpool Pleasure Beach are also producing some levels of skyglow in the distance as can be seen in VP03, VP04 and VP05.

15.6 Assessment

15.6.1 Installation of the surface and buried arrays

34. Installation of the seismic arrays will be undertaken during normal working hours, and it is envisaged that no significant task lighting will be required for this stage of work. Impacts arising from light obtrusion are therefore considered to be *minor adverse* for routine installation activities and **not significant**.

35. In the event of installation activities extending into twilight conditions, which may occur during the October-March period when dusk falls earlier, temporary works lighting may be used. Details of a typical temporary works lighting unit are included in Appendix O (Figure 4O2). It is concluded that any temporary works lighting unit may be visible from local dwellings and wildlife habitats, subject to localised vegetation and topography. The duration of the use of temporary lighting is a key factor. Impacts arising from infrequent, short duration temporary lighting are considered to be low, however frequent or longer duration (over one week) temporary lighting would be considered to be a significant adverse impact. Given that the duration of works at any one array point is expected to be between 1-2 days the lighting effect is assessed as being of *minor adverse* and is therefore **not significant**.

15.6.2 Construction of well pad, access track and gas pipeline connection

36. The construction of the wellpad, access track gas pipeline connection will take place during normal working hours. There will be security lighting around the contractor's site cabins during this period typically comprising low power over-door bulkhead luminaires using low energy (<20W) light sources which are considered unlikely to exceed the ILP GN01 guidance for minimising light obtrusion.

37. Temporary works lighting may be required during these works, if they occur during the October-March period when dusk falls earlier in the evening. Details of a typical temporary works lighting unit are included in Appendix O (Figure 4O) and the unit utilises four 400W lamp floodlights. These floodlights are likely to have a source intensity of approximately 5 kilocandelas (kcd) and would not exceed the pre-curfew limits for source intensity as defined in ILP GN01. It is not anticipated that these lights would be used post-curfew as all works are carried out during normal working hours. With a basic optic, wide-area light distribution would be likely, and would be readily visible from a distance. This type of floodlight does not feature a horizontal cut-off optic (Table 15.8) and is therefore considered likely to contribute towards light spillage outside of the Site boundary and sky glow. It is considered unlikely that perimeter or other planting would be mature enough to serve as an environmental screen to this type of lighting within the well pad construction period. The duration of the construction works also exceeds 1 week and as consequence of the above effects the lighting impact is assessed as having a *minor adverse* effect and is therefore **not a significant effect**.

15.6.3 Drilling

38. During drilling the Site will operate as follows:

- Drilling rig will operate 24hours/day 7 days per week; and
- Task lighting will be in operation at night .(similar to that in illustrated in Appendix O).

39. The exact lighting arrangements for the Site during the drilling stage will depend upon the drilling rig that is used, the position, orientation and type of lights and luminaries mounted on the rig and other equipment. However, it is likely that the lighting will use lighting equipment listed below and in Appendix O.

- Site lighting: four mobile lighting towers with 4No. 400W floodlights
- Drilling rig: 9No. 500W floodlights and 14No. 2x35W fluorescent luminaires
- Tank lighting: 2No. 2x18W luminaires
- The drilling rig lighting is located at various heights around the rig

Figure 3 - Indicative drilling rig lighting

40. Lighting design software has been used to test a typical, best practice, lighting scheme for the Site (as identified in Appendix O) against the ILP guidance. The output of this software can also be seen in Appendix O and is summarised in Table 15.7.

Table 15.7 - Lighting simulation summary

Metric	**Sky Glow UWLR**	**Light into Windows Ev (lux)**	**Source Intensity I (cd)**	**Average Building Luminance L (cd/m²)**
ILP Guidance	2.5%	1.0	500	5.0
Prediction	6.7%	(Maximum Values) VP1 = 0.43 VP2 = 0.38 VP3 = 0.34 VP4 = 0.42 VP5 = 0.21 VP6 = 0.09 VP7 = 0.73 VP8 = 0.29 VP7 = 0.11 VP1 = 0.06	(Maximum Values) VP10 = 116 VP2 = 260 VP3 = 264 VP4 = 220 VP5 = 360 VP6 = 244 VP7 = 174 VP8 = 104 VP7 = 193 VP1 = 190	<5 to >50

41. It can be seen from the results that the light (lux) into windows and light source intensity characteristics can be designed to be compliant with the ILP guidance. It can also be observed in Appendix O that the luminance of the rig (attributed to light projected onto the rig from temporary works lighting) is generally is below the limit for the taller sections of the rig, where the rig is most visible from a distance, although the low level luminance on the site cabins is exceeds the limits in Table 15.3.

42. The period for drilling Well 1 is likely to last for 5 months and up to 3 months each for the other the subsequent wells. Although this lighting will be temporary the duration will be greater than 1 week. As a consequence of this duration and the factors described above

the lighting effect is assessed as *moderate adverse* and therefore would result in a **significant effect** without mitigation.

15.6.4 Hydraulic fracturing

43. The task lighting for the hydraulic fracturing will be similar to that described for drilling (see section 15.6.3). This is because there will be a Site presence 24hours a day and will involve the use of tall pieces of equipment (such as a coiled tubing tower or workover rig).

44. Consequently the lighting effect is assessed as *moderate adverse* and therefore would result in a **significant effect** without mitigation for sky glow and build or faced luminance.

15.6.5 Initial flow testing

45. Where initial flow testing is undertaken in isolation from other activities (e.g. drilling or hydraulic fracturing) the lighting will be similar to that used during drilling and flow testing. Therefore the magnitude of the effect is *moderate adverse* and therefore a **significant effect** is predicted.

15.6.6 Extended flow testing

15.6.6.1 Installation of extended flow testing infrastructure

46. The installation and construction of the extended flow testing infrastructure will take place during normal working hours. There will be operating lighting around the wellpad using medium power (≤400W) floodlights. If construction occurs between October and March area specific task lighting may be required (e.g. for construction of the pipeline and works to connect to the gas main).

47. The likely effects are assessed to be the same as those in section 15.6.2.

15.6.6.2 Operation of extended flow testing infrastructure

48. Extended flow testing will require work site lighting and due to its nature will require bespoke lighting. As a result the predicted effects are the same as initial flow testing (see section 15.6.5).

15.6.7 Decommissioning and Restoration

49. The predicted effects are the same as those predicted for construction (see section 15.6.2).

15.7 Cumulative and Interactive Effects

50. Cumulative effects of pad illumination are unlikely to arise from the development and operation of this Site with other similar activities in the area, due to distance between locations and individual site contexts. In addition, there are no known proposed or committed developments of a relevant scale or nature that would generate significant cumulative effects on the nocturnal environment.

51. Light spillage can have an effect on local sensitive/protected wildlife habitats and during nesting seasons. However, by directing lighting away from sensitive habitats potentially significant effects can be avoided. These effects are assessed in Chapter 10.

15.7.1 Multiple project activities occurring simultaneously

52. During the life of the Project drilling, initial and extended flow testing are likely to occur at the same time. Likewise hydraulic fracturing and flow testing also likely to occur together. The combination of these activities will not result in more severe effects than those already assessed because they would not increase the level of lighting in use at the Site.

15.7.2 Roseacre Wood and Preston New Road

53. The separation of the two exploration Sites and the intervening landscape means that there are no viewpoints that will view both sites in the same view.

15.8 Mitigation Measures

15.8.1 Installation of surface and buried arrays

54. Mitigation will only be required if construction occurs between the months of October and March and the use of temporary works lighting will be minimised in terms of frequency and duration wherever possible. In addition the following measures will minimise risk of adverse effects on residents and wildlife:

- Confining lighting to the task area (using horizontal cut-off optics and zero floodlight tilt angles);
- Orientating floodlights away from any dwellings; and
- Operate a curfew and minimise the duration of any floodlighting .

55. Particular attention will be paid to the potential for skyglow and light spill beyond array station when lighting may be required. When lighting is used it will be visually checked from potentially sensitive receptors (e.g. nearby residential properties) and any necessary adjustments made to ensure its visibility and intensity is reduced to a minimum.

15.8.2 Construction of well pad, access track, gas pipeline connection, decommissioning and restoration

56. The measures described for installation of the arrays (see section 15.8.1) will also be applied to the construction of the well pad, access track and gas pipeline connection. These will only be required if construction occurs between the months of October and March.

15.8.3 Drilling Hydraulic fracturing, Initial and Extended Flow Testing

57. All lighting will be installed and arranged with reference to current health and safety requirements and lighting design best-practice, to establish the feasibility of using a lower impact lighting scheme.

58. All task and operational lighting will be verified by a competent lighting design engineer to ensure compliance with the ILP guidance. The impact of any obtrusive light effects on the nocturnal environment will be reduced by applying the following measures as applicable:

- Adhere to ILP/CIE guidance
- Use the lowest powered light sources as reasonably practicable;
- Direction task lighting to the area required; avoiding 'wide-area' lighting schemes
- Preventing luminaires from emitting light above the horizontal plane
- All lighting will be aimed to where it is required utilising and chose precision optics which keep the light where it's needed.
- Plant lighting will be shielded from view by the nearby dwellings and sensitive habitats.
- Low key security lighting, where appropriate, will use movement sensor controlls or 'part-night' dimming.
- Use the site cabins etc to provide shielding of the lighting from beyond the Site.
- Minimise the height of lighting columns (to approximately 6m)
- Observe a curfew when reasonable practicable (; and
- Monitor the Site environs and respond to complaints promptly.

59. Examples of typical mitigation methods recommended in ILP GN01 are set out in Table 15.8. This table is not an exhaustive list.

Description	Example of Non-Compliance	Example of Good Practice
Luminaires with no upward light spill (i.e. horizontal 'flat glass' lens, compact light source for better light control)		
Luminaires correctly specified and installed to efficiently place the light on the task area and not beyond		
Area lighting with horizontally mounted asymmetric luminaires		

Table 15.8 - Examples of recommended mitigation techniques

15.8.4 Drilling Hydraulic fracturing, Initial and Extended Flow Testing

60. Any specific requirements for the use and set up of lights will be incorporated into the EOS prior to any works commencing on Site.

61. The lighting should be regularly monitored, measured and visually checked from all viewpoints (Figure 15.2) and any necessary adjustments made to ensure its visibility and intensity is reduced to a minimum.

15.9 Residual Effects

62. It is anticipated that avoidance of light obtrusion beyond the Site boundary will minimise any significant residual effect on local wildlife habitats or residents and result in a *negligible or minor adverse* effect. Therefore the residual effects will be **not significant**.

15.10 Assessment Summary Matrix

63. The following table summarises the obtrusive light effects.

Table 15.9 - Light obtrusion assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Installation of surface and buried arrays Construction of well pad and access. Decommissioning and Restoration			
Light spill beyond Site boundary	Minor adverse Not Significant	Best practice lighting design, commissioning and monitoring	Minor adverse Not Significant.
Skyglow	Minor adverse Not Significant	Ensure all luminaires have horizontal cut-off optics and are installed to prevent direct light up into the sky.	Minor adverse Not Significant.
Light source intensity	Minor adverse Not Significant	As above, and consider use of lower powered lighting and efficient optics. Use floodlight cowls and other screening devices.	Minor adverse Not Significant.
Building Luminance	Negligible Significant	As above	Negligible Significant.
Drilling. Hydraulic fracturing. Initial flow testing and extended flow testing			
Light spill beyond Site boundary	Major adverse Significant	As above	Minor adverse Not Significant.
Skyglow	Major adverse Significant	As above	Moderate adverse Significant.
Light source intensity	Major adverse Significant	As above	Minor adverse Not Significant.
Building Luminance	Major Adverse Significant	As above	Moderate adverse Significant.

16 Noise

Chapter Summary- Noise

This chapter assesses the noise and vibration impacts from the Project and their effects on the surrounding sensitive receivers.

Baseline noise levels have been established by a measurement survey. This data is used to assess the potential significance of any effects. The Site is in a rural location. However the proximity of the M55 to the north and A583 to the south means that during the day time road noise is a particular feature of the current environment.

Different stages of the Project will have different noise levels. The noisiest activities are most likely to occur within the first two to three years of the Project. However, the noise levels for all stages of the Project have been assessed. The only stage with the potential to result in a significant noise effect is where hydraulic fracturing occurs during night time (2300-0700) where noise limits are at their most stringent.

This will be mitigated by only operating the pumps used (only for up to 3 hours at a time during hydraulic fracturing) during weekday daytime and Saturday mornings.

Vibration impacts have been ruled out because of the nature of the Project, method of construction for the well pad, arrays and pipeline connection for the extended flow testing.

The Roseacre Wood and Preston New Road Sites are sufficiently distant from one another that there will not be a combined or cumulative lighting impacts on receptors from both sites.

16.1 Introduction

1. This section reviews the noise and vibration impacts from the Project and their effects on the surrounding sensitive receivers. The noisier activities (site construction, drilling and hydraulic fracturing) will have a combined duration of two to three years. Depending on the findings of the exploration, extended flow testing may be undertaken following which the Site will be decommissioned and restored.

2. The various stages of the Project will cause different noise and vibration impacts and last for various time periods (see Chapter 4, Table 3 Appendix A and B). Each stage is therefore assessed separately and in terms of temporary impacts and effects. The assessment includes concurrent activities at the Preston New Road site and the cumulative impacts of the Preston New Road and Roseacre Wood sites.

3. Baseline noise levels have been established by a measurement survey. his data is used to assess the potential significance of any effects.

4. The effects of traffic noise generated by the Project are assessed based on measured and predicted flow data is taken from the Transport Chapter (18).

5. Given the distance of the Site from dwellings and the drilling depth, a vibration assessment is not considered to be required. Vibration is not expected generally to be perceptible from the Project. Vibration associated with potential microseismic events during hydraulic fracturing is addressed in Chapter 12.

16.2 Key Development Issues

6. The assessment considers the following activities associated with the construction, operation and decommissioning of the site:

- Construction;
- Installation of monitoring works;
- Drilling;
- Hydrualic fracturing;
- Initial flow testing;
- Extended flow testing;
- Decommissioning and restoration;
- Changes in road traffic flow or composition on existing surrounding roads and;
- Plant associated with temporary buildings and facilities.

16.3 Scoping and Consultation

7. A scoping report was submitted to Lancashire County Council (LCC) and Fylde Borough Council (FBC) in relation to the Project. No comments, specific to noise and vibration, were made in the Scoping Opinion. In addition to this, a two stage consultation was undertaken with the general public and local stakeholders.

16.4 Methodology

16.4.1 Introduction and guidance documents

8. This section briefly describes the relevant policies and guidance for noise and vibration assessments. It then sets out the assessment methodologies used and the significance criteria against which effects are quantified.

9. Noise impacts are assessed on the basis of BS 5228:2009+A1:2014 –*Code of Practice for Noise and Vibration Control on Construction and Open Sites* and the Calculation of Road Traffic Noise (CRTN) methodology for assessing the impact of noise from traffic flow associated with the Project.

16.4.1.1 BS 5228:2009+A1:2014 – Code of practice for noise and vibration control on construction and open sites

10. British Standard BS 5228 Part 1 (noise) is relevant not only for the construction phase, but also for other activities since much of the equipment and plant required will be the same as or similar to construction plant and the activities will be variable in their nature and the duration of each stage. The noise emission data provided in BS 5228 is therefore applicable to calculation of the noise impacts.

11. The standard also describes the legislative background to noise control and recommendations are given regarding procedures for creating effective liaison between developers, site operators and local authorities. Methods for predicting and assessing noise are presented and guidance is given concerning the measurement of noise.

12. Annex E.3.2 of BS5228-1:2009+A1:2014, defines thresholds of potentially significant effects on the basis of existing noise levels using the ABC method.

13. For the appropriate period (night, evening/weekends or day), the ambient noise level is determined and rounded to the nearest 5dB and evaluated in relation to the threshold values set out in Table 16.1.

Assessment category and threshold value period	**Threshold values in decibels (dB), $L_{Aeq,T}$**		
	Category A	**Category B**	**Category C**
Night-time (23:00 – 07:00)	45	50	55
Daytime (07:00 – 19:00) Saturdays (07:00 – 13:00)	65	70	75
Other: Weekday evenings (19:00 – 23:00) Saturdays (13:00 – 23:00) Sundays* (07:00 – 23:00)	55	60	65
Where: Category A: are threshold values to use when ambient noise levels (rounded to the nearest 5dB) are less than these values. Category B: are values to use when ambient noise levels (rounded to the nearest 5dB) are the same as category A values. Category C: are values to use when ambient noise levels (rounded to the nearest 5dB) are higher than category A values.			

*Bank holidays to be treated as Sundays

Table 16.1 Threshold of potential significant effects at dwellings from on-site noise sources (from BS 5228-1:2009+A1:2014).

A potential significant effect is indicated where the construction noise (L_{Aeq}) level exceeds the threshold level for the category appropriate to the ambient noise level. If the ambient noise level exceeds the highest threshold values given in *Bank holidays to be treated as Sundays

14. Table 16.1 (i.e. the ambient noise level is higher than the Category C values), then a potential significant effect is deemed to occur if the construction L_{Aeq} noise level for the period is greater than the ambient noise level.

15. Where the noise calculations indicate a potential significant effect, professional judgement is then used to assess whether the effect is deemed significant.

16.4.1.2 BS4142: 1997 Method for rating industrial noise affecting mixed residential and industrial areas

16. British Standard BS 4142 describes a method for determining the likelihood of complaints arising from noise from fixed installations and sources of an industrial nature in commercial premises.

17. Given that the Site will operate with a variety of different plant over various different timescales, this method of assessment (which is intended for fixed installations) is not considered appropriate.

16.4.1.3 Calculation of Road Traffic Noise

18. Noise from road traffic generated by new or altered roads associated with a proposed development can be calculated using the Calculation of Road Traffic Noise (CRTN) methodology. Noise levels are based on the volume, average speed, road surface type and composition of traffic. The resulting noise levels at receiver locations are then calculated taking into account the propagation distance, intervening screening and other effects.

16.4.1.4 ISO 9613-1 Attenuation of sound during propagation outdoors - Part 1: Calculation of the absorption of sound by the atmosphere

19. International Standard ISO 9613-2 describes a method of calculating the attenuation of noise levels outdoors due to atmospheric absorption.

16.4.1.5 ISO 9613-2 Attenuation of sound during propagation outdoors - Part 2: General method of calculation

20. International Standard ISO 9613-2 describes a method of calculating the attenuation of noise levels outdoors due to ground absorption.

16.4.1.6 Noise Policy Statement for England, Defra, 2010

21. The Noise Policy Statement for England (NPSE) aims to promote good health and quality of life through the effective management of noise within the context of Government policy on sustainable development. The vision is supported by the aim that through the effective management and control of environmental, neighbour and neighbourhood noise:

    - Significant adverse impacts on health and quality of life are avoided;
    - Adverse impacts on health and quality of life are mitigated and minimised; and
    - Where possible, the development contributes to the improvement of health and quality of life.

22. NPSE does not prescribe any targets for environmental noise.

16.4.1.7 National Planning Policy Framework, DCLG 2012

23. The National Planning Policy Framework (NPPF) sets out the Governmental requirements for the planning system in England and must be considered in conjunction with local development plans during planning decisions. In reference to noise, the NPPF states (paragraph 123):

    Planning policies and decisions should aim to:

    - *avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;*
    - *mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development, including through the use of conditions;*

- *recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established.*

24. NPPF provides the following guidance in relation to minerals planning:

> *Subject to a maximum of 55dB(A)$L_{Aeq,\ 1h\ (free\ field)}$, mineral planning authorities should aim to establish a noise limit at the noise-sensitive property that does not exceed the background level by more than 10dB(A).*

25. NPPF also notes that in locations where the existing background noise level is low, it would be difficult not to exceed the background noise level by more than 10dB(A) without imposing unreasonable restrictions on the mineral operator and therefore recommends the following freefield[337] noise standards:

Day (07.00 to 19.00 hrs)	$L_{Aeq,1h}$ as near as practicable to background+10dB(A)
Evening (19.00 to 22.00 hrs)	$L_{Aeq,1h}$ not greater than background+10dB(A)
Night (22.00 to 07.00 hrs)	Not greater than 42dB$L_{Aeq,\ 1h}$

26. The noise guidance in NPPF is specifically aimed at large scale mineral working. The shale gas exploration site is a relatively small scale activity, with relatively short duration and hence more similar to construction works than to mineral extraction in terms of noise impacts. Assessment only on the basis of NPPF would be unduly cautious for the exploration site

16.4.2 Baseline methodology

27. Baseline noise data has been acquired through a noise survey conducted at locations representative of the noise sensitive receivers (NSRs) (dwellings) closest to the Project. Details of the survey and full results are reported in Appendix P. The measurement locations (shown on the map in Appendix P) were:

- Location 1 (Plumpton Hall Farm): Plumpton Hall Farm includes two residential properties. It is approximately 380m to the east of the well pad boundary, with a direct line of sight to the well pad. The measurement location was in the garden on the north-east of the dwelling closest to the well pad boundary.
- Location 2 (representative of the properties at Staining Wood Cottages and Staining Wood Farm): This measurement location was situated in the field on the north side of Preston New Road at an equal distance from the roadside as Staining Wood Cottages are to the south. The measurement position was approximately 270m from the well pad boundary.

28. Assessing existing noise levels and ensuring control of noise at Plumpton Hall Farm and Staining Wood Cottages will ensure that other (more distant) noise sensitive premises are protected from noise from the Site.

[337] Freefield noise is that measured or experienced in a location free of reflections, usually taken to be at least 3.5m from a reflecting surface (other than the ground surface)

16.4.3 Assessment methodology

29. Based on the documents described in Section 1.4.1, the assessment approach reflects the requirements of the EIA Directive, current best practice, and the Government's noise policy.

30. The NPSE uses the key phrases 'significant adverse' and 'adverse'. In clarifying what these mean, the NPSE notes that: '…*there are two established concepts from toxicology that are currently being applied to noise effects, for example, by the WHO (World Health Organization)*'. They are:

- NOEL – No Observed Effect Level

  This is the level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.

- LOAEL – Lowest Observed Adverse Effect Level

  This is the level above which adverse effects on health and quality of life can be detected.

31. The Policy extends these concepts to include:

- SOAEL – Significant Observed Adverse Effect Level

  This is the level above which significant adverse health effects on health and quality of life occur.

32. These terms are adopted in the Government's National Planning Practice Guidance (NPPG), which presents example outcomes to help characterise these effects. In general terms an observed adverse effect, ie above LOAEL is characterised in the NPPG as:

- LOAEL - perceived as 'noticeable and intrusive'

  Example outcome: *'Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.'*

  NPSE required action – *'Mitigate and reduce to a minimum'*

33. The NPPG characterises SOAEL as:

- SOAEL - perceived as 'noticeable and disruptive'

  Example outcome: *'The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.*'

  NPSE required action – *'Avoid'*

34. The noise policy notes that triggers should be defined for the onset of adverse effects (LOAELs) and significant adverse effects (SOAELs) in terms of total levels of exposure.

Also, that these trigger values should reflect the nature of the noise source, the sensitivity of the receptor and local context.

35. The NPSE notes that it is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times. It is for a project to identify the relevant SOAEL taking account the different sources of exposure and different receptors.

16.4.3.1 Assessment Thresholds for On-Site Noise Sources

36. In addition to the Government policy approaches described above, the Environmental Statement also examines noise change, in addition to absolute level. In government policy terms, noise level changes are observed adverse effects but they are not significant observed adverse effects. When the noise climate is below the SOAEL, these adverse effects relate to people's response to changes in local acoustic character, particularly outdoors and to a lesser extent indoors. Noise insulation cannot change outdoor noise levels, and hence minimising adverse effects is centred on maximising on-site mitigation.

37. For the purpose of this assessment, potential adverse effect thresholds have been established by reference to the ABC method described in BS5228-1, reflecting the temporary nature of the exploration operations and the various phases within the exploration works. Table 16.2 provides noise level thresholds, based on the ABC method, in the context of the government guidance on observable adverse effects.

Effect threshold (residential)	Threshold value
NOAEL	Day <65dBL$_{Aeq, daytime}$
	Evening <55dBL$_{Aeq, 1hr}$
	Night <45dBL$_{Aeq, 1hr}$
LOAEL	Day 65dBL$_{Aeq, daytime}$
	Evening 55dBL$_{Aeq, 1hr}$
	Night 45dBL$_{Aeq, 1hr}$
SOAEL	Day 75dBL$_{Aeq, daytime}$
	Evening 65dBL$_{Aeq, 1hr}$
	Night 55dBL$_{Aeq, 1hr}$

Table 16.2 Thresholds of potential effects of on-site noise at dwellings.

38. In terms of the Environmental Impact Assessment, noise from on-site sources has been assessed using the ABC method and, where a potential significant effect is indicated, professional judgement has been used to assess whether the effect is deemed significant. This judgement is based on considerations such as: the likely duration of the effect; the number of properties and proportion of the community affected; and the existing noise level.

39. Attenuation of noise with distance from the source has been calculated using ISO 9613-2 methodology assuming soft ground across the entire area.

40. The noise survey results (see section 16.6 and Appendix P) show the daytime noise levels to be below 65dBL$_{Aeq}$ at the dwellings closest to the site. Referring to *Bank holidays to be treated as Sundays

41. Table 16.1, the assessment is therefore conducted using Category A thresholds, with the exception that Category B applies to night time assessment at Staining Wood Cottages and Staining Wood Farm due to the higher existing ambient noise level.

16.4.3.2 Assessment Thresholds for Off-Site Road Traffic

42. In terms of Government policy, the Project needs to consider two aspects of traffic noise in the assessment: the predicted absolute level and the change in level.

43. For absolute levels, the World Health Organization and Noise Insulation Regulations values provide appropriate references. Table 16.3 provides threshold values for road traffic noise based on these documents.

Effect threshold (residential)	Threshold value
NOAEL	Day <50dBL$_{Aeq, 16hr}$ (equivalent to <52dBL$_{A10, 18hr}$)
	Night <40 dBL$_{Aeq, 1hr}$
LOAEL	Day 50dBL$_{Aeq, 16hr}$ (equivalent to 52dBL$_{A10, 18hr}$)
	Night 40dBL$_{Aeq, 1hr}$
SOAEL	Day ≥68dBL$_{A10, 18hr}$
	Night >55dBL$_{Aeq, 8hr}$

Table 16.3 Thresholds of potential effects of road traffic noise at dwellings.

44. In addition to considering the absolute levels in Table 16.3 to assess effects in line with policy requirements, it is necessary also to consider the change in noise level to assess potentially significant effects for the Environmental Statement. The assessment, therefore, is also undertaken in accordance with DMRB Volume 11, Section 3, Part 7, HD 213/11 Revision 1, which provides guidance on the effects of magnitude of changes in noise.

45. Noise from freely flowing road traffic is relatively uniform and broadband, without strong tonal or impulsive characteristics. It is common practice to evaluate the significance of noise effects on the basis of the change in traffic noise level due to a proposed development.

46. There is no established UK guidance that clearly defines criteria for the assessment of significant effects arising from road traffic noise. The response of people to noise is subjective, and sensitivity to changes in traffic noise varies across the population. Given the variability of response and the potential for non-acoustic factors to influence perceptions of noise, any assessment of significance can only represent the general community response to traffic noise.

47. Chapter 3 of DMRB HD 213/11 Revision 1[1] notes that "A change of 1dBL$_{A10,18h}$ in the short-term (e.g. when a project is opened) is the smallest that is considered perceptible. In the long-term, a 3dBL$_{A10,18h}$ change is considered perceptible."

[1] The Highways Agency, Transport Scotland, Welsh Assembly, the Department for Regional Development Northern Ireland (2011), *Design Manual for Roads and Bridges Volume 11, Section 3, Part 7, HD 213/11 – Revision 1, TSO*

48. DMRB provides categories for assessing road noise impact magnitude. On the basis of the available guidance, Arup has developed significance criteria for changes in road traffic noise at sensitive receptors. The impact criteria and potential significance thresholds are given in Table 16.4.

Change in noise level (dB)	Impact category	Initial indicator of significance
>10	Major adverse	Potential for increase to be significant
≥5 to <10	Moderate adverse	
≥3 to <5	Minor adverse	
0 to <3	Negligible adverse	Unlikely to be significant
>-3 to 0	Negligible beneficial	
≤-3 to >-5	Minor beneficial	Potential for decrease to be significant
≤-5 to >-10	Moderate beneficial	
≤-10	Major beneficial	

Table 16.4 Summary of noise impact evaluation criteria for changes in traffic noise.

49. Where a noise change of +3dB is identified, the effect may be potentially significant and an assessment is made of the receptors affected by the change.

50. For residential receptors, the overall significance of the effect is assessed using professional judgement by considering not only the DMRB noise impact criteria but also by using professional judgement based on the following factors:

- The number of receptors subject to the impacts;
- The proportion of the community subject to the impact;
- The existing absolute noise levels (particularly very noisy and quiet/tranquil areas); and
- Duration of exposure.

51. Notwithstanding the guidance in DMRB in relation to noise change, for consistency with the approach to assessing absolute noise levels, if a receptor is already at or above SOAEL, then a change of +1dB is considered potentially significant.

16.4.4 Assessment methodology for the effects from installation of surface network and buried array

52. The assessment is based upon a qualitative review of the machinery, plant equipment and processes required.

16.4.5 Assessment methodology for operational effects

16.4.5.1 Off-site road traffic

53. Access to the Site is along main roads from the M55. The traffic noise impacts have therefore been considered in terms of the number of additional vehicle movements and calculated using CRTN.

16.4.5.2 On-site activities

54. Impacts from each of the on-site activities during each operational stage have been assessed using the ABC method from BS 5228-1. The source noise levels used in the assessments are taken from BS 5228-1 and, where required and available, make use of data measured at other exploration sites.

16.4.5.3 Drilling

55. Drilling will need to be continuous, 24 hours a day (see Chapter 4 section 4.7.2). The assessment is based on noise data acquired during drilling for a similar project[338]. This data has been used to assess noise levels at the nearest noise sensitive receivers with the attenuation between the source and noise sensitive receivers calculated using ISO 9613-2.

56. Noise impact from an alternative Type T-208 (53m high) drilling rig has been compared with that used to calculate the noise maps (see Appendix P). Comparing noise levels from the two rigs with the approximate distance of the closest dwellings from the Site shows the noise levels from both rigs to be very similar.

16.4.5.4 Hydraulic fracturing

57. Noise predictions at the closest sensitive receivers to the Preston New Road site have been based on measured data from hydraulic fracturing at the Preese Hall Exploration Site [339].

58. The sound power level for hydraulic fracturing pumping operations at the Preese Hall site was calculated from noise measurements using the method described in ISO 8297:1994. This sound power level was used in conjunction with ISO 9613-2 to calculate noise levels at the nearest noise sensitive receivers to the Preston New Road site.

16.4.5.5 Initial flow testing

59. The noise assessment is based on expected plant equipment used on site for this element of the Project and plant noise data from BS5228.

60. Noise levels for the flaring have been predicted using data provided by McLorinan Consulting Limited (see Appendix P), from which the flare noise at the surrounding dwellings has been calculated, assuming two flares will be operational simultaneously.

16.4.5.6 Extended flow testing

61. The main noise impact for this stage of the Project is from the construction of a pipeline connection to the gas grid. The construction activity is very short, having a duration of a few weeks. The noise assessment is made using BS5228-1 for plant equipment necessary for the construction works. The quantity of plant required during flow testing is relatively small and will require little site activity.

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[338] Sound Power Assessment Drillmec HH-220 Drilling Rig Operated by Cuadrilla Resources Limited. September 2010, Spectrum Acoustics *Report ref. PJ2809/PJ/10193*

[339] Sound Power Assessment Frac Operations Preese Hall Exploration Site. April 2011, Spectrum Acoustics *Report reference: PJ2877/10193*.

16.4.6 Assessment methodology for decommissioning and restoration effects

62. The noise assessment of decommissioning and restoration effects is made using BS5228-1 for plant equipment necessary for the construction of the well pad and access road, as decommissioning and restoration will be of a similar scale.

16.5 Assumptions and limitations

63. Wherever possible, measured noise data has been used in this assessment, either from British Standards or from exploration processes elsewhere. Where no noise data is available, predictions have been made on the basis of available data and professional judgement.

64. Construction noise predictions are based on assumed equipment and processes, to enable a quantitative evaluation to be undertaken. Based on experience from other sites, this approach is considered to yield a representative assessment of construction noise.

65. The approach taken in the assessment of operational plant and equipment is to calculate noise levels and evaluate them against the existing measured site background noise level. This provides a meaningful assessment of the potential for disturbance and identifies where measures will be required to control noise emissions.

66. The assessment includes the embedded mitigation arising from most operations only taking place during the daytime and the use of best practicable means of working.

16.6 Baseline

67. Baseline noise surveys were undertaken by Arup at appropriate times of the day and night on Friday 22nd November 2013. All measurements were attended throughout. The ambient noise levels have been averaged to obtain a representative noise level. These levels are summarised in Table 16.5 and Table 16.6.

Receptor	Ambient daytime noise level (dBL_{Aeq})	Daytime noise criteria (dBL_{Aeq})
1 – Plumpton Hall Farm	55	65
2 – Staining Wood Cottages	62	65

Table 16.5 Ambient daytime noise levels and assessment criteria at NSRs

Receptor	Ambient night-time noise level (dBL_{Aeq})	Night-time noise criteria (dBL_{Aeq})
1 – Plumpton Hall Farm	42	45
2 – Staining Wood Cottages	46	50

Table 16.6 Ambient night-time noise levels and assessment criteria at NSRs

68. Measurements were taken periodically over the quietest times of day and night. The levels used in the assessment are the logarithmic average of the sampled noise levels. This method provides a cautious assessment since the measurements were made during the quietest times of day or night and therefore the assumed baseline ambient noise level is lower than that for the whole day or night period.

69. The receptors are categorised using the BS5228 ABC method to give the assessment criteria shown in Table 16.5 and Table 16.6 above.

70. As the daytime criteria are the lowest of those specified in the ABC method (see Table 16.1) and the night time only marginally exceed the lowest, assessment during weekday evenings and weekends (at the times defined in Table 16.1) takes the lowest evening criterion, which is 55dBL_{Aeq}.

71. In addition to the properties located where the surveys were undertaken, there are also dwellings at greater distances from the Site, including those on Moss House Lane and at Carr Bridge. The existing ambient noise level may be lower at some of these dwellings than at those measured. The lowest assessment criteria from the ABC method would therefore also apply at these locations.

16.7 Assessment

16.7.1 Construction of Well Pad and Access

16.7.1.1 Off-site road traffic

72. Construction of the access road and well pad will require materials and equipment to be transported to the Site by HGVs. In addition, site personnel will travel to and from the Site in their own vehicles. The additional traffic will affect the noise levels from Preston New Road. Table 7 provides a summary of the traffic noise change for the days with the highest predicted traffic flow.

Location	Road traffic noise, dB$L_{Aeq,16hr}$		
	Without site	With well pad and access related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.5	0.0

Table 7 Noise levels from traffic during the construction of the well pad and access road.

73. The data shows that even the worst case assessment gives no increase in daytime traffic noise levels. This is categorised as a negligible adverse impact (see Table 16.2) and is unlikely to be significant. Consequently road traffic noise during site preparation is assessed as a **not significant effect.**

16.7.1.2 Construction

74. Construction activities will only take place during the day. The construction noise levels are calculated using the methodology given in BS5228 and based on assumed equipment and on-times set out in Table 16.8.

Plant	Quantity	On-time [%]	dBL_{Aeq} at 10m	Effective dBL_{Aeq} at 10m	BS5228 reference
Tracked Excavator (71t)	1	25	77	71	BS5228 Table C 2-2
Dump Truck (Tipping Fill)	1	25	79	73	BS5228 Table C 2-30
Dumper	2	100	76	79	BS5228 Table C 4-4
Tracked Excavator (22t)	1	100	78	78	BS5228 Table C 2-3
Dump Truck (Empty)	2	100	87	90	BS5228 Table C 2-31
Dozer	1	15	81	73	BS5228 Table C 2-12
Vibratory Roller	1	15	74	66	BS5228 Table C 2-39
Wheeled Mobile Crane	1	50	70	67	BS5228 Table C 3-30
Lorry	4	75	80	85	BS5228 Table C 2-34
Diesel Generator	2	100	61	64	BS5228 Table C 4-76

Table 16.8 Construction equipment noise data from BS5228-1.

75. The calculated highest construction noise levels are given in Table16.9 and compared with the threshold for potential significant effect.

Receptor	Calculated construction noise level (dBL_{Aeq})	Criteria (dBL_{Aeq})
1 – Plumpton Hall Farm	54	65
2 – Staining Wood Cottages	58	65

Table16.9 Construction noise levels during access road and well pad construction.

76. Parts of the planned access road are closer to Staining Wood Cottages than the well pad. The construction of this part of the road will only last for a short period. The construction noise level at this shorter distance (180m) is 63dBL_{Aeq}.

77. The predicted noise levels are all below the assessment criteria. Consequently the noise from construction activities for the access road and well pad is assessed as a **not significant effect**.

16.7.2 Installation of monitoring works

16.7.2.1 Surface array

78. Installation of surface arrays will require only small scale plant and very short duration works at each location. Typical plant will be a small excavator and light vehicles for personnel and equipment. Such plant will generate low level noise and only during the working day. Consequently these activities are assessed as a **not significant effect**.

79. During their operation, the arrays will require occasional servicing and maintenance. Only one or two personnel, travelling in a light vehicle, will need to attend each array. Consequently this is assessed as a **not significant effect**.

16.7.2.2 Buried array

80. Installation and maintenance of the microseismic buried arrays will have similar requirements in noise terms as the surface array. The main difference will be that a site investigation type drilling rig will be required rather than a small excavator. Such plant will only be operated during the working day and will only generate a low level of noise. Consequently these activities are assessed as a **not significant effect**.

81. During their operation, the arrays will require occasional servicing and maintenance. Only one or two personnel, travelling in a light vehicle, will need to attend each array. Consequently this is assessed as a **not significant effect**.

16.7.2.3 Groundwater monitoring boreholes

82. Installation of groundwater monitoring boreholes will require only small scale plant and very short duration works at each location. Typical plant will be a site investigation type drilling rig and light vehicles for personnel and equipment. Such plant will generate low level noise and only during the working day. Consequently these activities are assessed as a **not significant effect**.

83. During their operation, the boreholes will require occasional visits to take samples. Only one or two personnel, travelling in a light vehicle, will need to attend each borehole. Consequently this is assessed as a **not significant effect**.

16.7.3 Drilling

16.7.3.1 Off-site road traffic

84. Mobilisation and operation of the drilling rig will require additional traffic movements on Preston New Road to bring equipment and materials to and from the Site. Table 16.10 presents the worst case traffic noise assessment for the days when the site activities are predicted to generate the greatest traffic flow.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without site	With drilling related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.6	0.1

Table 16.10 Worst case changes in traffic noise during the drilling phase

85. Table 16.10 shows only a very small increase in traffic noise levels. This is categorised as a negligible adverse impact (see Table 16.2) and is not significant. Furthermore, this is a worst case assessment based on the day with the most traffic movements necessary for the drilling procedure. Consequently noise from traffic generated during the drilling phase is assessed as a **not significant effect**.

16.7.3.2 Operation of the drilling rig

Predicted drilling noise levels are illustrated in the noise map in Appendix P and are summarised in *Times defined in Table 16.1

86. Table 16.11, together with the assessment criteria. Drilling will be a continuous process, operating 24 hours per day.

Receptor	Predicted noise level (dBL_{Aeq})	Weekday daytime and Saturday mornings criteria* (dBL_{Aeq})	Weekday evening, Saturday afternoon, Sunday criteria* (dBL_{Aeq})	Night-time criteria (dBL_{Aeq})
1 – Plumpton Hall Farm	39	65	55	45
2 – Staining Wood Cottages	47	65	55	50

*Times defined in Table 16.1

Table 16.11 Predicted noise levels from drilling and assessment criteria

87. The predicted noise levels at both receptors are below the assessment criteria derived from BS5228. Consequently these activities are assessed as a **not significant effect**.

16.7.4 Hydraulic Fracturing

16.7.4.1 Off-site road traffic

88. Mobilisation and operation of the hydraulic fracturing rig will involve transporting equipment to the Site and import and removal of materials, leading to an increase in traffic on local roads. Table 16.12 shows the calculated noise levels from the increased traffic during hydraulic fracturing based on the day when maximum traffic numbers are expected, to give a worst case assessment.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without Site	With fracturing related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.6	0.1

Table 16.12 Calculated changes in traffic noise during hydraulic fracturing

89. The data shows only a very small increase in traffic noise levels during hydraulic fracturing. This is based on the days during the works predicted to have the largest traffic flow; consequently this is assessed as a **not significant effect**.

16.7.4.2 Operation of hydraulic fracturing equipment

90. The following assessment focusses on the pumping stage of the hydraulic fracturing process, as this is the period when the equipment generating the highest noise levels is in use. The pumping operates for around 3 hours per hydraulic fracturing stage. No noisy equipment is operated during the rest of the process.

91. Hydraulic fracturing pumping operations (the principal noise source for this stage) will not take place at night. Based on the measured data from hydraulic fracturing reported by

Spectrum Acoustics, the predicted noise levels during hydraulic fracturing pumping operations are illustrated in Appendix P and summarised in Table 16.1 and Table 16.3

92.

Receptor	Predicted noise level (dBL_{Aeq})	Week day and Saturday morning criteria* (dBL_{Aeq})	Criteria for weekday evening, Saturday (after 13.00hr), Sunday* (dBL_{Aeq})
1 – Plumpton Hall Farm	60	65	55
2 – Staining Wood Cottages	67	65	55

Table 16.13 Calculated noise levels from hydraulic fracturing

93. The predicted noise levels from the hydraulic fracturing pumping operations exceed the daytime and evening criteria at Staining Wood Cottages. At Plumpton Hall Farm (and therefore also at the more distant properties), the noise level is predicted to be below the daytime criterion but above the criterion for weekday evening and weekends.

94. Given the duration (approximately 3 hours), the small exceedence of the criterion and the small number of dwellings affected, combined with the existing traffic noise levels, hydraulic fracturing pumping operations are assessed as a **not significant effect** for weekday daytime and Saturday morning (07.00 to 13.00hrs) use**.**

95. A potential effect is indicated by exceedence of the weekday evening, Saturday (after 13.00hrs) and Sunday criteria. Noise from hydraulic fracturing pumping operations during weekday evenings, Saturdays (after 13.00hrs) or Sundays are assessed as a **significant effect**.

16.7.5 Initial Flow Testing

16.7.5.1 Off-site road traffic

96. The mobilisation and operation of the initial flow testing will require equipment, materials and personnel vehicle movements on local roads.

97. Table 16.14 shows the calculated worst case noise levels from the increase in traffic movements during initial flow testing.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without site	With initial flow testing related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.6	0.1

Table 16.14 Calculated noise levels from increased traffic flow during the initial flow testing

98. Table 16.14 shows a very small increase in traffic noise during initial flow testing. This is categorised as a negligible adverse impact and therefore is assessed as causing a **not significant effect**.

16.7.5.2 Operation of initial flow testing plant

99. The main noise sources will be a diesel engine associated with the service rig; a generator to supply the offices and site lighting; coiled tubing rig (for which a wheeled crane and idling truck have been used for source noise levels); and the flare stacks. The flares produce very low noise levels and can also be adjusted to reduce noise levels further by restricting the gas flow, or by shutting them down temporarily, if necessary.

100. Considering noise data from BS5228 (with the same specification as those in Table 16.8), without screening, would lead to 41dBL_{Aeq} at Staining Wood Cottages, which is well below the assessment criteria.

101. Noise from initial flow testing (excluding the flares) is therefore assessed as a **not significant effect**.

102. Noise from the flares is also predicted to be low (less than 20dBL_{Aeq}) at all dwellings, and is therefore assessed as a **not significant effect**.

16.7.6 Extended Flow Testing

16.7.6.1 Construction

103. Excavation and construction at the well pad for the pipeline connection to the gas grid would take place only during the day. An assessment of the construction noise has been made using the BS5228 methodology and typical plant. Table 16.15 presents the predicted noise levels.

Receptor	Predicted noise level (dBL_{Aeq})	Criteria (dBL_{Aeq})
1 – Plumpton Hall Farm	48	65
2 – Staining Wood Cottages	51	65

Table 16.15 Predicted noise levels from pipeline excavation for extended flow testing

104. The gas grid connection will also require excavation of a trench in the fields alongside Preston New Road, installation of the pipe and reinstatement. At the closest point to Staining Wood Cottages, assuming typical trenching and reinstatement plant, the predicted noise level is 66dBL_{Aeq}. This level would only exist for a short period as the works pass closest to the dwellings; the level will reduce as the distance increases.

105. The predicted noise levels resulting from excavation for the pipeline connection are below the thresholds stated in BS5228-1. Consequently these activities are assessed as a **not significant effect.**

16.7.6.2 Off-site road traffic

106. Table 16.16 shows the noise levels from traffic movements during extended flow testing. These levels would occur daily throughout this stage of the works.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without site	With extended flow testing related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.6	0.1

Table 16.16 Calculated noise levels from increased traffic flow during the extended flow testing

107. These effects are categorised as a negligible adverse impact and are unlikely to be significant. Noise from road traffic during extended flow testing is therefore assessed as a **not-significant effect.**

16.7.6.3 Operation of extended flow testing plant

108. The operation of the extended flow testing will require a small amount of gas processing plant on site and filling of HGV tankers to remove waste water from the Site for treatment. A small flare will be installed which would only be used very infrequently

109. The operation of the extended flow testing in terms of increased traffic flow and use of plant is assessed as a **not-significant effect**.

16.7.7 Decommissioning and Restoration

16.7.7.1 Off-site road traffic

110. Table 16.17 provides the predicted traffic noise levels alongside the roads during the worst case decommissioning and restoration works.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without site	With decommissioning and restoration operations related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.5	0.0

Table 16.17 Calculated worst case noise levels from increased traffic flow during decommissioning and restoration operations

111. Table 16.17 shows no increase in traffic noise during decommissioning and restoration works. This is categorised as a negligible adverse impact (see Table 16.2) and therefore is assessed as causing a **not significant effect**.

16.7.7.2 On-site works

112. Decommissioning and restoration of the site would require a variety of plant, including small scale earth moving equipment. The works would be of a similar scale and require similar plant and processes as those assessed for the construction of the site and well pad.

113. Noise from the decommissioning and restoration is therefore assessed as a **not significant effect.**

16.7.8 Assessment in terms of Government policy aims

114. The preceding sections consider the noise impacts in terms of the requirements of Environmental Impact Assessment. With regard to the Government policy aims, set out in Section 16.4.3:

- Noise from on-site activity is below the LOAEL for all works except:
  - night time drilling, which is 2dB above night time LOAEL at Staining Wood Cottages. However the existing traffic noise level is also above the night time LOAEL.
  - hydraulic fracturing pumping operations, which would exceed daytime and evening LOAEL at Staining Wood Cottages and would exceed evening LOAEL at Plumpton Hall Farm. In addition, the evening SOAEL would be exceeded at Staining Wood Cottages; this can be avoided by operating the pumping equipment only during daytime.
- Off-site road traffic leads to only very small increases in noise levels. Existing traffic noise levels at the Plumpton Hall Farm and Staining Wood Cottages currently exceed the LOAEL. The additional traffic generated by the Project does not increase traffic noise levels to the SOAEL.
- No on-site activity creates noise at or above SOAEL, as long as hydraulic fracturing pumping operations take place only in the weekday daytime and Saturday morning (as defined in Table 16.1).

115. In terms of Government noise policy aims (as defined in section 16.4.3), noise impacts would be minimised and there would be no significant adverse effects provided that hydraulic fracturing pumping operations are restricted to the times noted above.

16.8 Cumulative and Interactive Effects

16.8.1 In-combination effects

116. There will be periods when more than one of the operations assessed above will take place concurrently, although drilling will not be concurrent with hydraulic fracturing. In-combination operations could be:

- Drilling, initial flow testing and extended flow testing; and
- Hydraulic fracturing, initial flow testing and extended flow testing.

117. Extended flow testing may occur concurrently with drilling and hydraulic fracturing. Given that extended flow testing will give rise to low levels of noise, the contribution to the overall noise from the site, if operating concurrently with other activities, will be negligible.

118. Table 16.18 provides the predicted traffic noise levels alongside the roads during the worst case in-combination operations.

Location	Road traffic noise, $dBL_{Aeq,16hr}$		
	Without site	With in-combination operations related traffic	Change
Preston New Road (40mph section)	68.0	68.0	0.0
Preston New Road (50mph section)	69.5	69.6	0.1

Table 16.18 Calculated noise levels from increased traffic flow during in-combination operations

119. With reference to Table 16.2, these are categorised as a negligible adverse impact and are unlikely to be significant. Noise from traffic generated during the periods of in-combination operations is assessed as a not significant **effect**.

Noise from in-combination on-site operations

120. The addition of noise levels is logarithmic, so the combination of processes does not lead to large increases in the total noise. For example, two sources having the same noise level give rise to a total noise level 3dB higher than one of the sources individually. If the noise levels of two sources differ by 10dB or more, the combined level is the same as the higher level alone.

121. Since, at any of the dwellings, there is a greater than 10dB difference between the operations that will operate concurrently, the total noise levels will not be greater than those from the individual activities. Noise from on-site sources during in-combination operations is therefore assessed as a **not significant effect** (provided that hydraulic fracturing pumping operations only take place during the daytime and Saturday mornings (times as defined in *Bank holidays to be treated as Sundays

122. Table 16.1).

16.8.2 Combined operations

123. The Preston New Road exploration site is one of two sites that are currently being proposed, the other being at Roseacre Wood.

124. Given the distance separation of the sites being considered, there will be no cumulative or interactive significant effects arising as a consequence of noise associated with the concurrent operation of these sites. Access to and from the sites is by different routes so there is no significant cumulative traffic noise effect.

16.9 Mitigation Measures

125. Best practicable means (BPM) of working will be used during all stages to minimise noise from the site. This mitigation will be embedded within the works, even though the assessments show no significant effects from noise during the daytime. BPM measures will include but not be limited to:

- careful selection of plant and construction methods, with plant conforming to relevant national, EU or international standards, directives and recommendations on noise and vibration emissions permitted for use;
- careful programming so that activities which may generate significant noise are planned with regard to sensitive receptors;
- vehicles and mechanical plant used for the purpose of the work will be fitted with effective exhaust silencers and shall be maintained in good and efficient working order and operated to minimise noise emissions;
- all compressors and generators will be 'sound reduced' models fitted with properly lined and sealed acoustic covers which will be kept closed when in use;
- all machines in intermittent use will be shut down in the intervening periods between work or throttled down to a minimum. Lorry engines will be switched off when vehicles are stationary:

126. The tonal character of some reversing alarms makes them more likely to be perceived as disturbing. The site will be arranged to minimise reversing manoeuvres. Deliveries will generally be made during the daytime, except where programme-critical delivery is required. Vehicles based on the site will use broadband sounders rather than tonal reversing alarms.

127. Noise monitoring will be undertaken to ensure that noise emissions are reviewed and site operations controlled to minimise noise.

16.9.1 Construction of Well Pad and Access

Off-site road traffic

128. No mitigation is necessary as the noise from road traffic generated by the well pad and access road construction and operation has been assessed as not significant.

Construction

129. No mitigation is necessary as the noise from construction of the well pad and access road has been assessed as not significant.

16.9.2 Installation of Monitoring Works

Surface array

130. No mitigation is necessary as the noise from installation and operation of surface arrays has been assessed as not significant.

Buried array

131. No mitigation is necessary as the noise from installation of the buried array has been assessed as not significant.

Groundwater monitoring boreholes

132. No mitigation is necessary as the noise from installation and operation of monitoring boreholes has been assessed as not significant.

16.9.3 Drilling

Off-site road traffic

133. No mitigation is necessary as the noise from road traffic during the drilling works has been assessed as not significant.

Drilling

134. No specific mitigation is necessary as the noise from the drilling operation has been assessed as not significant.

135. While the effect of noise is assessed as not significant, noise will be minimised by best practicable means of working. As far as is practicable, fixed items of plant such as generators will be placed in screened positions to minimise noise emission in the direction of the dwellings, in particular to screen Staining Wood Cottages.

136. All plant equipment would be adequately maintained to minimise noise emissions.

16.9.4 Hydraulic Fracturing

16.9.4.1 Off-site road traffic

137. No mitigation is necessary as the noise from traffic generated by hydraulic fracturing has been assessed as not significant.

16.9.4.2 Hydraulic fracturing

138. No mitigation is necessary for noise from weekday daytime and Saturday mornings (as defined in *Bank holidays to be treated as Sundays

139. Table 16.1) hydraulic fracturing pumping operation, which have been assessed as a not significant effect.

140. The evening and night time (as defined in *Bank holidays to be treated as Sundays

141. Table 16.1) noise criteria would be exceeded by the hydraulic fracturing pumping operation. The most effective and efficient mitigation would be to manage the works so that fracturing pumps are operated only during weekday daytime and Saturday mornings.

16.9.5 Initial Flow Testing

16.9.5.1 Off-site road traffic

142. No mitigation is necessary as the noise from traffic generated by initial flow testing has been assessed as not significant.

16.9.5.2 Initial flow testing

143. No mitigation is necessary as the noise from flow testing has been assessed as not significant.

16.9.6 Extended Flow Testing

Construction

144. No mitigation is necessary as the noise level resulting from the excavation works associated with the pipe connection for the extended flow testing has been assessed as not significant.

Operation

145. No mitigation is necessary as the noise from extended flow testing operation has been assessed as not significant.

16.9.7 Decommissioning and Restoration

146. No mitigation is necessary as the noise from decommissioning and restoration of the well pad, access track and extended well testing infrastructure has been assessed as not significant.

16.10 Residual Effects

147. Noise from the Project is assessed as not significant for all stages. Provided that the hydraulic fracturing pumping operations are undertaken only during weekday daytime and Saturday mornings (as defined in Table 16.1), in which case there are no significant adverse residual effects from on-site activity.

148. No other residual adverse effect of noise has been identified.

16.11 Assessment Summary Matrix

Table 16.19. Assessment summary table.

Description of effect	Significance	Mitigation	Residual effect
Construction of the well pad and access			
Construction noise	**Not significant**	Not required	**Not significant**
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**
Installation of the monitoring works			
Installation of surface arrays	**Not significant**	Not required	**Not significant**
Installation of buried arrays	**Not significant**	Not required	**Not significant**
Drilling			
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**
Operation of drilling rig	**Not significant**	Not required	**Not significant**
Hydraulic fracturing			
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**

Description of effect	Significance	Mitigation	Residual effect
Hydraulic fracturing pumping operations (weekday daytime and Saturday morning* use only)	**Not significant**	Not required	**Not significant**
Hydraulic fracturing pumping operations (evening, night-time, weekends*)	**Significant**	Required – Only operate during the weekday daytime and Saturday mornings	**Not significant**
Initial flow testing			
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**
Operation of flow testing	**Not significant**	Not required	**Not significant**
Operation of flares	**Not significant**	Not required, but can be reduced or shut down if necessary	**Not significant**
Extended flow testing			
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**
Operation of extended flow testing	**Not significant**	Not required	**Not significant**
Decommissioning and restoration			
Decommissioning and restoration of exploration well, pad, access track and extended well testing infrastructure	**Not significant**	Not required	**Not significant**
Noise from increased traffic flow	**Not significant**	Not required	**Not significant**

*see *Bank holidays to be treated as Sundays

Table 16.1 for definition of the times

17 Resources and waste

Chapter Summary – Resource and Waste

This chapter is concerned with the quantity of waste generated by the different stages of the Project, how they are disposed of and, where relevant the availability of suitable waste treatment facilities for the different types of wastes that the Project will produce.

The quantity of inert, non-hazardous and hazardous waste generated by the Project (construction, drilling, hydraulic fracturing, initial and extended flow testing and decommissioning) will not result in a significant effect.

Likewise, the quantity of wastewater and industrial wastewater generated by the Project will not result in a significant effect.

However, although there is sufficient capacity to treat flowback fluid it is still anticipated to result in a significant effect because at peak times it will use up to 65% of the identified treatment capacity.

The cumulative effects of the Preston New Road and Roseacre Wood Projects will use up to 68% of the identified treatment capacity.

Embedded mitigation to reduce this effect includes re-using flowback fluid generated during the hydraulic fracturing stage for re-use back into the hydraulic fracturing process.

Additional measures to mitigate the effect have been developed and these include:

- Fracturing of wells at both Preston New Road and Roseacre Wood will be staggered to avoid increasing weekly wastewater production rates due to cumulative effects;
- Use of additional treatment capacity at facilities within northern England;
- Investigate the opportunity to invest in on site treatment to recycle flowback fluid and reduce the total volume of material removed from Site;
- Using the choke manifold to restrict the flow rate of fluid from the well;
- Temporarily store flowback fluids onsite to reduce the impact at the treatment facility; and

As a contingency case where flowback fluid treatment capacity was unavailable, the operation will be suspended until treatment capacity becomes available.

17.1 Introduction

1. This Chapter provides an assessment of the likely significant effects of waste generation during all stages of the Project. These effects are assessed in the context of relevant national, regional and local waste management legislation and policies as well as local, regional and national waste management treatment and disposal capacity.

2. The generation, transportation, treatment and disposal of waste can create environmental and health impacts including exposure to harmful materials, soil, air, ground and surface water pollution, odour, nuisance as well as contributing to climate change. The environmental effects of waste generated onsite are assessed within the hydrogeology and

contamination, water resources and air quality assessments and the results referenced in the resources and waste assessment.

3. Mitigation measures to reduce the quantity of waste generated, increase the re-use, recycling and recovery of materials and improve waste management are identified where feasible. Furthermore good practice waste management is recommended to protect public health and reduce the impact of the other environmental aspects identified above.

17.2 Development and key issues

4. Under the Environmental Permitting Regulations[340] the proposed management of extractive waste at the Site represent a Mining Waste Facility. Cuadrilla[341] has produced a Mining Waste Management Plan for the Project which will be submitted to the Environment Agency (EA) as part of an Environmental Permit Application for the Site. This plan demonstrates how Cuadrilla will manage key extractive waste streams at the Site during drilling, hydraulic fracturing and flow testing. These waste streams would include :

- Drilling muds;
- Drill cuttings;
- Cement;
- Flowback fluid[342];
- Fluids retained in the formation;
- Scale;
- Surplus natural gas; and
- Silica sand[343].

5. A draft Mining Waste Management Plan has been reviewed to identify the management of waste during the Project.

6. The precise composition of drilling mud used may differ at different drilling locations and when drilling at different depths in different strata. As a contingency it is likely that during the drilling phase Cuadrilla may use low toxicity oil based emulsion drilling muds (LTOBM) below the layer of the Manchester Marls. The LTOBMs operate in a closed loop system and at the conclusion of the Project are sent for re-use and therefore no LTOBM waste is generated during the Project. However drill cuttings will be contaminated by LTOBM and this waste stream will be classified as hazardous and stored onsite pending removal for treatment and/or disposal offsite by a licensed waste management contractor. Other types of drill muds that could potentially be used such as polymer based water drilling muds and the associated drill cuttings would be recovered offsite. All management, transportation and treatment of drilling muds and drill cuttings will meet the requirements of the environmental permit

7. Flowback fluid is likely to include minerals such as sodium, chloride, bromide, iron, magnesium, zinc, magnesium and lead. Flowback fluid is also likely to contain Naturally Occurring Radioactive Materials (NORM) which are returned to the surface following

[340] The Environmental Permitting (England and Wales) Regulations 2010 No. 675
[341] Cuadrilla (2014) Waste Management Plan
[342] In this chapter flowback fluid refers to fluid that is potentially contaminated with minerals and Naturally Occurring Radioactive Materials (NORM) and returned to the surface following well stimulation.
[343] Sand is injected into the target reservoir to act as a proppant as part of the composition of the hydraulic fracturing fluid.

well stimulation[344]. Flowback fluid during the hydraulic fracturing stage will be re-used directly back into the hydraulic fracturing process.

8. This will reduce the amount of flowback fluid waste requiring treatment as well as water consumption and transport movements. This activity would form part of the Waste Management Plan which will be part of the Mining Waste Environmental Permit application to the EA and with which Cuadrilla will be required to comply by the terms of its Environmental Permit for the mining waste operation..

9. Flowback fluid waste generated during initial and extended flow testing phases will be treated offsite at a specialist authorised facility as a low level radioactive waste. The disposal of radioactive wastes is regulated under Schedule 23 of the Environmental Permitting Regulations. Cuadrilla will apply for a radioactive substances activityenvironmental permit to manage radioactive substances associated with the flowback fluid which may contain NORM. As part of the application for a permit to manage flowback fluid, Cuadrilla has produced an RSR Waste Management Arrangements document which details how radioactive wastes would be managed and monitored[345].

10. Cuadrilla may also be required to transfer scale containing NORM and materials (such as sand) contaminated with NORM for disposal at a Low Level Waste (LLW) facility. Dissolved NORM can potentially form solid LLWs, such as scale that can accumulate inside pipes, treatment or storage tanks[346]. LLW contains radioactive materials other than those acceptable for disposal with municipal and general commercial or industrial waste. LLW contains small amounts of radioactivity. It is defined as radioactive waste having a radioactive content not exceeding four gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma radioactivity[347]. Cuadrilla does not anticipate that this would be a routine requirement, as only small amounts of solid NORM and scale related wastes are likely to be generated by each well for removal and disposal. This view is supported by the independent Environmental Risk Assessment undertaken by the EA[348].

11. After separation from the flowback fluid, extracted natural gas would be tested for its quality and composition. Surplus gas that remains after testing (during prospecting) is subsequently discarded by flaring and, at that point, becomes a waste in accordance with the revised Waste Framework Directive[349].

12. Cuadrilla will comply with a range of European Union, national, regional, county and local waste policy and legislation. There are a number of relevant key policies and legislation that seek to influence sustainable waste management. These include:

- Mining Waste Directive 2006/21/EC;
- The Waste Framework Directive 2008/98/EC;
- Industrial Emissions Directive 2010/75/EU;
- The Environmental Permitting (England and Wales) Regulations 2010;
- The Waste (England and Wales) Regulations 2011[350];

[344] Environment Agency (2011) *Shale Gas North West – Monitoring of Flowback Water*
[345] Cuadrilla Resources (2014) *Draft RSR Waste Management Arrangements*
[346] The Royal Society and The Royal Academy of Engineering (2012) *Shale gas extraction in the UK : a review of hydraulic fracturing*
[347] Environment Agency (2011) *Low Level Waste : Frequently asked questions*
[348] Environment Agency (2013) A*n Environmental Risk Assessment for shale gas exploratory operations in England*
[349] European Commission (EC) (2008) *Directive 2008/98/EC on waste (Waste Framework Directive)*
[350] The Waste (England and Wales) Regulations (2011) No.988

- The Environmental Protection Act 1990[351];
- The Environment Act 1995;
- The Hazardous Waste Regulations 2005[352];
- Government Review of Waste Policy in England in 2011[353];
- The Updated Regional Waste Strategy for England's North West February 2010[354];
- Strategy for the Management of Naturally Occurring Radioactive Material (NORM) waste in the United Kingdom[355]

17.3 Scoping and consultation

13. A Scoping Report was issued to Lancashire County Council Planning and Waste Disposal Departments as part of the EIA process (see Appendix C). In addition the Scoping Report was sent to onsultees, including the EA and United Utilities.

14. The waste chapter in the Scoping Report included a description of the baseline, identification of potential significant impacts due to the development and the assessment methodology. Table 17.1 below displays a summary of the responses, associated with waste, from key stakeholders.

Table 17.1: Waste scoping and consultation overview

Consultee	Comment	Response
Environment Agency	Information on waste generated through the installation of the buried array is not required under the Mining Waste Directive Permit.	This chapter has been amended appropriately.
	Table 9 identifies the waste streams likely to be generated by the Project. Identify the different types of waste that will be generated by the project and under which regime each waste identified will be regulated.	The key legislation covering different waste streams has been included in the chapter.
	The statement about NORM in flowback fluid only identifies it as an issue, without saying what will be considered or done to address this through the EIA.	The physical and radiological capacity to treat flowback and NORM is assessed in the chapter.
	Obtain a number of baseline NORM samples from the existing site as a reference for the surrender of any subsequent RSR permit.	Cuadrilla will obtain soil and surface water samples and assess NORM levels and carrying out NORM monitoring using mobile equipment for NORM

[351] The Environmental Protection Act 1990 c.43
[352] The Hazardous Waste Regulations 2005 No. 898
[353] Department for Environment Food and Rural Affairs (2011) *Government Review of Waste Policy in England in 2011*
[354] 4NW (2010) *The Updated Regional Waste Strategy for England's North West February 2010*
[355] The Scottish Government (2014) Strategy for the Management of Naturally Occurring Radioactive Material (NORM) waste in the United Kingdom: A consultation.

Consultee	Comment	Response
		contamination before, during and after operations.
Campaign to Protect Rural England	The way waste associated with the abandonment of the wells is to be managed is too vague.	The chapter takes into account all waste streams throughout the lifetime of the Project. The restoration phase considers all waste that would need to be removed to return the site back to its original environment. The environmental effects of the restoration, including the retained fluid, have been assessed within the Hydrogeology and Ground Gas Chapter (11).
	It is not sufficient to assume waste receiving facilities are in compliance with relevant EA permits and consents.	Third party waste treatment and disposal sites will operate under an Environmental Permit, issued by the EA. Key waste treatment contractors and facilities shall be subject to a Duty of Care[356] audit by Cuadrilla to ensure compliance with their Environmental Permit prior to the site receiving waste.

17.4 Methodology

17.4.1 Introduction

16. This section sets out the methodology that has been used to identify the current waste generation and treatment baseline, identify the scale of waste generation as a result of the Project, and to assess the significance of any effects, due to these changes.

17. In the absence of a regulatory prescribed methodology, the approach has been developed based on Arup's professional opinion, expertise and experience of waste assessments for EIAs. The approach considered the following aspects:

- The local, regional and national policy context for the management of waste;
- The existing conditions in terms of the types and quantities of waste currently generated at the Site and in the local and regional area;
- The existing and future waste management methods and infrastructure capacity in the sub-regional, regional and national area;
- Previous data established during the hydraulic fracturing at Preese Hall;
- Reference data from the shale gas industry in the USA;

[356] The Duty of Care (DoC) forms part of the Environmental Protection Act 1990 and associated amendments. The DoC requires waste producers to take all reasonable steps to ensure waste is managed correctly, recovered or disposed in a safe manner, does not cause environmental pollution or harm to human health and is only transferred to a person or persons who are authorised to receive it.

- The quantities of waste forecast to be generated across the lifecycle of the Project;
- A review of the Mining Waste Management Plan, including the proposed waste management options for the waste streams identified as well as alternative treatment measures in the event waste streams could not be treated by the proposed methods;
- The predicted impact on the capacity of the existing waste treatment and disposal infrastructure;
- The proposed restoration plan, in order to determine the likely waste generated and identify opportunities for sustainable resource and waste management measures to reduce waste generation; and
- Residual and cumulative effects, which have been assessed quantitatively where feasible.

18. The Project could have an effect on sub-regional, regional and national waste management infrastructure. Where waste could be treated or disposed in the sub-region (e.g. inert waste, non-hazardous waste and wastewater, etc.) the impact of this waste was assessed using sub-regional baseline data. Where waste would need to be treated or disposed nationally (e.g. flowback fluid and Low Level Waste) the impact of this waste was assessed using site specific baseline data.

19. This assessment measures the effects on existing waste infrastructure with respect to waste generation as a result of the Project, and the magnitude of this effect according to the amount of waste generated that would require offsite treatment or disposal to landfill.

20. The initial assessment of the likely significant environmental effects of the Project took into account the measures already specified at the design phase. Mitigation measures, designed to reduce waste generation and/or divert waste from treatment and landfill in accordance with the waste hierarchy, were suggested. These mitigation measures were influenced by national, regional and local waste management policy.

17.4.2 Sustainable waste management

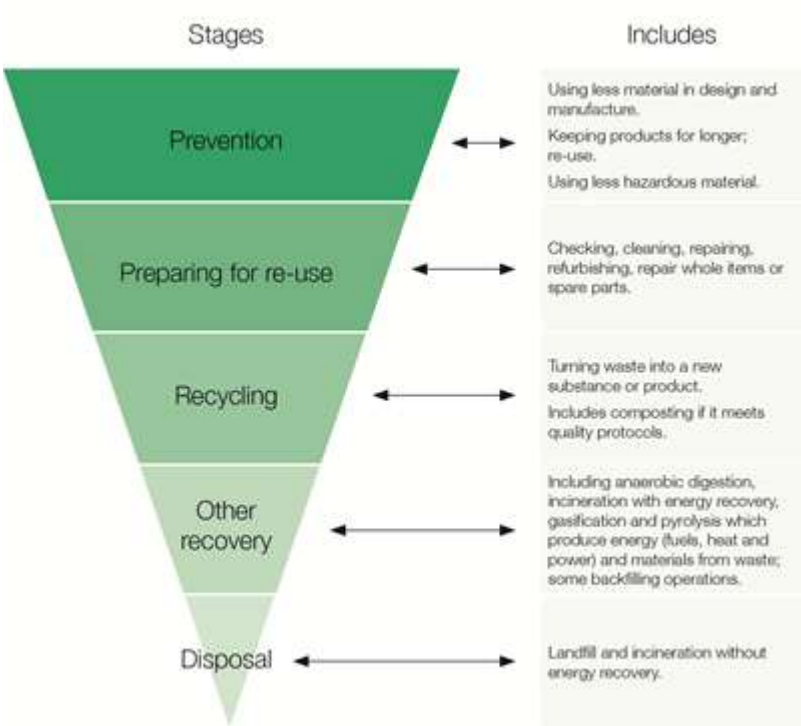
21. The principal objective of sustainable resource and waste management is to use material resources more efficiently, to reduce the amount of waste that is produced and manage waste that is produced more sustainably, thereby reducing the quantity requiring final disposal by landfill.

22. Where waste would be generated it should be managed in accordance with the waste hierarchy shown in Table 17.1 The waste hierarchy advocates, in the following order of preference:

- Prevention;
- Preparing for re-use;
- Recycling;
- Other recovery; and
- Disposal as a last resort.

23. Resource and waste management should actively contribute to the economic, social and environmental goals of sustainable development.

Figure 17.1: The Waste Hierarchy



17.4.3 Baseline methodology

24. Baseline information was obtained through a review of documentation provided by the EA [357] as well as information provided by Cuadrilla, United Utilities, Studsvik and Augean. This data is available in section **Error! Reference source not found.**

17.4.4 Assessment methodology for the effects from construction of the well pad and access track

25. Waste during this phase is typical of a construction project.

26. During construction clean soil would be generated through earthworks but these are not classified as waste. In addition concrete and mixed construction waste would be generated from the construction of the compound and associated infrastructure. The waste arisings generated during the construction of the well pad comprises of a number of waste streams as detailed in the Table 17.2 below.

Table 17.2: Waste streams generated through the construction of the well pad

Waste Stream	EWC Code	Category	Predicted Recovery/ Treatment / Disposal Method
Excavation materials e.g. soil, sub-soil, etc.		Non- waste	Re-use on site
Vegetation	17 02 01	Non-hazardous	Composted where feasible Residual waste to landfill
Concrete	17 01 01	Inert waste	Recovered offsite where feasible Residual waste to landfill
Mixed construction e.g. packaging, food, etc.	17 09 04	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility

[357] Environment Agency (2011) *North West – Waste Inputs and Capacity 2011* [online] available at http://www.environment-agency.gov.uk/research/library/data/132647.aspx#North_West

Waste Stream	EWC Code	Category	Predicted Recovery/ Treatment / Disposal Method
			Residual waste to landfill
Various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste Disposal Facility

27. All excavated materials, top soils and sub-soils, generated during the construction of the well pad would be included in the design for re-use on site to form bunds.

28. Concrete volumes for the construction of the well chamber have been estimated using data provided by Cuadrilla[358]. A recognised wastage rate has been applied to the likely quantity of concrete to be used in construction to estimate the volume of concrete waste. A wastage rate of 5% identified by the Waste and Resources Action Programme (WRAP)[359] for standard practice has been applied. The concrete volumes have been converted to tonnage using a conversion factor of 2.7 tonnes/m^3 developed by WRAP[360] for insitu C30 or higher concrete.

29. The volume of mixed construction waste has been calculated using benchmarking data from the Building Research Establishment (BRE) on behalf of WRAP[361]. A benchmark has been selected from the BRE data for Energy Utility projects which advocates that 0.46 tonnes of mixed construction waste would be produced for every £100,000 spent on a project. Generic data from the Institute of Directors has been used to estimate construction costs[362].

30. It is assumed that there would be no waste aggregates from the construction of the access track.

31. Hazardous wastes such as oil and diesel waste have not been assessed quantitatively due to the likelihood that only small quantities will be generated onsite. The environmental effects of hazardous substances were assessed within the Hydrogeology and Ground Gas Chapter (11).

32. Industrial wastewater from the pad has not been assessed during construction as the volume of surface water from the pad requiring treatment will be small.

33. Foul effluent has not been assessed during construction as there are few full time employees onsite for a small period of time. Therefore the volume of foul effluent at the Site will be small. This small amount of foul effluent will be sent to the local Wastewater Treatment Works (WwTWs) for appropriate treatment.

34. Predicted waste arisings generated during the construction of the well pad have been considered against the existing and future waste management methods and infrastructure capacity in the sub-region to assess the significant of the effect of the waste generated. The baseline used in the assessment for the construction of the well pad is detailed in section 17.6.

35. The assumptions and limitations made in the construction of the well pad waste calculations can be found in Appendix Q1.

[358] Cuadrilla (2013) *PEDL 165 Wells 2014-15*
[359] WRAP (2008) *Net Waste Tool Guide to Reference Data*
[360] Ibid.
[361] Building Research Establishment (BRE) on behalf of the Waste and Resources Action Programme (WRAP) (2013) *SMART Waste Data and Reporting*
[362] Institute of Directors (2013) *Getting Shale Gas Working*

17.4.5 Assessment methodology for the effects from installation of the surface and buried arrays

36. The waste streams generated during the installation of surface network and buried array are detailed in Table 17.3 below.

Table 17.3: Waste streams generated during the installation of surface network and buried array

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
Soil, stone	-	Non-waste	Re-use on site
Cement waste	17 05 01	Non-hazardous	Recycled where feasible Residual waste to landfill
Bentonite slurry	17 05 04	Non-hazardous	Treatment offsite Disposal at a specialist site for slurry
General waste e.g. packaging. paper, scrap-metal, etc.	20 03 01	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility Residual waste to landfill
Any contaminated materials from remediating oil or diesel spills, various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility

17.4.5.1 Ground water monitoring boreholes

37. There are three groundwater monitoring boreholes.

38. It is assumed that soil and stone from the installation of the groundwater monitoring boreholes would be re-used onsite.

39. Developing each of these groundwater monitoring boreholes will generate 3m^3 of bentonite slurry waste and 0.03 m^3 of cement waste.

17.4.5.2 Surface array

40. There are eight surface array stations.

41. It is assumed that soil and stone from the installation of the surface arrays would be re-used onsite and no waste would be exported offsite.

17.4.5.3 Buried array

42. There are 80 buried array stations.

43. It is assumed that soil and stone from the installation of the buried array would be re-used onsite.

44. Developing each of these buried arrays will generate 3m^3 of bentonite slurry waste and 0.03 m^3 of cement waste.

45. Cement waste and bentonite slurry have been estimated using quantitative and qualitative data provided by Cuadrilla[363].

46. The bentonite slurry has been converted to tonnage using a conversion factor of 1.06 tonnes/m^3 developed by Scottish Environment Protection Agency (SEPA)[364] for waste with the European Waste Catalogue (EWC) Code 17 05 04.

47. The cement volumes have been converted to tonnage using a conversion factor of 1.2 tonnes/m3 developed by WRAP for cement screed.

48. It is assumed that any small quantities of general waste generated during the installation of the array would be removed from the Site to a Cuadrilla site pending offsite disposal or will collected directly by their sub-contractors in compliance with legislation before the proper treatment or disposal.

49. Hazardous wastes such as oil waste have not been assessed quantifiably due to the small quantities generated onsite. The environmental effects of hazardous substances were assessed within the Hydrogeology and Ground Gas Chapter (11).

50. Predicted waste arisings generated during the installation of the surface network and buried array have been assessed against the existing and future waste management methods and infrastructure capacity in the sub-region. The baseline used in the assessment for the installation of surface network and buried array is detailed section 17.6.

51. The assumptions and limitations made in the installation of the surface network and buried array waste calculations can be found in Appendix Q2.

17.4.6 Assessment methodology for drilling

52. The types and quantities of waste forecast to be generated during the drilling phase were estimated by Cuadrilla and the assessment team. These waste arisings would comprise a number of waste streams as detailed in Table 17.4 below.

Table 17.4 : Waste streams generated through the drilling phase

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
Polymer based water drilling muds	01 05 04	Non-hazardous	Recycled offsite where feasible A small amount may be lost to formation Residual waste to specialist disposal facility
Drill cuttings used with polymer based water muds	01 05 04	Non-hazardous	Treatment at a specialist facility Residual waste to specialist disposal facility
Low-toxicity oil based emulsion drilling muds		Non-waste	Close loop system, muds are-reconditioned by the supplier for re-use A small amount may be lost to formation
Drill cuttings used with low-toxicity oil based emulsion	01 05 05*	Hazardous waste	Treatment as Hazardous Waste Residual waste to Hazardous

[363] Email from Cuadrilla to Arup 20 December 2013
[364] Scottish Environment Protection Agency (SEPA) (2002) *Density Conversion Factors*

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
muds			Waste disposal facility
Losses to formation	01 01 02	Non-hazardous / Hazardous	It is unlikely Cuadrilla will be able to recover losses to formation
Cement waste from the well casing	17 01 01	Non-hazardous	Recycled where feasible Residual waste to landfill
Spacer fluid	01 05 08	Non-hazardous	Treatment offsite and disposal at a specialist site for liquids
Any contaminated materials from remediating oil or diesel spills, various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
General waste e.g. paper, timber, scrap-metal, food waste	20 03 01	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility Residual waste to landfill
Wastewater (foul effluent)	20 03 06	Non-hazardous	Recovery at a local Wastewater Treatment Works
Industrial wastewater (rainwater captured by the pad during drilling)	20 03 04	Non-hazardous	Recovery for treatment at a local Wastewater Treatment Works

53. The waste forecast for the drilling phase is based on a vertical wellbore drilled from surface into the subsurface shale rock followed by horizontal wellbores section drilled laterally underground through the shale within the planning consent boundary.

54. The quantity of drill cuttings and drilling muds has been estimated using quantitative and qualitative data provided by Cuadrilla (see Appendix B). The composition of the drilling mud would not be confirmed until later in the Project. There are a number of drilling muds available to Cuadrilla[365] including:

- Drilling with air (reduces material consumption and waste);
- Polymer based water systems (non-hazardous with greater potential for re-use than bentonite based spud mud);
- Bentonite based spud mud (non-hazardous waste); and
- Low-toxicity oil-based emulsion muds (closed loop system minimises waste).

55. The drilling muds utilised by Cuadrilla would depend on the specific wellbore sections and their formation and drilling conditions. For the purposes of this assessment a mix of polymer based water muds and low-toxicity oil-based muds (LTOBM) have been assessed, as these represent two options that are most likely to be used by Cuadrilla. As required by the EA, only polymer based water muds will be used when drilling through sensitive groundwater-bearing formations.

56. The polymer based water drilling muds have been converted to a tonnage using a conversion factor of 1.48 tonnes/m^3 developed by SEPA[366] for waste with the EWC Code 01 05 04.

57. The drill cuttings covered with polymer based water muds have been converted to a tonnage using a conversion factor of 1.48 tonnes/m^3 developed by SEPA[367] for waste with the EWC Code 01 05 04.

[365] Cuadrilla (2013) *PEDL 165 Wells 2014-15*
[366] Scottish Environment Protection Agency (SEPA) (2002) *Density Conversion Factors*

58. The drill cuttings used with LTOBMs have been converted to tonnage using a conversion factor of 1.48 tonnes/m^3 developed by SEPA[368] for waste with the EWC Code 01 05 05*.

59. The environmental effects of the drilling muds, including the LTOBMs, have been assessed within the Hydrogeology and Ground Gas Chapter (11).

60. Drilling fluids are designed to minimise loss to the adjacent rock formations during drilling, although it is possible that some small losses into the formation will occur. Cuadrilla will seek to minimise such losses. Losses to formation have not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. Losses to formation are also included in the drfat Waste Management Plan[369].

61. The environmental effects of any losses to formation have been assessed within the Hydrogeology and Ground Gas Chapter (11).

62. Spacer fluid waste generated has also been estimated using data provided by Cuadrilla[370]. Spacer fluid is pumped into the wellbore to remove the drilling mud from the wellbore and prepare the wellbore for the cement. It is estimated that there would be 30m^3 of spacer fluid waste per well[371]. The spacer fluid waste have been converted to a tonnage using a conversion factor of 1.48 tonnes/m^3 developed by SEPA[372] for waste with the EWC Code 01 05 08.

63. Cement waste generated from the well casing have also been estimated using data provided by Cuadrilla[373]. It is estimated that there would be 20m^3 of cement waste per well. The cement volumes have been converted to tonnage using a conversion factor of 1.2 tonnes/m^3 developed by WRAP[374] for cement screed. Non-hazardous waste would be generated during drilling by the staff working onsite. The quantity of general waste generated by site staff has been estimated using the British Standards Institution's Waste Management in Buildings: Code of Practice (BS 5906:2005)[375].

64. It is estimated there would be 44 employees onsite during the drilling phase. The drilling phase would take place over approximately 400 days. The mass (tonnes) per employee has been converted to a volume (m^3) using a conversion factor for general industrial waste of 0.4 tonnes/per m^3 produced by the HM Revenue and Customs[376].

65. The proportion of general waste likely to require treatment has been determined by assuming that the total quantity of general waste to be recycled would be the same as the target for re-use, composting and recycling in the *Updated Waste Strategy for England's North West.* Therefore, it has been assumed that 55 per cent of general waste would be recycled.

66. Hazardous wastes such as used spill kits contaminated with oil or diesel have not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be

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[367] Ibid.
[368] Ibid.
[369] Cuadrilla (2014) Draft Waste Management Plan.
[370] Cuadrilla (2014) Comments by Cuadrilla 01/02/2014
[371] Cuadrilla (2014) Draft Waste Management Plan.
[372] Scottish Environment Protection Agency (SEPA) (2002) *Density Conversion Factors*
[373] Cuadrilla (2014) Comment from Cuadrilla Resources on 11 March 2014
[374] WRAP (2008) *Net Waste Tool Guide to Reference Data*
[375] British Standards Institution (2005) *Waste Management in Buildings: Code of Practice (BS 5906: 2005)*
[376] HM Revenue and Customs (2012) *Notice LFT1 – A general guide to landfill tax*

generated onsite. The environmental effects of hazardous substances have been assessed within the Hydrogeology and Ground Gas Chapter (11).

67. The interceptor valve on the well pad would be closed during drilling and the rainfall captured by the pad during drilling would be tankered off site to United Utilities treatment facilities at the Davyhulme or Blackburn WwTWs[377]. The quantity of rainfall captured by the pad during drilling has been estimated using average rainfall information for the drilling period, extracted from the catchment descriptors in Flood Estimation Handbook (FEH)[378].

68. The quantity of foul effluent generated during flow testing has been estimated using data from British Water[379].

69. The assumptions and limitations made in the drilling waste calculations can be found in Appendix Q3.

70. Waste arisings generated during the drilling phase have been considered against the existing and future waste management methods and infrastructure capacity in the sub-regional to assess the significance of the effect of the waste generated. The baseline used in the assessment for the drilling phase is detailed in section 17.6.

17.4.7 Assessment methodology for hydraulic fracturing

71. Non-hazardous, hazardous, radioactive waste and wastewater would be generated from the hydraulic fracturing process and by the staff working onsite. The types and quantities of waste forecast to be generated during the hydraulic fracturing phase were estimated by Cuadrilla and the assessment team.

72. The waste stream likely to be produced are summarised in Table 17.5 below.

Table 17.5: Waste streams generated through the hydraulic fracturing phase

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
Flowback fluid	01 01 02	Radioactive – Non-hazardous380	Re-use onsite
Sand	01 04 09	Non-hazardous	Recycled into secondary aggregates
Solid scale	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Materials and equipment contaminated by NORM	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Surplus natural gas	16 05 04*	Hazardous	Flared onsite

[377] This treatment has tentatively been approved by United Utilities, however it is still subject to their formal approval.
[378] FEH CD-ROM database (Version 3) 2009
[379] British Water (2009) *Code of Practice Flows and Loads - 3 Sizing Criteria, Treatment Capacity for Sewage Treatment Systems*
[380] Sampling and analysis will be performed on flowback fluids in order to ensure appropriate classification and adequate handling and disposal. However it anticipated that the flowback fluids will be similarly classified as radioactive waste with non-hazardous composition.

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
		waste (Highly Flammable)	
Any contaminated materials from remediating oil or diesel spills, oil from separators, various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
General waste e.g. paper, timber, scrap-metal, food waste	20 03 01	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility Residual waste to landfill
Wastewater (foul effluent)	20 03 06	Non-hazardous	Recovery at a local Wastewater Treatment Works
Industrial wastewater (rainwater captured by the pad during hydraulic fracturing)	20 03 04	Non-hazardous	Recovery at a local industrial Wastewater Treatment Works

73. Flowback fluid generated during the hydraulic fracturing stage will be re-used back into the hydraulic fracturing process and will not be a waste at this stage. Therefore the infrastructure and capacity to treat flowback fluid from the hydraulic fracturing phase has not been assessed.

74. It is highly unlikely, due to the short term nature of the operations that any significant scale will build up inside equipment. Therefore solid scale has not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. A radioactive substances activity permit application is being submitted to manage the accumulation and disposal of waste scale.

75. Although not expected from this exploratory project, materials such as sand could be contaminated with NORM during the hydraulic fracturing phase. It is estimated that a worst case volume of 20 m^3 of solid LLW could potentially be generated across the Project. This information has been provided by Studsvik[381]. The estimated radioactivity associated with the solid LLW that could potentially be generated has also been provided by Studsvik. The solid LLW generated across the Project has been included in the Cumulative Assessment in section 17.7.9.6.

76. The interceptor valve on the well pad would be closed during hydraulic fracturing. The rainfall captured by the pad during hydraulic fracturing would be tankered off site to United Utilities treatment facilities at the Davyhulme or Blackburn WwTWs[382]. The quantity of rainfall captured by the pad during hydraulic fracturing has been estimated using average rainfall information for the hydraulic fracturing period, extracted from the catchment descriptors in Flood Estimation Handbook (FEH)[383].

77. The estimated quantity of daily rainfall captured by the pad during hydraulic fracturing that would be tankered off site for treatment has been compared to the baseline capacity detailed in section 17.6.

[381] Studsvik (2014) *Email from Studsvik to Cuadrilla 19/03/2014*
[382] This treatment has tentatively been approved by United Utilities however it is still subject to their formal approval.
[383] FEH CD-ROM database (Version 3) 2009

78. The quantity of foul effluent generated during the hydraulic fracturing phase has been estimated using data from British Water[384]. The estimated quantity of foul effluent generated during hydraulic fracturing that would be tankered off site for treatment has been compared to the baseline capacity detailed in section 17.6.

79. The assessment of waste during hydraulic fracturing is based on the following assumptions:

- The quantity of foul effluent generated has been estimated using data from British Water[385];
- The volume of sand waste likely to be generated by the Project has been calculated using information provided by Cuadrilla[386];
- Non-hazardous waste would be generated by the staff working onsite. The quantity of general waste generated by site staff has been estimated and assessed using the same approach as the drilling phase as detailed above;
- It is estimated there would be an average of 21 full time employees onsite during the hydraulic fracturing mobilisation phase;
- The hydraulic fracturing mobilisation phase would take place over approximately 32 days (8 days per well);
- It is estimated there would be an average of 30 employees onsite during the hydraulic fracturing phase; and
- The hydraulic fracturing phase would take place over approximately 178 days in total.

80. Hazardous wastes such as used spill kits contaminated with oil or diesel have not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. The potential environmental effects of hazardous substances have been assessed within the Hydrogeology and Ground Gas Chapter (11).

81. The potential environmental effects of redundant hydraulic fracturing fluid which has flowed backed to the surface have been assessed within the Hydrogeology and Ground Gas Chapter (11).

82. Natural gas that is produced during hydraulic fracturing would be flared onsite, therefore there is unlikely to be any issues relating to capacity. The environmental effects of the natural gas combustion, and any potential effects on air quality and human health, are assessed within the air quality assessment in Chapter 6.

83. Waste arisings generated during the hydraulic fracturing phase would be assessed against the existing and future waste management methods and infrastructure capacity in the sub-region and nationally.

84. The impact of waste that would need to be treated or disposed nationally (e.g. flowback fluid and Low Level Waste) was assessed using site specific baseline data. The baseline used in the assessment for hydraulic fracturing is detailed in section 17.6.

85. The assumptions and limitations made in the hydraulic fracturing waste calculations can be found in Appendix Q4.

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[384] Ibid.

[386] Cuadrilla (2014) *Waste Management Plan*

17.4.8 Assessment methodology for initial flow testing

86. Non-hazardous, hazardous and radioactive waste would be generated during the flow testing phase. The types and quantities of waste forecast to be generated during the flow testing phase were estimated by Cuadrilla and the assessment team. Waste arisings generated during flow testing comprise a number of waste streams as detailed in Table 17.6.

Table 17.6: Waste streams generated through flow testing

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
Flowback fluid	01 01 02	Radioactive Waste-Non-hazardous	Flowback fluid is recovered offsite at specialist sites
Sand	01 04 09	Non-hazardous	Recycled into secondary aggregates
Solid scale	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Materials and equipment contaminated by NORM	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Any contaminated materials from remediating oil or diesel spills, oil from separators, various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
General waste e.g. paper, timber, scrap-metal, food waste	20 03 01	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility Residual waste to landfill
Surplus natural gas	16 05 04*	Hazardous (Highly Flammable)	Flared onsite
Wastewater (foul effluent)	20 03 06	Non-hazardous	Recovery at a local Wastewater Treatment Works
Industrial wastewater (rainwater captured by the pad during flow testing)	20 03 04	Non-hazardous	Recovery at a local Wastewater Treatment Works

87. Non-hazardous waste would be generated from the flow testing phase by the staff working onsite. The quantity of general waste generated by site staff has been estimated and assessed using the same approach as the drilling phase as detailed in 48.

88. The estimated volume (m^3) of flowback fluid that would be generated from the flow testing phase has been provided by Cuadrilla 387. This data assumes that 40% of the total hydraulic fracturing fluid injected will return as flowback fluid.

89. The quantity of flowback fluid generated during flow testing that would be tankered off site for specialist treatment has been assessed using the maximum weekly volume produced by the Project. This peak weekly volume produced onsite has been compared to the baseline capacity at the specialist sites detailed in section 17.6.

[387] Cuadrilla (2014*) 4 Wells Combined - With Reuse- Rev 5*

90. The assessment has been undertaken using the assumption that flowback fluid arising during the flow testing phase, would need to be tankered offsite as wastewater.

91. The estimated radionuclide content associated with the NORM in the flowback fluid that would be generated from the flow testing phase has been provided by Studsvik 388. The estimated data is based on the monitoring undertaken by the Environment Agency and Cuadrilla.

92. The Average Specific activities adopted for Radium-226 and Radium-228 are 29 Bq/l and 7 Bq/l respectively. The Average Specific Activity has been selected as this is considered more representative of the majority of flowback fluid waste which will be generated[389]. The radionuclide content has been assessed against the variable, peak daily volumes produced during flow testing across all proposed wells and has been compared to the baseline capacity.

93. It is highly unlikely, due to the short term nature of the operations that any significant scale will build up inside equipment. Therefore solid scale has not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. A radioactive substances activity permit application is being submitted to manage the accumulation and disposal of waste scale.

94. Although not expected from this exploratory project materials such as sand could be contaminated with NORM during the flow testing phase. It is estimated that a worst case volume of 20 m^3 of solid LLW could potentially be generated across the Project. This information has been provided by Studsvik[390]. The estimated radioactivity associated with the solid LLW that could potentially be generated has also been provided by Studsvik. The solid LLW generated across the Project has been included in the Cumulative Assessment in section 17.7.9.6.

95. Hazardous wastes such as used spill kits contaminated with oil or diesel have not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. The environmental effects of hazardous substances were assessed within the Hydrogeology and Ground Gas Chapter (11).

96. The assessment of flow testing activities are based on the following assumptions:

- The volume of sand waste likely to be generated by the Site has been calculated using information provided by Cuadrilla[391];
- There would be 11 employees onsite during the flow testing phase; and
- The flow testing phase would take place over approximately 408 days (102 days per well).

97. The interceptor valve on the well pad would be closed during flow testing. It is possible that large quantities of the estimated surface water runoff could be re-used onsite, however this process has not been finalised by Cuadrilla. Therefore the quantity of rainfall captured by the pad during flow testing would be tankered off site to United Utilities[392] treatment facilities at the Davyhulme or Blackburn WwTWs. The quantity of

[388] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[389] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[390] Studsvik (2014) *Email from Studsvik to Cuadrilla 19/03/2014*
[391] Cuadrilla Resources (2014) Draft *Waste Management Plan*
[392] This treatment has tentatively been approved by United Utilities, however it is still subject to their formal approval.

rainfall captured by the pad has been estimated using average rainfall information for the flow testing period, extracted from the catchment descriptors in FEH[393].

98. The estimated quantity of daily rainfall captured by the pad during flow testing that would be tankered off site for treatment has been compared to the baseline capacity detailed in section 17.6.

99. The quantity of foul effluent generated during the flow testing phase has been estimated using data from British Water[394]. The estimated quantity of foul effluent generated during flow testing that would be tankered off site for treatment has been compared to the baseline capacity detailed in section 17.6.

100. The assumptions and limitations made in the flow testing waste calculations can be found in Appendix Q5.

101. Waste arisings generated during the flow testing phase would be assessed against the existing and future waste management methods and infrastructure capacity in the sub-region.

102. Waste arisings that would need to be treated or disposed nationally (e.g. flowback fluid and Low Level Waste) has been assessed against site specific data.

103. The baseline used in the assessment for the flow testing phase is detailed in section 17.6.

17.4.9 Extended flow testing effects

104. The types and quantities of waste forecast to be generated during the extended well testing were estimated by Cuadrilla[395].Waste arisings generated during the extended well testing phase comprise a number of waste streams as detailed in Table 17.7 below.

Table 17.7 : Waste streams generated through the extended well testing phase

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
Flowback fluid	01 01 02	Radioactive – Non hazardous	Flowback fluid is recovered offsite at specialist sites
Solid scale	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Materials and equipment contaminated by NORM	01 05 06*	Radioactive Waste –Low Level Waste (LLW)	Augean Low Level Waste (LLW) facility
Any contaminated materials from remediating oil or diesel spills, oil from separators, various waste oils and lubricants	13 08 00	Hazardous	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste Disposal Facility
General waste- e.g. paper, timber, scrap-	20 03 01	Non-hazardous	Recycling where feasible onsite Materials Recovery Facility

[393] FEH CD-ROM database (Version 3) 2009
[394] Ibid.
[395] Data from Cuadrilla (2014)

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method
metal, food waste			Residual waste to landfill
Wastewater (foul effluent)	20 03 06	Non-hazardous	Recovery at a local Wastewater Treatment Works
Wastewater Industrial wastewater (rainwater captured by the pad)	20 03 04	Non-hazardous	Discharge to off-site watercourse during Extended Flow Testing

105. The assessment of extended flow testing activities are based on the following assumptions:

- There would be one full time employee onsite during the extended flow testing phase;
- The extended flow testing phase would take place over approximately 730 days per well; and
- Due to the overlapping of phases the extended well testing phase lasts 1,273 days (excluding the connection to the gas mains).

106. The estimated volume (m^3) of flowback fluid that would be generated from the extended flow testing phase has been provided by Cuadrilla[396]. The quantity of flowback fluid generated during extended flow testing that would be tankered off site for specialist treatment has been assessed using the maximum weekly volume produced by the Site. This peak weekly volume produced onsite has been compared to the baseline capacity detailed in section 17.6.

107. The estimated radionuclide content associated with the NORM in the flowback fluid that would be generated from the flow testing phase has been provided by Studsvik [397]. The estimated data is based on the monitoring undertaken by the Environment Agency and and Cuadrilla. The Average Specific activities adopted for Radium-226 and Radium-228 are 29 Bq/l and 7 Bq/l respectively.

108. The Average Specific Activity has been selected as this is considered more representative of the majority of flowback fluid waste which will be generated[398]. The radionuclide content has been assessed against the variable, peak daily volumes produced during extended flow testing across all proposed wells and has been compared to the baseline capacity.

109. It is highly unlikely, due to the short term nature of the operations that any significant scale will build up inside equipment. Therefore solid scale has not been assessed quantitatively in the Waste Chapter due to the negligible quantities likely to be generated onsite. A radioactive substances activity permit is being submitted to manage the accumulation and disposal of waste scale.

110. Although not expected from this exploratory project materials such as sand could be contaminated with NORM during the extended flow testing phase. It is estimated that a worst case volume of 20 m^3 of solid LLW could potentially be generated across the

[396] Data from Cuadrilla (2014)

[397] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[398] Studsvik (2014) *Waste Capacity Assessment Draft 4*

Project. This information has been provided by Studsvik[399]. The estimated radioactivity associated with the solid LLW that could potentially be generated has also been provided by Studsvik. The solid LLW generated across the Project has been included in the Cumulative Assessment in section 17.7.9.6.

111. Non-hazardous domestic waste would be generated from extended flow testing process by the staff working onsite. The quantity of general waste generated by site staff has been estimated and assessed using the same approach as the drilling phase as detailed in 48.

112. Hazardous wastes such as used spill kits contaminated with oil or diesel have not been assessed quantifiably in the Waste Chapter due to the negligible quantities likely to be generated onsite. The environmental effects of hazardous substances were assessed within the Hydrogeology and Ground Gas Chapter (11).

113. Industrial wastewater from the pad has not been assessed during extended flow testing as the volume of surface water from the pad requiring treatment will be small as the interceptor valve will be open during extended flow testing. This water will be sent to the local watercourse unless there is an unplanned spill, in which case the valve would be closed and the waste water tankered offsite for appropriate treatment.

114. The quantity of foul effluent generated during the extended flow testing phase has been estimated using data from British Water[400]. The estimated quantity of foul effluent generated during flow testing that would be tankered off site for treatment has been compared to the baseline capacity detailed in section 17.6.

115. The assumptions and limitations made in the extended flow testing waste calculations can be found in Appendix Q6.

116. Waste arisings generated during the extended flow testing phase would be assessed against the existing and future waste management methods and infrastructure capacity in the sub-region.

117. Waste arisings that would need to be treated or disposed nationally (e.g. flowback fluid and Low Level Waste) has been assessed against site specific data. The baseline used in the assessment for the extended flow testing phase is detailed section 17.6.

17.4.10 Assessment methodology for decommissioning and restoration effects

17.4.10.1 Decommissioning and Restoration

118. The basis for the calculation of waste arisings from works to restore the Site to its previous state. Waste arisings generated during the decommissioning and restoration comprise of a number of waste streams as detailed in the Table 17.8 below.

Table 17.8 : Waste streams generated through the restoration phase

Waste Stream	EWC Code	Category	Predicted Recovery/Treatment/Disposal Method

[399] Studsvik (2014) *Email from Studsvik to Cuadrilla 19/03/2014*
[400] Ibid.

Retained hydraulic fracturing fluid	**01 01 02**	**Radioactive - Non-hazardous**	**Mining waste disposal facility**
Clean aggregates	17 05 00	Inert	Re-used offsite
Contaminated aggregates	17 05 03	Hazardous waste	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
Pad surface-Impermeable Membrane – HDPE Liner	17 02 03	Non-hazardous	Recycled offsite
Contaminated pad surface-Impermeable Membrane – HDPE Liner	17 09 03	Hazardous waste	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
Pad surface-Geotextile Liner	17 09 00	Non-hazardous	Recovery offsite where feasible Residual waste to landfill
Contaminated pad surface-Geotextile Liner	17 09 03	Hazardous waste	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
Pad surface-Felt Liner	17 09 00	Non-hazardous	Recovery offsite where feasible Residual waste to landfill
Contaminated pad surface-Felt Liner	17 09 03	Hazardous waste	Treatment as Hazardous Waste Recovery where feasible Residual waste to Hazardous Waste disposal facility
Concrete	17 01 01	Inert	Recycled offsite

119. The amount of decommissioning waste has been estimated by the assessment team and is based on the data used for the construction phase.

120. Multiple stage hydraulic fracturing within the target formation has the potential for fluid injected into the formation to flowback completely over the period of operations. However depending on the geologic characteristics of the formation, some of the injected fluid maybe retained within the target formation. The remaining fluids have not been assessed quantifiably in the Waste Chapter, however, the environmental effects are considered in the the Hydrogeology and Ground Gas Chapter (11) as well as the draft Waste Management Plan as forming part of the Environmental Permit application to the EA.

121. It is possible that a small proportion of the well pad, liner and membrane would be hazardous waste as it may be potentially contaminated during the drilling, hydraulic fracturing, flow testing phase and extended flow testing phase. Any contamination would be from an unplanned spill of hazardous substances used or generated as part of the process (as indicated above) and thecontaminated wellpad, liner and membrane materials would be managed as hazardous waste. Therefore the following assumptions have been applied to the waste estimations:

- 95% of the sub-base aggregates would be re-used on another site;
- 95% of the other sub-base material and liners that formed the pad would be recycled;
- 5% of the sub-base aggregates, material and liners that formed the pad would be disposed as hazardous waste; and

- 100% of the concrete chamber would be recycled.

122. The aggregates have not been assessed in the waste assessment as these clean aggregates will be re-used without the need for treatment.

123. The waste from the geotextile liner and the felt liner have not been assessed in the Waste Chapter due to the small quantities generated onsite.

124. It is assumed that aggregates from the access track will be re-used without the need for treatment

125. General waste has not been assessed during restoration as there are few full time employees onsite for a short period of time therefore only small quantities of general waste will be generated. This small amount of general waste will be sent for appropriate treatment and disposal.

126. Industrial wastewater from the pad has not been assessed during restoration as the pad will be in the process of being removed.

127. Foul effluent has not been assessed during restoration as there are few full time employees onsite for a short period of time. Therefore the volume of foul effluent at the Site will be small. This small amount of foul effluent will be sent to the local WwTWs for appropriate treatment.

128. The assumptions and limitations made in the restoration waste calculations can be found in Appendix Q7.

129. Waste arisings generated during the restoration phase would be assessed against the existing and future waste management methods and infrastructure capacity in the sub-region. The baseline used in the assessment for the restoration phase is detailed in section 17.6.

17.4.11 Significance criteria

130. Significance criteria used for the assessment of the likely significance of the environmental effects of solid waste generation are shown in Table 17.9 below. These have been developed using professional judgement and take into account:

- The availability of treatment, recovery and landfill capacity in the local, sub regional and regional areas; and
- The magnitude of the quantity of waste requiring treatment, recovery and disposal.

131. In terms of the EIA Regulations a significant effect is one assessed as being of moderate or greater significance.

Table 17.9: Waste significance

Percentage Waste Generation Relative to Local / Regional Capacity	Significance	Criteria
>10%	Very Substantial Significant	Severe permanent reduction in landfill void space capacity on a local and regional scale. Need for large-scale waste treatment facilities to protect against adverse environmental effects.
5-10%	Substantial Significant	Major, local-scale reductions in landfill void space capacity. Need for appropriate waste treatment facilities to protect against adverse environmental effects.
2-5%	Moderate Significant	Moderate, local-scale reductions in landfill void space capacity. Need for medium-scale waste treatment facilities to protect against adverse environmental effects.
1-2%	Slight Not significant	Slight local scale reductions in landfill void space capacity reversible with time. Need for small-scale waste treatment facilities to protect against adverse environmental effects.
<1%	Negligible Not significant	No appreciable adverse effects to waste infrastructure.
0%	No impact Not significant	No impact is predicted.
<0%	Beneficial	Reduction in waste generation and diversion of waste from landfill resulting in an environmental improvement. Scale of beneficial impact in relation to the scale of detrimental impacts.

17.5 Assumptions and Limitations

17.5.1 Assumptions

132. This assessment is based on the following assumptions:

- Project data is provided in Appendix B;
- Excavated materials from the construction of the well pad would be re-used onsite and would not be exported offsite as waste;
- Soil and stone from the installation of surface network and buried arrays would be re-used onsite and no waste would be exported offsite;
- Flowback fluid during the hydraulic fracturing stage will be re-used back into the hydraulic fracturing process;
- Flowback fluid generated during the flow testing and extended flow testing phases will be treated offsite as a radioactive waste; and
- No significant waste would be generated during suspension. Therefore suspension waste has been scoped out of the assessment.

17.5.2 Limitations

133. The assessments are based on the best information about the Project available at the time of the assessment.

17.6 Baseline

17.6.1 Site baseline

134. The location of the Site and array locations do not currently produce any waste since there are no waste generating activities taking place. The baseline in terms of existing waste generation is, therefore, considered to be zero.

17.6.2 Future construction infrastructure capacity within the local and regional area

17.6.2.1 Landfill

135. The latest available information with respect to the capacity of existing landfill sites in Lancashire was identified from the EA's North West Waste Inputs and Capacity 2011[401]. The existing range of landfill capacity available in Lancashire is shown in Table 17.10. This was based on the latest available published information from the EA[402].

Table 17.10 : Landfill Capacity for Lancashire in 2011

Facility Type	Capacity (m3)
Hazardous Landfill403	310,000
Non-hazardous Landfill404	10,365,000
Inert Landfill	313,000
Total Landfill	10,988,000

136. Table 17.10 displays the total available capacity of non-hazardous landfill in Lancashire in 2011 estimated to be 10,365,000 m^3. It was anticipated that various types of waste

[401] Environment Agency (2011) *North West Waste Inputs and Capacity 2011*
[402] Ibid.
[403] Includes hazardous merchant landfill and hazardous restricted landfill.
[404] Includes non-hazardous landfill with stable non-reactive hazardous waste cell (usually a small proportion of overall site capacity), non-hazardous landfill and non-hazardous restricted landfill.

infrastructure capacity would continue to be available in Lancashire during the Project period (2014 onwards).

137. Table 17.11 below displays the projected inert, non-hazardous and hazardous landfill disposal capacity for Lancashire from 2011 to 2016. It also displays the projected landfill disposal capacity for the North West of England region, to which waste generated by the Project could be taken.

Table 17.11: Projected Landfill Disposal Capacity in Lancashire and the North West of England[405]

Year	Non-hazardous landfill capacity (m3)		Inert landfill capacity (m3)		Hazardous landfill capacity (m3)	
	North West	Lancashire	North West	Lancashire	North West	Lancashire
Input rates (2011)	4,941,563	1,020,920	354,400	64,800	127,586	31,034
2011	51,007,000	10,365,000	13,885,000	313,000	5,245,000	310,000
2012	46,065,437	9,344,080	13,530,600	248,200	5,117,414	278,966
2013	41,123,874	8,323,161	13,176,200	183,400	4,989,828	247,931
2014	36,182,310	7,302,241	12,821,800	118,600	4,862,241	216,897
2015	31,240,747	6,281,322	12,467,400	53,800	4,734,655	185,862
2016	26,299,184	5,260,402	12,113,000	-11,000	4,607,069	154,828

138. The projected landfill disposal capacities displayed in Table 17.11 assume an annual reduction of void capacity for each class of landfill equivalent to the annual input rates for 2011. It also assumed that 2011 landfill input levels would remain constant without any further increase in non-landfill capacity.

17.6.2.2 General Treatment Capacity in Lancashire

139. The latest available information with respect to the capacity of treatment capacity in Lancashire was been identified from the EA's North West Waste Inputs and Capacity 2011[406]. The treatment inputs in Lancashire are displayed in Table 17.12.

Table 17.12: Treatment Inputs for Lancashire in 2011

Facility Type	Inputs (tonnes)
Treatment	1,329,000
Metal recycling	119,000
Total Treatment Capacity	1,448,000

140. The total available treatment capacity in Lancashire in 2011 was estimated to be 1,448,000 tonnes. The EA had no capacity forecast available for future years.

17.6.2.3 Flowback fluid treatment capacity

141. Cuadrilla has identified existing facilities in the north of England to treat flowback fluid. These treatment facilities cannot be identified in the assessment due to commercial constraints However once commercial contracts have been established the treatment

[405] Environment Agency (2011) *North West Waste Inputs and Capacity 2011*
[406] Ibid

facilities shall be made available to the public. The treatment facilities for flowback fluid along with their physical capacities are shown in Table 17.13.

Table 17.13 : Physical capacity of flowback fluid treatment facilities

Site	Daily			Weekly		
	Tonnes	m3	Litres	Tonnes	m3	Litres
Treatment Site A	300	300	300,000	2,100	2,100	2,100,000
Treatment Site B	120	120	120,000	600	600	600,000
Total Capacity	420	420	420,000	2,700	2,700	2,700,000

142. Treatment Site A operates seven days a week. Treatment Site A sporadically receives radioactive waste from another source which could potentially reduce the capacity of the site whilst waste from that other source is being treated. There is no capacity data available for future years.

143. Treatment Site B operates Monday to Friday. Treatment Site B does not currently receive any radioactive waste from other sources.

144. Cuadrilla has also been in discussions with additional offsite treatment facilities who are currently in the process of applying for an environmental permit to treat flowback fluid.

17.6.2.4 Flowback fluid radioactivity capacity limits

145. The baseline radioactivity capacity limits at Treatment Site A is displayed in Table 17.14 as provided by Studsvik[407] and included in the Project's RSR Permit application.

Table 17.14 : Radioactivity accumulation and disposal capacity of Treatment Site A

Nuclide Type	**Activity Limit (MBq)**	**Permitted Limits (Volume and timescale)**
Accumulation		
Radium (Ra)-226	189	1500 m3 14 days
Ra-228	220	
Lead (Pb)-210	189	
Disposal		
Ra-226	141	1 Month
Ra-228	125	
Pb-210	141	

146. The baseline radioactivity capacity limits at Treatment Site B is displayed in Table 17.15 as provided by Studsvik[408] and included in the Project's RSR Permit application.

Table 17.15 : Radioactivity disposal activity capacity at Treatment Site B

Nuclide Type	**Activity Limit (MBq)**	**Permitted Limits (Volume and timescale)**
Accumulation		
Ra-226	2180	704 m3 365 days
Ra-228	293	
Pb-210	2180	

[407] Studsvik (2014)Waste Capacity Assessment Draft 4
[408] Studsvik (2014)Waste Capacity Assessment Draft 4

Disposal		
Ra-226	18.2	1 Month
Ra-228	2.4	
Pb-210	72.6	

17.6.2.5 Low Level Waste (LLW)

147. It is unlikely that any solid LLW would be produced during the Project. However if solid LLW was to be generated this would be disposed at Augean plc's disposal facility which is permitted to accept LLW. The disposal facility's capacity limits for the radionuclides likely to be contained in LLW is displayed in Table 17.15.

Table 17.15 : Radionuclide disposal capacity at the Augean facility

. Radionuclide group	Disposal Capacity Limit (GBq)
Ra-226	306
Pb-210	85
Pb-210	85
Thorium (Th)-228	85
Polonium (Po)-210	85

149. The Environmental Permit for the site restricts each package of waste to 200 Bq/g. There is no capacity forecast available for future years.

17.6.2.6 Wastewater

Domestic

150. Domestic wastewater would be tankered to the Davyhulme or Blackburn WwTWs), operated by United Utilities, for treatment. The treatment facility along with its treatment capacity is displayed in Table 17.16. This information has been provided by United Utilities[409].

Table 17.16: Capacity of wastewater treatment facilities

Facility	Average Daily Treatment Capacity (m3)
Davyhulme Wastewater Treatment Works	150
Blackburn Wastewater Treatment Works	300
Total Treatment Capacity	450

151. There is no capacity forecast available for future years. In addition to the treatment facilities above there are other WwTWs in Lancashire where the wastewater can be treated.

Industrial

152. Wastewater captured by the surface pad during drilling, hydraulic fracturing and flow testing would be tankered to the Davyhulme or Blackburn WwTWs operated by United Utilities, for treatment as industrial wastewater. The treatment facility along with its treatment capacity is displayed in Table 17.17.

[409] United Utilities (2014) *Email from United Utilities to Arup 03/04/2014*

Table 17.17: Capacity of industrial wastewater treatment facilities

Facility	Average Daily Treatment Capacity (m3)
Davyhulme Industrial Wastewater Treatment Works	720
Blackburn Industrial Wastewater Treatment Works	3,000
Total Treatment Capacity	3,720

22. There is no capacity forecast available for future years. In addition to the treatment facilities above there are other WwTWs in the North West where the industrial wastewater can be treated.

17.7 Assessment

17.7.1 Construction of Well Pad and Access

153. Inert waste and non-hazardous waste generation has been assessed during the construction of the well pad.

17.7.1.1 Inert Waste

154. The forecast of the total quantity of inert waste likely to be generated during the construction of the well pad has been calculated using information provided by Cuadrilla based on experience at other sites. The quantities of inert waste from the construction of the well pad are summarised in Table 17.18 below. The full details of the construction waste forecast are available in Appendix Q1.

Table 17.18: Estimated Inert Waste Generated during the Construction of the Well Pad

Type	Waste (m3)	Waste (tonnes)
Concrete	1.1	2
Total Inert Waste	1.1	2

17.7.1.2 Materials Recovery Capacity

155. The significance of the likely effects of the additional inert waste arisings has been considered in the context of the available materials recovery capacity within Lancashire and assessed against the criteria in Table 17.9. Sub-regional capacity has been assessed as it is likely inert waste would be treated and disposed in the sub-region following wherever possible the proximity principle.

156. The amount of inert waste recycled and recovered by the Project has been estimated using the inert waste data and the target identified in the Regional Waste Strategy for the North West [410] for recycling and recovery. Therefore it is assumed that 70% of inert waste generated during the construction of the well pad would be recycled or recovered. This target also matches the target to recycle construction waste included in the Waste Framework Directive. This recycled or recovered waste has been compared to the materials recovery capacity in 2011 estimated by the EA as displayed in Table 17.19.

[410] Regional Leaders Board (2010) *The Updated Regional Waste Strategy for England's Northwest*

Table 17.19 : Materials Recovery Capacity within Lancashire

Total Inert Waste (tonnes)	70% of Inert Waste Recycled/Recovered (tonnes)	Materials Recovery Capacity within Lancashire (tonnes)	% Materials Recovery Capacity within Lancashire
2	1.4	234,000	0.0006

157. The annual estimated tonnage of inert waste sent for recycling/recovery generated during the construction of the well pad is a maximum of 0.0006% of the material recovery capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Inert Waste Disposal Capacity

158. The inert waste forecast to require landfill disposal during the construction of the well pad has also been compared to the inert landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.20 which displays the amount of inert material that could potentially be sent to landfill.

Table 17.20 : Inert Disposal Capacity within Lancashire

Total Inert Waste (m3)	Maximum 30% Waste Disposed (m3)	Inert Landfill Capacity (m3)	% Inert Waste Disposal Capacity
1.1	0.3	151,000	0.0002

159. The estimated tonnage of inert waste which may potentially be sent for inert landfill disposal generated from the construction of the well pad is 0.0002% of the inert landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Non-hazardous Waste

160. Non-hazardous waste produced by the Project during the construction of the pad would consist of mixed construction waste. The quantities of non-hazardous waste from the construction of the well pad are summarised in Table 17.21 below. The full details of the construction waste forecast are available in Appendix Q1.

Table 17.21 : Estimated non-hazardous waste generated during the construction of the pad

Type	Waste (m3)	Waste (tonnes)
Mixed construction waste	37	32
Total Non-hazardous Waste	37	32

161. The significance of the likely effects of the additional non-hazardous construction waste arisings were considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9. Sub-regional capacity was assessed as it is likely that non-hazardous waste would be treated and disposed in the sub-region following wherever possible the proximity principle.

Non-hazardous Treatment Capacity

162. The amount of non-hazardous waste recycled and recovered during the construction of the pad was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West and the Waste Framework Directive target to recycle and recover 70% of non-hazardous construction waste. This recycled or recovered waste has been compared to the treatment capacity in Lancashire in 2011 estimated by the EA as displayed in Table 17.22.

Table 17.22**:** Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	70% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire	% Treatment Capacity within Lancashire
32	22.5	1,448,000	0.002

163. The annual estimated tonnage of non-hazardous waste from the construction of the well pad that is sent for recycling/recovery is a maximum of 0.002% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Non-hazardous Waste Disposal Capacity

164. The non-hazardous waste arising during the construction of the well pad that is likely to require landfill disposal has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.23 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.23 : Non-hazardous disposal capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 30% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
37	11	7,302,241	0.0002

165. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated from the construction phase is 0.0002% of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.2 Installation of Surface Network and Buried Arrays

166. Non-hazardous waste generation has been assessed during the installation of groundwater monitoring boreholes and the buried arrays.

17.7.2.1 Non-hazardous Waste

167. The quantities of non-hazardous waste from the installation of groundwater monitoring boreholes and the buried arrays are summarised in Table 17.24 below.

Table 17.24: Estimated non-hazardous waste generated during the installation of the groundwater monitoring boreholes and buried array

Waste Type	Project sub-total	
	Volume (m3)	Mass (tonnes)
Cement	2.6	3.1
Bentonite slurry	249	264
Total Non-hazardous Waste	252	267

17.7.2.2 Non-hazardous Treatment Capacity

168. The amount of non-hazardous waste recycled and recovered during the installation of surface network and buried arrays was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West and the Waste Framework Directive target to recycle and recover 70% of non-hazardous construction waste. This recycled or

recovered waste has been compared to the treatment capacity in Lancashire in 2011 estimated by the EA as displayed in Table 17.25.

Table 17.25**:** Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	70% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
267	187	1,448,000	0.01

169. The annual estimated tonnage of non-hazardous waste from the installation of the surface network and buried arrays that is sent for recycling/recovery is a maximum of 0.01% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.2.3 Non-hazardous Waste Disposal Capacity

170. The non-hazardous waste arising during the installation of the surface network and buried arrays that is likely to require landfill disposal has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table17.26 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table17.26: Non-hazardous disposal capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 30% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
252	75.5	7,302,241	0.001

171. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated from the installation of the surface network and buried arrays is 0.001% of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.3 Drilling

172. Non-hazardous waste, hazardous waste and wastewater have been assessed during drilling. It is assumed no significant waste would be generated during drilling mobilisation. Therefore mobilisation waste has been scoped out of the chapter.

17.7.3.1 Non-hazardous Waste

173. Non-hazardous waste produced during the drilling phase would consist of polymer based water drilling muds and drill cuttings covered in polymer based waterdrilling muds and general waste. The quantities of non-hazardous waste from the drilling phase are summarised in Table 17.27 below. The full details of the non-hazardous waste forecast from the drilling phase are available in Appendix Q3.

Table 17.27: Estimated non-hazardous waste generated during the drilling phase

Type	Waste (m3)	Waste (Tonnes)
Polymer based drilling muds	420	622
Polymer covered drill cuttings	3,000	4,400
Cement	80	96
Spacer fluid	120	177.6
General waste	116	46

Type	Waste (m3)	Waste (Tonnes)
Total Non-hazardous Waste	3,736	5,381

174. The significance of the likely effects of the additional non-hazardous drilling waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9.

17.7.3.2 Non-hazardous Treatment Capacity

175. The amount of non-hazardous waste recycled and recovered during the drilling phase was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West and the Waste Framework Directive target to recycle and recover 70% of construction waste. This recycled or recovered waste has been compared to the treatment capacity in Lancashire in 2011 estimated by the EA as displayed in Table 17.28.

Table 17.28**:** Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	70% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
5,381	3,767	1,448,000	0.3

176. The annual estimated tonnage of non-hazardous drilling waste sent for recycling/recovery generated during the drilling phase is a maximum of 0.3% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.3.3 Non-hazardous Waste Disposal Capacity

177. The non-hazardous waste forecast to require landfill disposal during the drilling phase has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.29 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.29 : Non-hazardous disposal capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 30% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
3,736	1,121	7,302,241	0.02

178. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated during the drilling phase is 0.02% of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.3.4 Hazardous Waste

179. Hazardous waste produced during the drilling phase would consist of drill cuttings contaminated with LTOBM. The quantities of hazardous waste from the drilling phase are summarised in Table 17.30 below. The full details of the hazardous waste forecast from the drilling phase are available in Appendix Q3.

Table 17.30: Estimated total hazardous waste generated during the drilling phase

Type	Waste (m3)	Waste (Tonnes)
Drill cuttings contaminated with low-toxicity oil-based emulsion muds	2,300	3,404
Total Hazardous Waste	2,300	3,404

17.7.3.5 Hazardous Waste Capacity

180. The hazardous waste generated during the drilling phase has been compared to the hazardous waste disposal capacity within Lancashire. The results are shown in Table 17.31 which displays the amount of hazardous waste that could potentially be sent to landfill.

Table 17.31 : Hazardous waste disposal capacity in Lancashire in 2014

Total Hazardous Waste Disposed (m3)	Hazardous Landfill Capacity Lancashire (m3)	% Hazardous Waste Disposal Capacity
2,300	216,897	1.1

181. The estimated tonnage of hazardous waste which may potentially be sent for hazardous landfill disposal generated during restoration is 1.1% of the hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *slight* and **not significant**.

17.7.3.6 Wastewater

182. Wastewater produced during the drilling phase would consist of:

- Foul effluent (blackwater) produced by on site toilets; and
- Foul effluent (greywater) produced by on site welfare facilities such as wash basins and showers.

183. The estimated daily quantity of wastewater during drilling are summarised in Table 17.32 below. A more detailed wastewater forecast for the drilling phase is available in Appendix Q3.

Table 17.32 : Estimated daily wastewater generated during drilling

Type	Daily Wastewater (m3)
Foul effluent	2.6

184. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at the Wastewater Treatment Works (WwTWs) which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.33.

Table 17.33 : Wastewater treatment capacity

Daily Wastewater (m3)	Daily Treatment Capacity(m3)	% Treatment Capacity
2.6	450	0.6

185. The estimated volume of wastewater generated during the drilling phase would be a maximum of 0.6% of the treatment capacity. Therefore the impact is considered to be *negligible* and **not significant.**

17.7.3.7 Industrial Wastewater

186. Industrial wastewater produced during drilling would consist of the quantity of rainfall captured that would be tankered off site to United Utilities industrial facility at the Davyhulme or Blackburn WwTWs.

187. The quantities of daily industrial wastewater estimated during the drilling phase are summarised in Table 17.34 below. A more detailed industrial wastewater forecast for the drilling phase is available in Appendix Q3.

Table 17.34 : Estimated daily industrial wastewater generated during drilling

Type	Daily Industrial Wastewater (m3)
Industrial wastewater	40.5

188. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at Davyhulme and Blackburn WwTWs to treat the industrial wastewater. This is displayed in Table 17.35. The environmental effects of the rainfall captured by the pad are assessed within the water assessment in Chapter 19.

Table 17.35 : Industrial wastewater treatment capacity

Daily Industrial Wastewater (m3)	Treatment Capacity(m3)	% Treatment Capacity
40.5	3,720	1.1

189. The estimated volume of industrial wastewater generated during the drilling phase would be a maximum of 1.1% of the identified treatment capacity. Therefore the impact is considered to be *slight* and **not significant.**

17.7.4 Hydraulic Fracturing

17.7.4.1 Mobilisation

190. Non-hazardous waste and wastewater would be generated during hydraulic fracturing mobilisation.

Non-hazardous Waste

191. Non-hazardous waste produced during the hydraulic fracturing mobilisation phase would consist of general waste. The quantities of non-hazardous waste generated during the hydraulic fracturing mobilisation phase are summarised in Table 17.36 below. A more detailed non-hazardous waste forecast for the hydraulic fracturing phase is available in Appendix Q4.

Table 17.36: Estimated non-hazardous waste generated during hydraulic fracturing mobilisation

Type	Waste (m3)	Waste (tonnes)
General waste	4.4	1.8
Total Non-hazardous Waste	4.4	1.8

192. The significance of the likely effects of the additional non-hazardous waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9.

Non-hazardous Waste Treatment Capacity

193. The amount of non-hazardous waste recycled and recovered during the hydraulic fracturing mobilisation phase was estimated using the non-hazardous waste data and

applying the Waste Strategy of England North West target to recycle and recover 55% of non-hazardous waste. This recycled or recovered waste has been compared to the treatment capacity in 2011 estimated by the EA, as displayed in Table 17.37.

Table 17.37**:** Treatment Capacity within Lancashire.

Total Non-hazardous Waste (tonnes)	55% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
1.8	1	1,448,000	0.00007

194. The annual estimated tonnage of non-hazardous waste sent for recycling/recovery generated during the hydraulic fracturing mobilisation phase is a maximum of 0.00007% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Non-hazardous Waste Disposal Capacity

195. The non-hazardous waste forecast to require landfill disposal during the Hydraulic Fracturing mobilisation phase has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. Table 17.38 displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.38 : Non-hazardous Disposal Capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 45% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
4.4	2	7,302,241	0.00003

196. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated during the hydraulic fracturing phase is 0.00003% of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Wastewater

197. Wastewater produced during the hydraulic fracturing mobilisation phase would consist of foul effluent (blackwater and greywater) produced by on site toilets and welfare facilities.

198. The forecast of the daily quantity of foul effluent likely to be generated during the hydraulic fracturing phase was estimated using information provided by Cuadrilla and benchmarking data developed by British Water. The estimated daily quantities of wastewater generated during the hydraulic fracturing mobilisation phase are summarised in Table 17.39 below. A more detailed wastewater forecast for the hydraulic fracturing phase is available in Appendix S4.

Table 17.39 : Daily estimated wastewater generated during hydraulic fracturing mobilisation phase

Type	Daily Wastewater (m3)
Foul effluent	1.3

Wastewater Treatment Capacity

199. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at the WwTWs which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.40.

Table 17.40 : Wastewater treatment capacity

Daily Wastewater (m3)	Treatment Capacity(m3)	% Treatment Capacity
1.3	450	0.3

200. The estimated volume of wastewater generated during the hydraulic fracturing mobilisation phase would be a maximum of 0.3% of the treatment capacity. Therefore the impact is considered to be negligible and not significant.

17.7.4.2 Hydraulic Fracturing Operation

201. Non-hazardous waste, radioactive waste and wastewater have been assessed during hydraulic fracturing. In order to assess the likely significant environmental effects of the hydraulic fracturing phase, the estimated quantity of waste for each type was forecast and assessed against the baseline.

Non-hazardous Solid Waste

202. Non-hazardous waste produced during the hydraulic fracturing phase would consist of sand and general waste. The quantities of non-hazardous waste during the hydraulic fracturing phase are summarised in Table 17.41 below. A more detailed non-hazardous waste forecast for the hydraulic fracturing phase is available in Appendix Q4.

Table 17.41 : Estimated non-hazardous waste generated during hydraulic fracturing

Type	Waste (m3)	Waste (tonnes)
Sand	10.5	20
General waste	35.1	14
Total Non-hazardous Waste	45.6	34

203. The significance of the likely effects of the additional non-hazardous waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9.

Non-hazardous Waste Treatment Capacity

204. The amount of non-hazardous waste recycled and recovered during the hydraulic fracturing phase was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West target to recycle and recover 55% of non-hazardous waste. This recycled or recovered waste has been compared to the treatment capacity in 2011 estimated by the EA, as displayed in Table 17.42.

Table 17.42: Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	55% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
34	18.7	1,448,000	0.001

205. The annual estimated tonnage of non-hazardous waste sent for recycling/recovery generated during the hydraulic fracturing phase is a maximum of 0.001% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Non-hazardous Waste Disposal Capacity

206. The non-hazardous waste forecast to require landfill disposal during the hydraulic fracturing phase has also been compared to the non-hazardous landfill capacity in

Lancashire in 2014 estimated by the EA. Table 17.43 displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.43: Non-hazardous Disposal Capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 45% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
45.6	20.5	7,302,241	0.0003

207. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated during the hydraulic fracturing phase is 0.0003% of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Radioactive Waste

208. Radioactive waste generated during the hydraulic fracturing phase would consist of flowback fluid and LLW in the form of materials such as sand contaminated with NORM.

Flowback Fluid

209. The forecast of the total quantity of flowback fluid likely to be generated during the hydraulic fracturing phase has been estimated using information provided by Cuadrilla[411]. The quantities of flowback fluid generated during the hydraulic fracturing phase are summarised in Table 17.44 below. Flowback fluid generated during hydraulic fracturing would be re-used in the hydraulic fracturing process.

Table 17.44: Estimated flowback fluid generated during hydraulic fracturing

Waste Type	Volume Generated (m^3)	Volume Re-used (m^3)
Flowback Fluid	24,891	24,891
Total Flowback Fluid	24,891	24,891

Wastewater

210. Wastewater produced during hydraulic fracturing would consist of foul effluent as per the drilling phase.

211. The estimated quantities of daily wastewater generated during the hydraulic fracturing phase are summarised in Table 17.45 below. A more detailed wastewater forecast for the hydraulic fracturing phase is available in Appendix Q4.

Table 17.45: Estimated daily wastewater generated during hydraulic fracturing

Type	Daily Volume (m3)
Foul effluent	1.8

Wastewater Treatment Capacity

212. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at the WwTWs which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.46.

[411] Cuadrilla (2014*) 4 Wells Combined - With Reuse- Rev 5*

Table 17.46: Wastewater treatment capacity

Foul Effluent Daily Volume (m3)	Daily Treatment Capacity(m3)	% Treatment Capacity
1.8	450	0.4

213. The estimated volume of daily wastewater generated during the hydraulic fracturing operation phase would be a maximum of 0.4% of the treatment capacity. Therefore the impact is considered to be *negligible* and **not significant.**

Industrial Wastewater

214. Industrial wastewater produced during hydraulic fracturing would consist of the quantity of rainfall captured by the pad that would be tankered off site to United Utilities industrial facility at the Davyhulme or Blackburn WwTWs.

215. The estimated quantities of the daily industrial wastewater during the hydraulic fracturing phase are summarised in Table 17.47 below. A more detailed industrial wastewater forecast for the hydraulic fracturing phase is available in Appendix Q4.

Table 17.47 : Estimated daily industrial wastewater generated during hydraulic fracturing

Type	Daily Volume (m3)
Industrial wastewater	40.5

Industrial Wastewater Treatment Capacity

216. The significance of the likely effects of the industrial wastewater arisings was considered in the context of the available capacity at Davyhulme and Blackburn WwTWs. This is displayed in Table 17.48. The environmental effects of the rainfall captured by the pad are assessed within the water assessment in Chapter X.

Table 17.48: Daily industrial wastewater treatment capacity

Industrial Wastewater Daily Volume(m3)	Daily Industrial Treatment Capacity(m3)	% Treatment Capacity
40.5	3,720	1.1

217. The estimated volume of industrial wastewater generated during the hydraulic fracturing operation phase would be a maximum of 1.1% of the treatment capacity Therefore the impact is considered to be *slight* and **not significant**.

17.7.5 Initial Flow Testing

218. Non-hazardous waste, radioactive waste and wastewater have been assessed during flow testing.

17.7.5.1 Mobilisation

219. It is assumed no significant waste would be generated during flow testing mobilisation. Therefore flow testing mobilisation waste has been scoped out of the assessment.

17.7.5.2 Flow Testing

Non-hazardous Waste

220. Non-hazardous waste produced during flow testing would consist of sand general waste. The quantities of non-hazardous waste from flow testing are summarised in Table 17.49

below. A more detailed non-hazardous waste forecast for the flow testing phase is available in Appendix Q5.

Table 17.49: Estimated non-hazardous waste generated during flow testing

Type	Waste (m3)	Waste (tonnes)
Sand	10.5	20
General waste	29.5	11.8
Total Non-hazardous Waste	40	31.8

221. The significance of the likely effects of the additional non-hazardous waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9. Sub-regional capacity was assessed as it is likely non-hazardous waste would be treated and disposed in the sub-region following wherever possible the proximity principle.

Non-hazardous Waste Treatment Capacity

222. The amount of non-hazardous waste recycled and recovered during flow testing was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West target to recycle and recover 55% of non-hazardous waste. This recycled or recovered waste has been compared to the treatment capacity in 2011 estimated by the EA as displayed in Table 17.50.

Table 17.50**:** Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	55% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
31.8	17.5	1,448,000	0.001

223. The annual estimated tonnage of non-hazardous waste sent for recycling/recovery generated during the flow testing is a maximum of 0.001% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Non-hazardous Waste Disposal Capacity

224. The non-hazardous waste forecast to require landfill disposal during flow testing has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.51 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.51: Non-hazardous disposal capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 45% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
40	18	7,302,241	0.0002

225. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated during flow testing is 0.0002 % of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

Flowback fluid

226. The forecast of the total quantity of flowback fluid likely to be generated during the flow testing phase has been calculated using information provided by Cuadrilla[412] based on a

[412] Cuadrilla (2014) *4 Wells Combined – With Re-use – Rev 5*

40% return rate. The quantities of flowback fluid generated during the flow testing phase are summarised in Table 17.52 below. More information on the flowback fluid forecast is available in Appendix Q5.

Table 17.52: Estimated flowback fluid generated during flow testing

Type	Waste (m3)
Flowback Fluid Waste	21,250
Total Flowback Fluid Waste	21,250

227. The volume of flowback fluid generated during flow testing that will be tankered off site for specialist treatment has been assessed against the physical capacity available at the treatment facilities being utilised by Cuadrilla. The volume of flowback fluid generated onsite is likely to vary on a weekly basis. Therefore the maximum volume of flowback fluid estimated to be produced by the Project has been assessed against the weekly capacity of the treatment facilities. With a 40% return rate the maximum volume of flowback fluid waste produced during flow testing is 1,750m^3. This peak weekly volume of flowback fluid has been produced onsite has been compared to the baseline capacity detailed in section 17.6.

Flowback fluid Physical Treatment Capacity

228. The significance of the likely effects of the flowback fluid waste has been considered in the context of the available weekly physical capacity at the sites which have been identified by Cuadrilla[413] to treat the flowback fluid waste as displayed in Table 17.53. The potential for significant environmental effects of the flowback fluid waste onsite are assessed within the hydrogeology and contamination assessment in Chapter 11.

Table 17.53: Maximum weekly flowback fluid treatment capacity during flow testing

Maximum Weekly Flowback Fluid (m3)	Weekly Treatment Capacity (m3)	%Treatment Capacity
1,750	2,700	65

229. The estimated volume of flowback fluid waste which will be treated during the flow testing phase is 65% of the identified treatment capacity. Therefore the impact is considered to be *very substantial* and **significant**.

Flowback Fluid – Radioactive Treatment Capacity

230. The estimated radionuclide content of the flowback fluid likely to be generated during the flow testing phase has been calculated using information provided by Studsvik[414]. The estimated radionuclide content associated with the flowback fluid produced during the flow testing phase has been assessed against the daily capacity of Treatment Site A and Treatment Site B.

231. The estimated peak daily volume of flowback fluid generated across the flow testing phase is 250m^3. A peak daily value of the estimated radionuclide content of the flowback fluid produced onsite has been compared to the baseline capacity detailed in section 17.6.

232. Flowback fluid would not be routinely stored at the treatment sites and the (effective) maximum accumulation period is one day.

[413] Cuadrilla (2014*) 4 Wells Combined - With Reuse- Rev 5*
[414] Studsvik (2014) *Waste Capacity Assessment Draft 4*

Table 17.54 : Radioactive capacity at Treatment Site A and B

Nuclide	Accumulation Period	Maximum Accumulated Activity (MBq)	Treatment Site A Accumulation Limit (MBq/14 days)	% of Site A limit (%)	Treatment Site B Limit (MBq/365 days)	% of Site B limit (%)
Ra-226	1 day	7	189	3.8	2,180	0.3
Ra-228	1 day	2	220	0.8	293	0.6
Pb-210	1 day	7	189	3.8	2,180	0.3

233. The Studsvik[415] assessment displayed in Table 17.54 identifies that Treatment Sites A and B have sufficient capacity to accumulate the estimated peak daily flowback fluid waste generated during the flow testing phase.

234. Table 17.55 displays the estimated radioactive disposal capacity at Treatment Site A and B. This is the maximum total activity that could be disposed of within a month (30 days) after treatment.

Table 17.56 : Radioactive Disposal Capacity at Treatment Site A and B assuming Average Activity Concentration.

Nuclide	Disposal Period	Maximum Disposed Activity (MBq)	Treatment Site A Limit (MBq/ Month)	% of Site A limit	Treatment Site B Limit (MBq/ Month)	% of Site B limit
Ra-226	30 days	11	141	7.6	18	59
Ra-228	30 days	3	125	2	2	106
Pb-210	30 days	63	141	45	73	87

235. The Studsvik[416] assessment displayed in Table 17.576 identifies that Treatment Site A has the necessary radioactivity limits to dispose of the peak daily flowback fluid generated during the flow testing phase. Radionuclide activity will be monitored during the lifetime of the Project, to ensure that no activity-related capacity issues arise.

Wastewater

236. Wastewater produced during flow testing would consist of foul effluent (blackwater and greywater) produced by on Site toilets and welfare facilities. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at the WwTWs which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.57.

Table 17.57: Wastewater treatment capacity

Daily Foul Effluent Volume (m3)	Daily Treatment Capacity(m3)	% Treatment Capacity
0.7	450	0.1

237. The estimated volume of daily wastewater generated during the flow testing phase would be a maximum of 0.1% of the treatment capacity. Therefore the impact is considered to be negligible and not significant.

[415] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[416] Studsvik (2014) *Waste Capacity Assessment Draft 4*

Industrial Wastewater

238. Industrial wastewater produced during flow testing would consist of the quantity of rainfall captured by the pad that would be tankered off site to United Utilities industrial facility at the Davyhulme or Blackburn WwTWs.

239. The estimated quantities of the daily industrial wastewater during the flow testing phase are summarised in Table 17.58 below. A more detailed industrial wastewater forecast for the flow testing phase is available in Appendix Q4.

Table 17.58 : Estimated daily industrial wastewater generated during flow testing

Type	Daily Volume (m3)
Industrial wastewater	40.5

Industrial Wastewater Treatment Capacity

240. The significance of the likely effects of the industrial wastewater arisings was considered in the context of the available capacity at Davyhulme and Blackburn WwTWs. This is displayed in Table 17.59. The environmental effects of the rainfall captured by the pad are assessed within the water assessment in Chapter 19.

Table 17.59: Daily industrial wastewater treatment capacity

Daily Industrial Wastewater (m3)	Daily Industrial Treatment Capacity(m3)	% Treatment Capacity
40.5	3,720	1.1

241. The estimated volume of industrial wastewater generated during the flow testing phase would be a maximum of 1.1% of the treatment capacity. Therefore the impact is considered to be *slight* and **not significant**.

17.7.6 Extended Flow Testing

242. Non-hazardous waste, radioactive waste and foul water has been assessed during extended flow testing.

17.7.6.1 Non-hazardous Waste

243. Non-hazardous waste produced during extended flow testing would consist of general waste. The quantities of non-hazardous waste from extended flow testing are summarised in Table 17.60 below. A more detailed non-hazardous waste forecast for the flow testing phase is available in Appendix Q6.

Table 17.60: Estimated non-hazardous waste generated during extended flow testing

Type	Waste (m3)	Waste (Tonnes)
General waste	8.4	3.3
Total Non-hazardous Waste	8.4	3.3

244. The significance of the likely effects of the additional non-hazardous waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9. Sub-regional capacity was assessed as it is likely non-hazardous waste would be treated and disposed in the sub-region following wherever possible the proximity principle.

17.7.6.2 Non-hazardous Waste Treatment Capacity

245. The amount of non-hazardous waste recycled and recovered during extended flow testing was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West target to recycle and recover 55% of non-hazardous waste. This recycled or recovered waste has been compared to the treatment capacity in 2011 estimated by the EA as displayed in Table 17.61.

Table 17.61**:** Treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	55% of Non-hazardous Waste Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
3.3	1.8	1,448,000	0.0001

246. The annual estimated tonnage of non-hazardous waste sent for recycling/recovery generated during extended flow testing is a maximum of 0.0001% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.6.3 Non-hazardous Waste Disposal Capacity

247. The non-hazardous waste forecast to require landfill disposal during extended flow testing has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.62 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.62: Non-hazardous disposal capacity within Lancashire

Total Non-hazardous Waste (m3)	Maximum 45% Waste Disposed (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
8.4	3.8	7,302,241	0.00005

248. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated during flow testing is 0.00005 % of the non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.6.4 Flowback fluid

249. The forecast of the total quantity of flowback fluid likely to be generated during the extended flow testing phase has been calculated using information provided by Cuadrilla based on a 40% return rate. The quantities of flowback fluid generated during the extended flow testing phase are summarised in Table 17.63 below.

Table 17.63 : Estimated flowback fluid generated during extended flow testing

Type	Volume (m3)
Flowback Fluid Waste	29,200
Total Flowback Fluid Waste	29,200

17.7.6.5 Flowback Fluid Physical Treatment Capacity

250. The volume of flowback fluid generated during extended flow testing that will be tankered off site for specialist treatment has been assessed against the capacity available at the treatment facilities being utilised by Cuadrilla. The volume of flowback fluid

generated onsite is likely to vary on a weekly basis. Therefore the maximum volume of flowback fluid produced by the Project has been assessed against the weekly capacity of the treatment facilities.

251. The maximum weekly volume of flowback fluid waste produced during extended flow testing is 280 m^3. This peak weekly volume of flowback fluid has been produced onsite has been compared to the baseline capacity detailed in section 17.6.

252. The significance of the likely effects of the flowback fluid waste has been considered in the context of the available weekly capacity at the sites which have been identified by Cuadrilla to treat the flowback fluid waste as displayed in Table 17.64. The potential for any significant environmental effects of the flowback fluid waste onsite are assessed within the hydrogeology and contamination assessment in Chapter 11.

Table 17.64 : Weekly flowback fluid treatment capacity during extended flow testing

Maximum Weekly Flowback Water (m3)	Weekly Treatment Capacity (m3)	%Treatment Capacity
280	2,700	10.3

253. The estimated volume of flowback fluid waste which will be treated during the hydraulic fracturing phase is 10.3% of the available capacity. Therefore the impact is considered to be *very substantial* **and significant**.

17.7.6.6 Flowback Fluid – Radioactive Treatment Capacity

254. The estimated radionuclide content of the flowback fluid likely to be generated during the extended flow testing phase has been calculated using information provided by Studsvik[417]. The estimated radionuclide content associated with the flowback fluid produced during the extended flow testing phase has been assessed against the daily capacity of Treatment Site A and Treatment Site B.

255. The estimated peak daily volume of flowback fluid generated across the extended flow testing phase is 40m^3. A peak daily value of the estimated radionuclide content of the flowback fluid produced onsite has been compared to the baseline capacity detailed in section 17.6.

256. Flowback fluid would not be routinely stored at the treatment sites and the (effective) maximum accumulation period is one day.

Table 17.65 : Radioactive capacity at Treatment Site A and B

Nuclide	Accumulation Period	Maximum Accumulated Activity (MBq)	Treatment Site A Accumulation Limit (MBq/14 days)	% of Site A limit (%)	Treatment Site B Limit (MBq/365 days)	% of Site B limit (%)
Ra-226	1 day	1	189	0.6	2,180	0.05
Ra-228	1 day	0.3	220	0.1	293	0.1
Pb-210	1 day	1	189	0.6	2,180	0.05

[417] Studsvik (2014) *Waste Capacity Assessment Draft 4*

257. The Studsvik[418] assessment displayed in Table 17.65 identifies that Treatment Sites A and B have sufficient capacity to accumulate the estimated peak daily flowback fluid waste generated during the extended flow testing phase.

258. Table 17.5766 displays the estimated radioactive disposal capacity at Treatment Site A and B. This is the maximum total activity that could be disposed of within a month (30 days) after treatment.

Table 17.66 : Radioactive Disposal Capacity at Treatment Site A and B assuming Average Activity Concentration

Nuclide	Disposal Period	Maximum Disposed Activity (MBq)	Treatment Site A Limit (MBq/ Month)	% of Site A limit	Treatment Site B Limit (MBq/ Month)	% of Site B limit
Ra-226	30 days	3	141	2.5	18	19
Ra-228	30 days	1	125	0.7	2	34
Pb-210	30 days	20	141	14.5	73	28

259. The Studsvik[419] assessment displayed in Table 17.66 identifies that Treatment Site A and Treatment Site B have the necessary radioactivity limits to dispose of the peak daily flowback fluid generated during the extended flow testing phase. Radionuclide activity will be monitored during the lifetime of the Project, to ensure that no activity-related capacity issues arise.

Wastewater

260. Wastewater produced during extended flow testing would consist of foul effluent (blackwater and greywater) produced by on site toilets and welfare facilities. The significance of the likely effects of the wastewater arisings was considered in the context of the available capacity at the WwTWs which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.67.

Table 17.67: Wastewater treatment capacity

Daily Foul Effluent Volume (m^3)	**Daily Treatment Capacity(m^3)**	**% Treatment Capacity**
0.06	450	0.01

261. The estimated volume of daily wastewater generated during the extended flow testing phase would be a maximum of 0.01% of the treatment capacity. Therefore the impact is considered to be *negligible* and **not significant.**

17.7.7 Decommissioning and Restoration

262. Anticpated inert waste, non-hazardous waste and hazardous waste volumes have been assessed during the decommissioning and restoration phase.

263. During the restoration phase inert, non-hazardous and hazardous waste would be generated through the removal of infrastructure this includes the granular sub-base material and the membrane and liner. It is likely that a small proportion of the pad, liner and membrane would potentially be contaminated during the drilling, hydraulic fracturing

[418] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[419] Studsvik (2014) *Waste Capacity Assessment Draft 4*

and flow testing phase. Therefore these contaminated materials would be classified as hazardous waste.

17.7.7.1 Inert Waste

264. The quantities of inert waste from the decommissioning and restoration phase are summarised in Table 17.68 below. The full details of the decommissioning and restoration phase waste forecast are available in Appendix Q7.

Table 17.68: Estimated inert waste generated during the decommissioning and restoration phase

Type	Waste (m3)	Waste (tonnes)
Concrete	21.9	39.4
Total Inert Waste	21.9	39.4

265. It is assumed that 100% of these inert materials will be recycled. Therefore the significance of the likely effects of the additional inert waste arisings have been considered in the context of the available materials recovery capacity within Lancashire and assessed against the criteria in Table 17.9. Sub-regional capacity has been assessed as it is likely inert waste would be treated and disposed in the sub-region following wherever possible the proximity principle. This recycled or recovered waste has been compared to the materials recovery capacity in 2011 estimated by the EA as displayed in Table 17.73.

Table 17.69 : Materials recovery capacity within Lancashire

Total Inert Waste (tonnes)	Materials Recovery Capacity within Lancashire (tonnes)	% Materials Recovery Capacity within Lancashire
39.4	234,000	0.02

266. The annual estimated tonnage of inert waste sent for recycling/recovery generated during the decommissioning and restoration is a maximum of 0.02 of the material recovery capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.7.2 Non-hazardous Waste

267. Hazardous waste produced during decommissioning and restoration would consist of any contaminated aggregate and HDPE liner from the pad.

268. The volume of hazardous waste anticipated to be generated during the restoration phase has been compared to the hazardous waste disposal capacity within Lancashire. A more detailed hazardous waste forecast for the decommissioning and restoration phase is available in Appendix Q7.

Table 17.70 : Estimated non-hazardous waste generated during decommissioning and restoration

Type	Waste (m3)	Waste (tonnes)
HDPE Liner	14.7	14
Total Non-Hazardous Waste	14.7	14

269. The significance of the likely effects of the additional non-hazardous waste arisings was considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9.

270. It is assumed that 100% of this non-hazardous waste will be recycled. The amount of non-hazardous waste recycled and recovered during decommissioning and restoration was estimated using the non-hazardous waste data and applying the Waste Strategy of England North West target to recycle and recover 55% of non-hazardous waste. This recycled or recovered waste has been compared to the treatment capacity in 2011 estimated by the EA as displayed in Table 17.71.

Table 17.71**:** Non-hazardous treatment capacity within Lancashire

Total Non-hazardous Waste (tonnes)	Treatment Capacity within Lancashire	% Treatment Capacity within Lancashire
14	1,448,000	0.001

271. The annual estimated tonnage of non-hazardous waste sent for recycling/recovery generated during decommissioning and restoration is a maximum of 0.001% of the treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.7.3 Hazardous waste

272. Hazardous waste produced during decommissioning and restoration would consist of the contaminated aggregate and HDPE liner from the pad.

273. The hazardous waste generated during the restoration phase has been compared to the hazardous waste disposal capacity within Lancashire. A more detailed hazardous waste forecast for the decommissioning and restoration phase is available in Appendix Q7.

274. The results are shown in Table 17.72 which displays the amount of hazardous waste that could potentially be sent to landfill.

Table 17.72 : Hazardous waste disposal capacity Lancashire 2014

Total -Hazardous Waste for Disposal(m3)	Hazardous Landfill Capacity Lancashire (m3)	% Hazardous Waste Disposal Capacity
233	216,897	0.1

275. The estimated tonnage of hazardous waste which may potentially be sent for hazardous landfill disposal generated during restoration is 0.1% of the hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.8 Cumulative and interactive effects

17.7.9 Project level

276. In order to assess the cumulative effects generated across the Project the following wastes types have been assessed:

- Inert waste;
- Non-hazardous waste;
- Hazardous waste; and
- Radioactive waste.

17.7.9.1 Inert Waste

277. The forecast of the total quantity of inert waste likely to be generated across the Preston New Road Project has been estimated and is summarised in Table 17.77 below.

Table 17.73: Estimated Inert Waste Generated on the Preston New Road Project

Phase	Project Total		Waste Re-used / Recycled / Recovered		Waste to Landfill	
	Waste (m3)	Waste (tonnes)	Waste (m3)	Waste (tonnes)	Waste (m3)	Waste (tonnes)
Construction of the Well Pad and Access	1.1	2	0.5	1.4	0.3	0.6
Decommissioning and Restoration	21.9	39.4	21.9	39.4	0	0
Total Inert Waste	23	41.3	22.4	40.7	0.3	0.6

17.7.9.2 Materials Recovery Capacity

278. The significance of the likely effects of the project's cumulative inert waste arisings has been considered in the context of the available materials recovery capacity within Lancashire and assessed against the criteria in Table 17.9.

279. This recycled or recovered waste has been compared to the materials recovery capacity in 2011 estimated by the EA as displayed in Table 17.74.

Table 17.74: Materials Recovery Capacity within Lancashire

Project Total Inert Waste Reused Recycled/Recovered (tonnes)	Materials Recovery Capacity within Lancashire (tonnes)	% Materials Recovery Capacity within Lancashire
40.7	234,000	0.02

280. The annual estimated tonnage of inert waste sent for recycling/recovery generated during the Preston New Road is a maximum of 0.02% of the material recovery capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.9.3 Inert Waste Disposal Capacity

281. The inert waste forecast to require landfill disposal during the Preston New Road Project has also been compared to the inert landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.75 which displays the amount of inert material that could potentially be sent to landfill.

Table 17.75: Inert Disposal Capacity within Lancashire

Project Total Inert Waste for Landfill (m3)	Inert Landfill Capacity (m3)	% Inert Waste Disposal Capacity
0.3	151,000	0.0002

282. The estimated tonnage of inert waste which may potentially be sent for inert landfill disposal generated from the Preston New Road Project is 0.0002% of the inert landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.9.4 Non-hazardous Waste

283. The forecast of the total quantity of non-hazardous waste likely to be generated across the Preston New Road Project has been estimated and are summarised in Table 17.76 below.

Table 17.76: Estimated Non-Hazardous Waste Generated on the Preston New Road Project

Phase	Project Total		Waste Re-used / Recycled / Recovered		Waste to Landfill	
	Waste (m3)	Waste (tonnes)	Waste (m3)	Waste (tonnes)	Waste (m3)	Waste (tonnes)
Construction of the Well Pad and Access	37	32.2	25.9	22.5	11.1	9.7
Installation of the Buried Array	252	267	176	187	75.5	80.1
Drilling	3,736	5,381	2,615	3767	1,121	1,614
Hydraulic Fracturing – Mobilisation	4.4	1.8	2.4	1	2.	0.8
Hydraulic Fracturing – Operation	45.6	34	25.1	18.7	20.5	15.3
Flow Testing	40	31.8	22	17.5	18	14.3
Extended Flow Testing	8.4	3.3	4.6	1.8	3.8	1.5
Restoration	14.7	13.8	14.7	13.8	0	0
Total Non-hazardous Waste	4,138	5,766	2,886	4,029	1,252	1,736

284. The significance of the likely effects of the additional non-hazardous construction waste arisings were considered in the context of the available treatment capacity within Lancashire and assessed against the criteria in Table 17.9. The amount of non-hazardous waste recycled and recovered during the Preston New Road Project has been compared to the treatment capacity in Lancashire in 2011 estimated by the EA as displayed in Table 17.77.

Table 17.77**:** Treatment capacity within Lancashire

Total Non-hazardous Waste Re-used Recycled/Recovered (tonnes)	Treatment Capacity within Lancashire (tonnes)	% Treatment Capacity within Lancashire
4,029	1,448,000	0.3

285. The estimated tonnage of non-hazardous waste which may potentially be sent for treatment from the Preston New Road Project is 0.3% of the non-hazardous treatment capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

286. The non-hazardous waste arising during the Preston New Road Project that is likely to require landfill disposal has also been compared to the non-hazardous landfill capacity in Lancashire in 2014 estimated by the EA. The results are shown in Table 17.82 which displays the amount of non-hazardous waste that could potentially be sent to landfill.

Table 17.78: Non-hazardous disposal capacity within Lancashire

Project Total Non-hazardous Waste for Landfill (m3)	Non-hazardous Landfill Capacity (m3)	% Non-hazardous Waste Disposal Capacity
1,252	7,302,241	0.02

287. The estimated tonnage of non-hazardous waste which may potentially be sent for non-hazardous landfill disposal generated from the Preston New Road Project is 0.02% of the

non-hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.9.5 Hazardous Waste

288. The forecast of the total quantity of hazardous waste likely to be generated across the Preston New Road Project has been estimated and are summarised in Table 17.79 below.

Table 17.79 : Estimated hazardous waste generated on the Preston New Road Project

Phase	Hazardous Waste Project Total	
	Waste (m3)	Waste (tonnes)
Drilling	2,300	3,404
Decommissioning and Restoration	233	419
Total Hazardous Waste	2,533	3,823

289. The hazardous waste generated during the Preston New Road Project is likely to require disposal at a hazardous waste facility. Therefore the hazardous waste has been compared to the hazardous waste disposal capacity within Lancashire. The results are shown in Table 17.80 which displays the amount of hazardous waste that could potentially be sent to landfill.

Table 17.80 : Hazardous waste disposal capacity Lancashire 2014

Total Hazardous Waste for disposal(m3)	Hazardous Landfill Capacity Lancashire (m3)	% Hazardous Waste Disposal Capacity
2,533	216,897	1.1

290. The estimated tonnage of hazardous waste which may potentially be sent for hazardous landfill disposal generated during the Preston New Road Project is 1.1% of the hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *slight* **and not significant**.

17.7.9.6 Radioactive Waste

Flowback Fluid

291. The total quantities of flowback fluid during the Preston New Road Project based on a 40% return rate are summarised in Table 11.81 below.

Table 11.81: Estimated flowback fluid generated during the Preston New Road Project

Phase	Waste (m3)	Number of weeks
Hydraulic Fracturing	0	N/A
Flow Testing	21,250	57
Extended Flow Testing	29,200	417
Total Flowback Fluid Waste	50,450	474

292. The total volume of flowback fluid generated during the project based on a 40% return rate that would be tankered off site for specialist treatment has been assessed against the capacity available at the treatment facilities across the project period as displayed in Table 17.82.

Table 17.82: Project flowback fluid treatment capacity

Project Total Flowback Fluid (m3)	Weekly Treatment Capacity (m3)	Capacity across the Project (231 weeks)	% of Project Treatment Capacity

Project Total Flowback Fluid (m3)	Weekly Treatment Capacity (m3)	Capacity across the Project (231 weeks)	% of Project Treatment Capacity
50,450	2,700	1,282,886	3.9

293. The estimated volume of flowback fluid waste which may potentially be sent for treatment generated from the Preston New Road Project is 3.9% of the flowback treatment capacity. Therefore the impact is considered to be *moderate* **and significant**.

Flowback Fluid – Radioactive Treatment Capacity

294. The estimated radionuclide content of the flowback fluid likely to be generated across the Preston New Road projects has been calculated using information provided by Studsvik[420]. The estimated peak radionuclide content associated with the flowback fluid produced by the Preston New Road Project has been assessed against the daily capacity of Treatment Site A and Treatment Site B.

295. The estimated peak daily volume of flowback fluid generated across the Preston New Road Project is 280m^3. A peak daily value of the estimated radionuclide content of the flowback fluid produced onsite has been compared to the baseline capacity detailed in section 17.6.

296. Flowback fluid would not be routinely stored at the treatment sites and the (effective) maximum accumulation period is one day.

Table 17.83 : Radioactive capacity at Treatment Site A and B

Nuclide	Accumulation Period	Maximum Accumulated Activity (MBq)	Treatment Site A Accumulation Limit (MBq/14 days)	% of Site A limit (%)	Treatment Site B Limit (MBq/365 days)	% of Site B limit (%)
Ra-226	1 day	8	189	4.3	2,180	0.4
Ra-228	1 day	2	220	0.9	293	0.7
Pb-210	1 day	8	189	4.3	2,180	0.4

297. The Studsvik[421] assessment displayed in Table 17.83 identifies that Treatment Sites A and B have sufficient capacity to accumulate the estimated peak daily flowback fluid waste generated across the Preston New Road Project.

298. Table 17.85 displays the estimated radioactive disposal capacity at Treatment Site A and B. This is the maximum total activity that could be disposed of within a month (30 days) after treatment.

Table 17.84 : Radioactive Disposal Capacity at Treatment Site A and B assuming Average Activity Concentration

Nuclide	Disposal Period	Maximum Disposed Activity (MBq)	Treatment Site A Limit (MBq/ Month)	% of Site A limit	Treatment Site B Limit (MBq/ Month)	% of Site B limit
Ra-226	30 days	18	141	12.5	18	97

[420] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[421] Studsvik (2014) *Waste Capacity Assessment Draft 4*

Ra-228	30 days	4	125	3.4	2	174
Pb-210	30 days	104	141	74	73	143

299. The Studsvik[422] assessment displayed in Table 17.854 identifies that Treatment Site A has the necessary radioactivity limits to dispose of the peak daily flowback fluid generated across the Preston New Road Project after treatment. Radionuclide activity will be monitored during the lifetime of the Project, to ensure that no activity-related capacity issues arise.

Low Level Waste (LLW)

300. The quantities of solid LLW that could potentially be generated durings the Preston New Road Project are summarised in Table 17.85 below.

Table 17.85 : Estimated solid LLW generated during the Preston New Road Project

Phase	Volume (m3)
LLW	20
Total LLW Waste	20

LLW Disposal Capacity

301. The maximum activity that could be generated from solid LLW forecast to require disposal during Preston New Road Project was compared to the disposal limits at the Augean facility as displayed in Table 17.86.

Table 17.86 : Radioactive capacity at the Augean facility

Radionuclide	**Maximum Project Limit (MBq)**	**Site Limit (GBq)**	**% of disposal capacity**	**Impact**
Ra-226	40	306	0.01	Negligible
Ra-228	16	85	0.02	Negligible
Pb-210	40	85	0.05	Negligible
Th-228	16	85	0.02	Negligible
Po-210	40	85	0.05	Negligible

302. The maximum annual amount of Ra-226 in the LLW that will require disposal during the Preston New Road Project is 0.01% of the available capacity. Therefore the impact is considered to be *negligible* and **not significant**.

303. The maximum annual amount of Ra-228 in the LLW that will require disposal during the Preston New Road Project is 0.02% of the available capacity. Therefore the impact is considered to be *negligible* and **not significant**.

304. The maximum annual amount of Pb-210 in the LLW that will require disposal during the Preston New Road Project is 0.05% of the available capacity. Therefore the impact is considered to be *negligible* and **not significant**.

305. The maximum annual amount of Th-228 in the LLW that will require disposal during the Preston New Road Project is 0.02% of the available capacity. Therefore the impact is considered to be *negligible* and **not significant**.

[422] Studsvik (2014) *Waste Capacity Assessment Draft 4*

306. The maximum annual amount of Po-210 in the LLW that will require disposal during the Preston New Road Project is 0.05% of the available capacity. Therefore the impact is considered to be *negligible* and **not significant**.

17.7.10 Other developments

307. Cumulative effects with other developments within the area surrounding Site would include concurrent activities at Roseacre Wood. Roseacre Wood is another Cuadrilla Shale Gas Exploration project where exploration works will be on-going at the same time as activities at Preston New Road.

308. In order to assess the cumulative effects generated across Preston New Road and Roseacre Wood projects the following wastes types have been assessed:

- Hazardous waste;
- Radioactive waste;
- Industrial Wastewater; and
- Wastewater.

17.7.10.1 Hazardous Waste

309. The forecast of the total quantity of hazardous waste likely to be generated across the two Projects has been estimated and are summarised in Table 17.87 below.

Table 17.87 : Estimated hazardous waste generated across the proposed developments

Site	Drilling Phase	Decommissioning and Restoration Phase	Total Hazardous Waste (m3)
	Hazardous Waste (m3)	Hazardous Waste (m3)	
Preston New Road	2,300	233	2,533
Roseacre Wood	2,300	233	2,533
Total Hazardous Waste	4,600	467	5,067

310. The hazardous waste likely to be generated across the two proposed developments has been compared to the hazardous waste disposal capacity within Lancashire. The results are shown in Table 17.88 which displays the amount of hazardous waste that could potentially be sent to landfill.

Table 17.88 : Hazardous waste disposal capacity Lancashire 2014

Total -Hazardous Waste for disposal(m3)	Hazardous Landfill Capacity Lancashire (m3)	% Hazardous Waste Disposal Capacity
5,067	216,897	2.3

311. The estimated tonnage of hazardous waste which may potentially be sent for hazardous landfill disposal generated during the Preston New Road project is 2.3% of the hazardous landfill capacity in Lancashire. Therefore the impact is considered to be *moderate* **and significant**. In order to reduce the impact on hazardous waste facilities in Lancashire Cuadrilla can use other suitable facilities in the North West.

17.7.10.2 Radioactive Waste

Flowback fluid

312. Cuadrilla[423] have provided data indicating the volumes of flowback fluid based on a 40% return rate that is generated at the two Projects across hydraulic fracturing, flow testing and extended flow testing. The volume of flowback fluid generated onsite is likely to vary on a weekly basis. The maximum cumulative volume of flowback fluid of 1,850m^3 produced by the two projects over a week has been assessed against the weekly capacity of the treatment facilities. This peak weekly volume of return water has been produced onsite has been compared to the baseline capacity detailed in section 17.6.

313. The significance of the likely effects of the flowback fluid waste has been considered in the context of the available weekly capacity at the projects which have been identified by Cuadrilla to treat the flowback fluid waste as displayed in Table 17.89. The potential for any significant environmental effects of the flowback fluid waste onsite are assessed within the Hydrogeology and Ground Gas in Chapter 11.

314. .

Table 17.89 : Weekly flowback fluid treatment capacity

Maximum Weekly Flowback Fluid (m3)	Weekly Treatment Capacity (m3)	%Treatment Capacity
11,850	2,700	68

315. The maximum cumulative volume of flowback fluid based on a 40% return rate which will be treated across Preston New Road and Roseacre Wood projects is 68% of the available capacity. Therefore the impact is considered to be *very substantial* and **significant**.

Flowback Fluid – Radioactive Treatment Capacity

316. The estimated radionuclide content of the flowback fluid likely to be generated across the Preston New Road and Roseacre Wood projects has been calculated using information provided by Studsvik[424]. The estimated radionuclide content associated with the flowback fluid produced by the two Projects has been assessed against the daily capacity of Treatment Site A and Treatment Site B.

317. The estimated peak daily volume of flowback fluid generated across the Preston New Road and Roseacre Wood Projects is 335m^3. A peak daily value of the estimated radionuclide content of the flowback fluid produced onsite has been compared to the baseline capacity detailed in section 17.6.

318. Flowback fluid would not be routinely stored at the treatment sites and the (effective) maximum accumulation period is one day.

Table 17.90 : Radioactive capacity at Treatment Site A and B

Nuclide	Accumulation Period	Maximum Accumulated Activity (MBq)	Treatment Site A Accumulation Limit (MBq/14 days)	% of Site A limit (%)	Treatment Site B Limit (MBq/365 days)	% of Site B limit (%)
Ra-226	1 day	30	189	15.9	2,180	1.4
Ra-228	1 day	4	220	1.8	293	1.4

[423] Cuadrilla (2014*) 4 Wells Combined - With Reuse- Rev 5*
[424] Studsvik (2014) *Waste Capacity Assessment Draft 4*

Pb-210	1 day	31	189	16.1	2,180	1.4

319. The Studsvik[425] assessment displayed in Table 17.90 identifies that Treatment Sites A and B have sufficient capacity to accumulate the estimated peak daily flowback fluid waste generated across the Preston New Road and Roseacre Wood Projects.

320. Table 17.90 displays the estimated radioactive disposal capacity at Treatment Site A and B. This is the maximum total activity that could be disposed of within a month (30 days) after treatment.

Table 17.91 : Radioactive Disposal Capacity at Treatment Site A and B assuming Average Activity Concentration

Nuclide	Disposal Period	Maximum Disposed Activity (MBq)	Treatment Site A Limit (MBq/ Month)	% of Site A limit	Treatment Site B Limit (MBq/ Month)	% of Site B limit
Ra-226	30 days	21	141	14.8	18	117
Ra-228	30 days	5	125	4.0	2	250
Pb-210	30 days	126	141	89.4	73	173

321. The Studsvik[426] assessment displayed in Table 17.91 identifies that Treatment Site A has the necessary radioactivity limits to dispose of the peak daily flowback fluid generated across the Preston New Road and Roseacre Wood Projects after treatment. Radionuclide activity will be monitored during the lifetime of the Project, to ensure that no activity-related capacity issues arise.

Wastewater

322. The estimated quantity of daily wastewater likely to be generated across the Preston New Road and Roseacre Wood projects has been estimated and are summarised in Table 17.92 below.

Table 17.92 : Estimated Wastewater Generated on the Preston New Road and Roseacre Wood Projects

Phase	Preston New Road Volume (m3)	Roseacre Wood Volume (m3)	Total (m3)
Drilling	2.6	2.6	5.3
Hydraulic Fracturing - Mobilisation	1.3	1.3	2.5
Hydraulic Fracturing – Operation	1.8	1.8	3.6
Flow Testing	0.7	0.7	1.3
Extended Flow Testing	0.1	0.1	0.1
Sub-total	6.4	6.4	12.8

Wastewater Treatment Capacity

[425] Studsvik (2014) *Waste Capacity Assessment Draft 4*
[426] Studsvik (2014) *Waste Capacity Assessment Draft 4*

323. The significance of the likely effects of the cumulative wastewater arisings was considered in the context of the available capacity which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.93.

Table 17.93 : Wastewater treatment capacity

Phase	Total (m3)	Wastewater Treatment Capacity (m3)	% Treatment Capacity
Drilling	5.3	450	1.2
Hydraulic Fracturing - Mobilisation	2.5	450	0.6
Hydraulic Fracturing – Operation	3.6	450	0.8
Flow Testing	1.3	450	0.3
Extended Flow Testing	0.1	450	0.03

324. The estimated cumulative volume of daily wastewater generated during the Preston New Road and Roseacre Wood Projects would be a maximum of 1.2% of the treatment capacity. Therefore the impact is considered to be *slight* and **not significant**.

Industrial Wastewater

325. The forecast of the daily quantity of industrial wastewater likely to be generated across the across the Preston New Road and Roseacre Wood Projects has been estimated and are summarised in Table 17.94 below.

Table 17.94 : Daily Estimated Industrial Wastewater Generated on the Preston New Road and Roseacre Wood Projects

Waste	Roseacre Wood Daily Volume (m3)	Preston New Road Daily Volume (m3)	Total (m3)
Industrial Wastewater	40.5	40.5	81

Wastewater Treatment Capacity

326. The significance of the likely effects of the cumulative daily industrial wastewater arisings was considered in the context of the available capacity which have been identified by Cuadrilla to treat the wastewater. This is displayed in Table 17.95.

Table 17.95 : Wastewater treatment capacity

Waste	Total (m3)	Wastewater Treatment Capacity (m3)	% Treatment Capacity
Industrial Wastewater	81	3,720	2.2

327. The estimated cumulative volume of industrial wastewater generated during the Preston New Road Project and the Roseacre Wood Projects would be a maximum of 2.2% of the treatment capacity. Therefore the impact is considered to be *moderate* **and significant**.

17.8 Mitigation measures

328. The site will operate under an installation environmental permit incorporating permits for a mining waste operation (including mining waste facilities), a groundwater activity permit, a radioactive substances activity permit and an industrial emissions permit for the flaring of waste gas during initial flow testing (the "Environmental Permit").This would require that the design and operation of the Site with regard to the regulated activities covered by the permit meets the necessary standards described as Best Available Techniques (BAT) by the relevant guidance documents. The permit would require that the regulated activities at the Site would be carried out in such manner to ensure that any emissions to the environment are limited to levels considered to represent BAT for the activities being carried out.

329. The environmental permit will contain conditions imposed by the EA, which are likely to include:

- A requirement for Cuadrilla to manage and operate the activities in accordance with a written management system that identifies and minimises the risks of pollution;
- A requirement that Cuadrilla observe and implement the terms of its Mining Waste Management Plan;
- A restriction of the activities to those specifically included within the permit;
- The obligation to renew the Mining Waste Management Plan every 5 years or as substantial changes occur;
- Restrictions with regard to point source emissions to water air and land, and with regard to odour, noise and vibration generated by the activities; and
- Monitoring, reporting and notification requirements

330. Cuadrilla will aim to minimise waste being generated onsite which would reduce the amount of materials that need to be handled, transported, treated or disposed. Minimising the amount of waste produced would reduce environmental impact, environmental risk and lessen the burden on waste capacity.

331. Cuadrilla will seek to fulfil its Duty of Care with regard to waste consigned for offsite disposal by requiring its contractors to produce evidence that they are appropriately authorised to handle the waste in question. For example Cuadrilla will check the necessary permits/licenses and exemptions for key waste management contractors and facilities (e.g. those for drill muds, drill cuttings, flowback fluid, solid materials contaminated with NORM).

17.8.1 Construction of the Well Pad and Access

332. A number of mitigation measures have been proposed to help the Project promote sustainable resource and waste management during the construction phase.

17.8.1.1 Construction Site Waste Management Plan

333. A Construction Site Waste Management Plan has been developed for the construction phase of the Project with the aim of reducing and promoting the recovery of waste. The Construction Site Waste Management Plan includes a number of actions to achieve sustainable resource and waste management on the Project including:

- Considering waste at the design stage to encourage waste avoidance, through designing out waste;
- Planning resource management to ensure that the minimum amount of material is wasted;
- Optimisation of the recovery of excavated materials arising from excavation works, including reusing excavation materials onsite followed by alternative recovery routes; and
- The Preferred Construction Contractor would strive to reduce the quantity of material sent to landfill during the construction phase through effective waste management. Where waste generated by the project cannot be avoided this would be recovered through re-use and recycling where feasible.

334. More efficient use of materials would make a major contribution to reducing the environmental effects of construction including reducing demand for landfill and the depletion of finite, natural resources through:

- Minimising the overall creation of waste resulting from, for example, over ordering or inefficient design;
- Reducing the quantity of material sent to landfill during the construction process through effective waste management;
- Re-using or recycling materials existing materials onsite into the new construction project; and
- Using more recycled materials and mainstream products with higher recycled content.

335. The Design Team for the Project shall consider opportunities to avoid waste generation at the conclusion of the Project when the operation is suspended and the Site is restored.

336. A copy of the Preston New Road Wood Site Waste Management Plan Guidance Note is available in Appendix Q8.

17.8.1.2 Other mitigation

337. Table 17.96 demonstrates the sustainable practices which would be undertaken to reduce, re-use and recycle waste during construction.

Table 17.96: Sustainable resource and waste management for the construction phase

Good Practice	Description
Designing out waste	Waste management would be considered at the design stage of the development to ensure that the minimum amount of material is wasted. 'Design for deconstruction', the processes by which the Site is restored and can be deconstructed, re-used and recycled, shall also be investigated during the design stage of the process.
Sustainable procurement	Materials selected would be durable to ensure long life and reduced need for replacement. Over-ordering of materials would be avoided and suppliers that minimise packaging shall be used. Any packaging would be returned for recycling. Construction material specifications would prioritise the procurement and use of recycled/secondary aggregates and other recycled materials e.g. recycled aggregates for pad. Ensure materials used to construct access roads can be easily

Good Practice	Description
	recycled.
Construction Site Waste Management Plan	A Project specific Construction Site Waste Management Plan has been developed based on an over-arching strategy that is easy to communicate and disseminate. This includes procedures for monitoring, measuring and reporting hazardous and non-hazardous waste.
Supply chain partners	All members of the supply chain would be aware of the Construction Site Waste Management Plan. The Project Manager would ensure that someone is responsible for the implementation of the Plan.
Materials management	Materials would be appropriately handled and stored throughout their lifecycle from delivery to inclusion, e.g. return surplus materials to storage. Materials would be delivered to the Site 'just-on-time', this would limit the need for excess on-site storage and would limit the chance of wastage through damage of the stored materials. There would be a designated area for the storage of materials.
Waste management	While reduction of waste would remain the highest priority, waste produced shall be segregated. This would allow materials to be re-used/recycled and ultimately reduce the amount of waste that has to be finally disposed of. The waste stream colour-coding developed by the Institute of Civil Engineers427 to raise waste awareness would be considered.
Effective Hazardous Waste Management	Hazardous waste would be correctly labelled, shall not be mixed with non-hazardous waste, securely contained and disposed of by a certified waste carrier for hazardous waste. The Duty of Care (DoC) applies to hazardous wastes.

338. Cuadrilla shall ensure that all materials exported off site are segregated and collected for recycling by a waste management contractor. Where this is not feasible (e.g. lack of space or insufficient quantities of materials) materials shall be recovered through a Materials Recovery Facility (MRF) to divert waste from landfill.

17.8.2 Installation of Surface and Buried Arrays

339. Cuadrilla shall re-use soils and stones from the installation of arrays.

340. Waste arising from the installation of the arrays shall be included in the Construction Site Waste Management Plan for the construction phase. These waste arisings include any excavated materials that are re-used on site.

341. Bentonite slurries must only be disposed of to landfill if it is a solid waste. Cuadrilla shall check with their waste management contractor or broker where the material will be taken and how it will be treated as there are a limited number of licensed waste disposal sites that can accept slurries for treatment prior to disposal.

342. Small quantities of general waste and hazardous waste generated during the installation of the surface and buried array would be removed from the Site to a Cuadrilla operation or their sub-contractors premises in compliance with legislation before appropriate treatment or disposal.

[427] Further information is available on the Institute of Civil Engineers website - www.ice.org.uk

17.8.3 Drilling

17.8.3.1 Mobilisation

343. There are no mitigation measures relating to the drilling mobilisation.

17.8.3.2 Drilling

344. There would be a range of waste streams generated during the drilling phase, these are identified in Table 17.97 below, along with Cuadrilla's proposed method of waste management.

Table 17.97 Drilling Phase Waste Streams

Waste Stream	How does this arise?	Storage	Predicted Recovery/Treatment/Disposal Method
Polymer Based Water Drilling Muds	When drilling the well bore, drilling muds (also referred to as drilling fluids) are used to lubricate and cool the drill bit and to aid the direction of the drill. During the drilling process, drilling muds are recirculated through a mechanical separation device which is used to extract solid drill cuttings. The cleaned mud would be re-used in the drilling process. The polymer mud systems can nbe formulated from materials which are classed as non-hazardous pollutants to groundwater[428].	Spent drilling muds are muds that can no longer be recycled. These muds will be temporarily accumulated onsite in dedicated, well maintained, appropriately sized, metallic containers. These containers shall be covered and labelled appropriately and will be subject to annual thickness inspections and weekly visual integrity inspections. The shale shaker will remove large solids from the drill muds.	Spent polymer based drilling muds would be removed by a licensed waste management carrier to tanker the muds to an appropriately permitted waste management facility to receive, keep, store and treat industrial wastes of this nature in accordance with published guidance[429].
Drill Cuttings associated with Polymer Based Water Drilling Muds	When drilling the wellbore, fragments of the various rocks encountered travel to the surface in a mixture with the drilling muds. During the drilling process, drilling muds are passed through a mechanical separation device which is used to extract solid drill cuttings.	Drill cuttings will be temporarily accumulated onsite in dedicated, well maintained, appropriately sized, metallic containers. These containers shall be labelled appropriately and will be subject to annual thickness inspections and weekly visual integrity inspections.	Drill cuttings would be separated from the polymer based drilling muds to enable them to be recycled. The drill cuttings are most likely to be recycled into secondary aggregate. Drill cuttings separated from the polymer based drilling muds would be removed by a licensed waste management carrier to transfer the cuttings to an appropriately permitted waste management facility to receive, keep, store and treat industrial wastes of this nature in accordance with published guidance.

[428] Cuadrilla (2013) *PEDL 165 Wells 2014 – 15 Basis of Design (Draft)*
[429] Environment Agency (2012) *Position Statement : Regulating the recovery of drilling muds MWRP PS 037 Version 1*

Drill Cuttings associated with LTOBM	When drilling the wellbore, fragments of the various rocks encountered travel to the surface in a mixture with the drilling muds. During the drilling process, drilling muds are passed through a mechanical separation device which is used to extract solid drill cuttings.	Drill cuttings that are separated from the LTOBM will be temporarily accumulated onsite in dedicated, well maintained and appropriately sized metallic containers. These containers shall be labelled appropriately and will be subject to annual thickness inspections and weekly visual integrity inspections.	Though LTOBM results in the drilled cuttings being coated with residual oil, the total amount of cuttings generated is usually less than with water-based muds for the same formation, due to greater inhibition and improved wellbore stability. There are licensed waste sites available for accepting oily cuttings, and also processing facilities available for recovering the oil on cuttings. Drill cuttings contaminated with LTOBM will be classified as hazardous waste and disposed offsite.
Losses to formation	Drilling fluids are designed to minimise loss to the adjacent rock formations during drilling, although it is possible that some small losses into the formation will occur. Cuadrilla will seek to minimise such losses. When drilling through potentially sensitive groundwater receptors (Middle Sands and Sherwood Sandstone) no chemicals considered to be hazardous to groundwater (as defined by the Groundwater Directive) will be used	Any losses experienced during drilling that are detected by the monitoring systems will be recorded by the drilling mud engineer on a daily basis.	It is unlikely Cuadrilla will be able to recover losses to formation.
Cement	During the process of drilling, steel casing is cemented in the wellbore in a series of stages to protect groundwater and maintain well integrity. The cement is pumped in slurry form down the inside of the casing and rises up through the annular space between the drilled hole and the casing, and once in place sets hard. A proportion of this cement is returned to the surface as waste. Returning cement would be kept to a minimum by controlling the volumes inputted into the well by a competent contractor.	Returning cement to the surface is temporarily stored into appropriate skips before being sent off site to an authorised waste facility.	Returning cement cannot be re-used on site. Due to the small quantities the cement can be sent for recycling to an offsite authorised waste facility.
General waste- e.g. paper, timber, scrap-metal	General waste such as paper, cardboard, timber, scrap-metal, food would be generated by Site staff and packaging during the operation of the facility	General waste would be segregated in containers.	General waste would be recycled onsite where feasible before being sent to a Materials Recovery Facility to maximise the amount of waste diverted from landfill.

Rainfall runoff	Rainfall runoff is generated from surface water from the pad.	Rainfall runoff would be collected in perimeter ditches contained by basal membrane.	Rainfall runoff is tankered offsite and treated at a local WwTW.
Foul effluent	Blackwater and greywater produced by on site welfare facilities – toilets and washbasins	Blackwater and greywater is stored separately.	Foul effluent is tankered offsite and treated at a local WwTW.

345. Cuadrilla has developed a Mining Waste Management Plan for Preston New Road as part of the environmental permitting application. This plan will provide the characteristics of mining waste generated from the Project as well as the associated management of these wastes.

346.

17.8.3.3 Drilling Muds and Drill Cuttings

347. Where feasible Cuadrilla will use non-hazardous polymer based drilling muds that reduce the environmental risks associated with LTOBM drilling muds and improve the opportunities for recycling of both drilling muds and drill cuttings.

348. Any excess drilling muds that have not been used will be returned to the supplier.

349. Early identification of, and communication with the waste broker will be undertaken by Cuadrilla to help identify opportunities to recycle polymer based drilling muds and drill cuttings.

350. Drilling muds and drill cuttings will be treated at an appropriately permitted waste management facility in accordance with published guidance. Cuadrilla shall obtain all Waste Transfer Notes (WTNs) s and any consignment notes relating to drilling muds and drill cuttings to record a clear audit trail for the wastes. In addition Cuadrilla shall consider retaining a right or seeking permission to conduct an auditthe waste management facilities for drill cuttings and drilling muds as part of their duty of care.

351. The quantity of drilling mud and drill cuttings waste arising each day would be monitored and recorded, along with the quantities despatched off site for treatment / disposal. This data would be used to inform waste prevention strategies. All stored waste would also be sampled before it is collected by the waste management contractor. The frequency for this testing would be at a minimum once every two weeks or when the composition of the drilling mud is changed due to the geological conditions encountered. Any changes in the chemical profile of the waste would inform decisions concerning future waste management arrangements and environmental risk control measures, as well as sampling and testing frequency.

352. Where low-toxicity oil-based emulsion muds are used the liquid waste and the associated drill cuttings will need to be handled and stored appropriately. Low -toxicity oil-based emulsion muds and cuttings will be collected in specially designed cuttings bins and sent for treatment or disposal as hazardous waste.

353. In order to reduce the quantities of hazardous waste generated during drilling Cuadrilla shall identify industry best practice to treat and recover the drill cuttings contaminated with LTOBM. Where this is not feasible the low -toxicity oil-based emulsion muds and cuttings will be disposed as hazardous waste.

354. Cuadrilla shall implement the proximity principle and recycle drilling waste streams in as close proximity as possible to the Site. However, in order to reduce the impact on hazardous waste facilities in Lancashire, Cuadrilla will identify other suitable facilities in the North West.

17.8.3.4 Spacer Fluid

355. Spacer fluid must only be disposed of to a specialist facility. Cuadrilla shall check with their waste management contractor or broker where the material will be taken and how it

will be treated as there are a limited number of licensed waste disposal sites that can accept liquids for treatment prior to disposal.

17.8.3.5 General waste

356. Cuadrilla would also ensure that general waste (e.g. paper, cardboard, timber, scrap-metal) is segregated and collected for recycling by a waste management contractor. Where this is not feasible, for example due to low quantities, general waste shall be recovered through a MRF to divert waste from landfill.

17.8.3.6 Hazardous waste

357. Hazardous waste would be correctly labelled, not be mixed with non-hazardous waste, securely contained and transported off site and disposed of by an appropriately permitted waste carrier and disposal sites for hazardous waste.

358. Mitigation measures relating to the environmental effects of drill cuttings and spent drilling muds are included within the hydrogeology and contamination assessment in Chapter 11.

17.8.3.7 Industrial wastewater

359. Cuadrilla would regularly test the surface water from the pad to identify if it is possible to be sent to the local watercourse. This would reduce the need to tanker water offsite and the treatment capacity required.

17.8.4 Hydraulic Fracturing

17.8.4.1 Mobilisation

360. There are no mitigation measures relating to the hydraulic fracturing mobilisation.

17.8.4.2 Operation

361. There is a range of waste streams that would be generated during the hydraulic fracturing phase, these are identified in Table 17.98 below along with Cuadrilla's proposed method of waste management.

362. The Mining Waste Management Plan for Preston New Road is part of the environmental permitting application. The plan provides the characteristics of waste generated from the Project as well as the associated management of these wastes.

Table 17.98 : Hydraulic Fracturing Waste Streams.

Waste Stream	How does this arise?	Storage	Predicted Recovery/Treatment/Disposal Method
Flowback fluid	The composition of fracturing fluid (typically water and sand 99.95%, polyacrylamide friction reducer 0.05%), experiences a change during the hydraulic fracturing process. During the course of the hydraulic fracturing process, a proportion of the fracturing fluid that is injected returns to the surface along with water naturally present in the formation and natural gas. This is known as flowback fluid or Return Water and, after separation from the gas at the surface, is currently considered to be an extractive waste. Although measured at very low levels, the anticipated presence of Naturally Occurring Radioactive Material (NORM) at levels that exceed 1 Becquerel per litre (>1Bq/l) means that the Flowback fluid would be defined as radioactive waste in accordance with Schedule 23 to the Environmental Permitting (England and Wales) Regulations 2010.	Flowback fluid waste is sent to the flowback tanks for measurement and storage until it is removed for re-use. For details of the storage tank capacity see Appendix B. The tanks are located on amembrane providing secondary containment. The integrity of these tanks will be checked on a daily basis.	Flowback fluid will be re-used back into the hydraulic fracturing process. Cuadrilla will use a separating process to remove sands/floating oil/ gas. They will then apply an ultra-violet (UV) disinfection system to clean the water. There will be no chemical treatment onsite.
Sand	The flowback fluid contains a small quantity of the sand that is injected into the target reservoir (as part of the composition of the hydraulic fracturing fluid) to act as a proppant. The sand is removed in the 4 stage separator process that separates the flowback fluid from any natural gas that is extracted.	Sand is removed via the separator into a sand bin, which is subsequently transferred into a waiting skip to be removed from Site for appropriate treatment or disposal.	Recycled into secondary aggregates.
Surplus natural gas	After separation from the flowback fluid, extracted natural gas is tested for its quality and composition etc. Surplus gas that remains after testing (during the Project) is subsequently discarded by flaring and, at that point, becomes a waste in accordance with the revised Waste Framework Directive.	It is not currently planned to store surplus natural gas at the Site. However, there may be the potential to store gas in the future for compression and exporting off the Site.	During the Project, the gas is discarded by flaring (as a cleaner and safer alternative to venting). After separation from the flowback fluid and sand, and following appropriate testing, surplus natural gas becomes an extractive waste and is discarded by being diverted to a flare system and substantively destroyed at temperatures exceeding 800 degrees Celsius.

Waste Stream	How does this arise?	Storage	Predicted Recovery/Treatment/Disposal Method
Solid scale	It may also be necessary to occasionally transfer solid scales for treatment and subsequent disposal of the scales, although Cuadrilla' s previous drilling experience identifies it is not anticipated that this would be a routine requirement. Scale is likely to comprise insoluble barium, calcium and strontium compounds arising from the wastewater due to changes in temperature and pressure[430]. In addition radium is chemically similar to these elements and may also be integrated into the scales.	Any solid LLW generated and identified would be subject to quantitative lab analysis. Cuadrilla would package any LLW in accordance with relevant technical and regulatory requirements and arrange for it to be collected for treatment and disposal.	The recipient for the LLW that is generated would handle it safely, taking all reasonable precautions to prevent its escape from control and reduce the risk of adverse environmental effects. LLW would be deposited in sealed landfill cells, in accordance with the operator's environmental permit(s).
Equipment contaminated by NORM	It may be necessary to occasionally transfer equipment contaminated with NORM for treatment and subsequent disposal of the scales, although is it not anticipated that this would be a routine requirement.	Cuadrilla would package any LLW in accordance with relevant technical and regulatory requirements and arrange for it to be collected for treatment and disposal.	Specialist treatment facilities.
Materials contaminated by NORM	It may be necessary to occasionally transfer materials such as sand, sediment and sludge for treatment and subsequent disposal, although is it not anticipated that this would be a routine requirement .	Cuadrilla would package any LLW in accordance with relevant technical and regulatory requirements and arrange for it to be collected for treatment and disposal.	Specialist treatment facilities.
General waste- e.g. paper, timber, scrap-metal	General waste such as packaging, paper, cardboard, timber, scrap-metal, food would be generated by site staff during the operation of the facility	General waste would be segregated in containers.	General waste would be recycled onsite where feasible before being sent to a Materials Recovery Facility to maximise the amount of waste diverted from landfill.
Rainfall runoff	Rainfall runoff is generated from surface water from the pad.	Rainfall runoff would be collected in perimeter ditches contained by basal membrane	Rainfall runoff is tankered offsite and treated at a local WwTW.
Foul effluent	Blackwater and greywater produced by on site welfare facilities – toilets and washbasins	Blackwater and greywater is stored separately.	Foul effluent is tankered offsite and treated at a local WwTW.

[430] The Royal Society and The Royal Academy of Engineering (2012) *Shale gas extraction in the UK : a review of hydraulic fracturing*

Environmental Risk Assessment (ERA)

363. As part of the Environmental Permitting application, Cuadrilla[431] have produced an Environmental Risk Assessment (ERA) in accordance with EA[432] [433] guidance. The Mining Waste ERA describes and assesses the environmental risks associated with waste generated at the Site. It considers, noise, fugitive emissions, , air emissions, releases to water, waste, Global Warming potential, and potential for accidents and incidents as these relate directly to the mining waste operation. This has been completed in addition to the assessments carried out as part of the EIA reported in this ES.

364. The Mining Waste ERA relates only to the extractive and not the other activities performed at the Site which are the subject of separate risk assessment (e.g. general waste produced by staff). The Mining Waste ERA identifies a range of measures and mitigation measures to reduce the environmental risks relating to waste storage, removal and processing as well as well abandonment.

17.8.4.3 Flow back fluid

365. In addition to achieving the various permitting requirements, Cuadrilla has also introduced embedded mitigation during the design and planning stage of the project. This embedded mitigation includes:

- The volume of water used per fracturing stage is proposed to be 765m^3 (as opposed to a more typical 1,000m^3) to reduce the volume of flowback fluid produced; and
- Flowback fluid generated during the hydraulic fracturing stage will be re-used back into the hydraulic fracturing process. This will avoid the need for flowback fluid requiring treatment as well as reducing water consumption and transport movements during hydraulic fracturing.

17.8.4.4 Other mitigation

Sand

366. Cuadrilla would ensure identification and communication with processors to help identify opportunities to recover sand waste.

General waste

367. Cuadrilla would also ensure that general waste (e.g. paper, cardboard, timber, scrap-metal) is segregated and collected for recycling by a waste management contractor. Where this is not feasible, for example due to low quantities, general waste shall be recovered through a MRF to divert waste from landfill.

Hazardous waste

368. Hazardous waste would be correctly labelled, not be mixed with non-hazardous waste, securely contained transported off site and disposed of by appropriately permitted waste carrier and disposal sites for hazardous waste.

[431] Cuadrilla (2014) *Environmental Risk Assessment for Preston New Road Exploration Pad*
[432] Environment Agency (2011) *Horizontal Guidance Note H1 Overview document Version 2.1*
[433] Environment Agency (2011) *EPR 6.14 How to comply with your environmental permit. Additional guidance for : mining waste operations*

369. Other mitigation measures relating to the environmental effects of hazardous wastes such as surplus natural gas are included within the air assessment in Chapter 6.

370. Mitigation measures relating to the environmental effects of waste are included within the hydrogeology and contamination assessment in Chapter 11.

Industrial wastewater

371. Cuadrilla will regularly test the surface water from the pad to identify if it is possible to:

- use the surface water in the hydraulic fracturing process; or
- send the surface water to the local watercourse.

17.8.5 Initial Flow Testing

17.8.5.1 Mobilisation

372. There are no mitigation measures relating to flow testing mobilisation.

17.8.5.2 Operation

373. Mitigation measures for the general waste and hazardous waste generated during flow testing are the same as those identified for the hydraulic fracturing phase.

17.8.5.3 Flowback Fluid

374. Flowback fluid generated during the flow testing and extended flow testing phases will be treated offsite at a specialist facility as a radioactive waste. Upon receipt at the specialist waste treatment facility, the flowback fluid waste would be sampled to ensure compliance with permit conditions, and then unloaded into dedicated reception/ storage tanks. Cuadrilla will engage waste contractors that demonstrate they can handle the waste in accordance with the permits and comply with all legislative requirements to minimise environmental impact. Flowback fluid is then subjected to an acid/alkali treatment reaction to remove NORM followed by dewatering in accordance with the waste contractor's environmental permit(s).

Embedded mitigation

375. In addition to achieving the various permitting requirements Cuadrilla has introduced embedded mitigation during the design and planning stage to reduce the amount of flowback fluid generated by the Project. This embedded mitigation includes:

- Fracturing of wells at both Preston New Road and Roseacre Wood will be staggered to avoid increasing weekly wastewater production rates due to cumulative effects;
- The volume of water used in hydraulic fracturing is proposed to be 750m^3 per fracturing stage (as opposed to a more typical 1000m^3/stage) to reduce the volumes of water required and flowback fluid produced;
- The re-use of flowback fluid during hydraulic fracturing to further reduce water consumption and flowback fluid production;

Additional mitigation

376. The significant effects identified in the assessment in relation to the physical treatment of flowback fluid and associated radioactivity capacity will be managed by Cuadrilla through additional mitigation for the Project during operation. This operational mitigation will require logistical input and could potentially impact on Cuadrilla's programme. The mitigation is detailed below to buffer the impact on the flowback fluid treatment facilities during peak periods and when implemented will help to ensure the impacts on the treatment facilities are managed. With these mitigation measures at no time should the production of flowback fluid exceed the capacity of the treatment facilities to manage the flowback fluid.

- Investigate the potential to recycle the flowback fluid from the flow testing process. This flowback fluid would need to be treated before recycling. If feasible this activity would need to be assessed by the EA in a later variation of the Environmental Permit;
- Storage of up to 3000m³ capacity for flowback fluid within steel containers as part of the Cuadrilla RSR permit application.
- Investigate the potential to pre-treat flowback fluid onsite before it is transported to the specialist WwTW. There are likely to be additional facilities in the UK with experience of treating similar wastes from industrial sectors such as Oil and Gas;
- Cuadrilla will use the choke manifold to restrict the flow rate of fluid from the well;
- Radionuclide activity shall be monitored during the lifetime of the Project, to ensure that no activity-related capacity issues arise;
- Temporarily store flowback fluids onsite if required to alleviate the treatment capacity at the disposal facility; and
- As a contingency case where flowback fluid treatment capacity was unavailable, the operation will be suspended until treatment capacity becomes available.

377. In addition to the operational mitigation identified above Cuadrilla will undertake strategic actions to tackle the very substantial impacts associated with the potential inadequate capacity for treating flowback fluid:

- Continue discussions with the identified offsite treatment facilities to increase their current treatment capacity. Treatment Site A can potentially increase its treatment capacity to 500m^3 per week;
- Identify additional offsite treatment facilities to treat flowback fluid. Cuadrilla are currently discussing potential treatment opportunities with a number of operators who are applying for environmental permits to treat flowback fluid containing NORMs. Should these permits be granted, this will provide additional treatment capacity within the region; and
- Discuss any issue relating to insufficient capacity with appropriate stakeholders. If additional flowback fluid treatment capacity cannot be identified Cuadrilla shall notify the EA, Water UK and UKOOG to discuss the problem.

378. Were Cuadrilla were to experience higher flowback fluid production than expected they would :

- Provide additional tank capacity onsite to store flowback fluids temporarily so that off-site disposal does not exceed treatment rate agreed with relevant treatment works;
- Consider shutting off the well for a short period (ie stop flowback temporarily). This will also allow flows off site to be controlled to within the available treatment capacity; and

- Reconsider future hydraulic fracturing operations to reduce flowback volumes – e.g. reduced number of hydraulic fracturing stages, smaller volumes, etc.

379. Cuadrilla shall obtain all WTNs and any consignment notes relating to flowback fluid waste to record a clear audit trail for the wastes..

17.8.5.4 Hazardous Waste

380. Surplus natural gas will be burned at a temperature above 800°C to ensure complete combustion.

17.8.6 Extended Flow Test

17.8.6.1 Construction

381. The Design Team for the project would investigate opportunities to avoid, reduce and re-use excavated materials generated from the construction of the extended well testing infrastructure.

382. Waste arising from the construction of the extended well testing infrastructure shall be included in the construction site waste management plan. These waste arisings include any excavated materials that are re-used on site.

17.8.6.2 Operation

383. Mitigation measures for the flowback fluid, general waste and hazardous waste generated during extended flow testing are the same as those identified for the initial flow testing phase.

17.8.7 Decommissioning and Restoration

17.8.7.1 Extended Well Testing Infrastructure

384. In relation to the decommissioning of any extended well testing infrastructure, Cuadrilla shall investigate the opportunity to re-use or recycle materials.

17.8.7.2 Exploration Well Pad

385. In relation to the decommissioning of the exploration well, pad and access track, Cuadrilla shall investigate the opportunity to re-use or recycle materials. Aggregates shall be removed in a manner that optimises the amount that can be re-used.

386. Where any of the well pad becomes contaminated this shall be disposed of as hazardous waste.

Suspension Brine

387. Suspension brine must only be disposed of to a specialist facility. Cuadrilla shall check with their waste management contractor or broker where the material will be taken and how it will be treated as there are a limited number of licensed waste disposal sites that can accept liquids for treatment prior to disposal.

17.9 Residual effects

388. The mitigation measures summarised in section 17.9 will reduce the Project's waste effects wherever practicable. Detailed quantitative assessment of the residual effects has not been undertaken

17.10 Assessment summary matrix

389. The summary matrix for the waste assessment for the project is displayed in Table 17.99.

Table 17.99 : Waste assessment summary matrix

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
Construction of the Well Pad and Access				
Inert waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of inert waste.	Negligible Not significant	Not applicable
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Installation of Surface and Buried Arrays				
Inert waste	Negligible Not significant	N/A	Negligible Not significant	Not applicable
Drilling				
Mobilisation				
Not applicable				
Drilling				
Inert waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of inert waste.	Negligible Not significant	Not applicable
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Hazardous Waste	Slight Not significant	Cuadrilla shall investigate the opportunities	Slight Not significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		to access industry best practice to treat and recover the drill cuttings contaminated with LTOBM. Identify suitable hazardous waste treatment facilities in the North West.		
Wastewater	Negligible Not significant	N/A	Negligible Not significant	Not applicable
Industrial wastewater	Slight Not significant	Cuadrilla shall regularly test the surface water from the pad to identify if it is possible send the surface water to the local watercourse or use the surface water in the hydraulic fracturing process.	Slight Not significant	Not applicable
Hydraulic Fracturing				
Mobilisation				
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Hydraulic Fracturing				
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-	Negligible Not significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		hazardous waste.		
Low Level Waste	Negligible Not significant	N/A	Negligible Not significant	Not applicable
Wastewater	Slight Not significant	N/A	Slight Not significant	Not applicable
Industrial wastewater	Slight Not significant	Cuadrilla shall regularly test the surface water from the pad to identify if it is possible send the surface water to the local watercourse; Use the surface water in the hydraulic fracturing process.	Slight Not significant	Not applicable
Flow testing				
Mobilisation				
Not applicable				
Flow testing				
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Flowback Fluid	Very substantial Significant	Investigate the potential to recycle and treat the flowback fluid from the hydraulic fracturing process. Identify additional appropriate treatment capacity with alternative	Very Substantial Significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		treatment facilities. Discuss any issue relating to insufficient capacity with the EA and other stakeholders. During peak flows Cuadrilla will restrict the volume of flowback fluid. Store flowback fluids onsite to reduce the impact at the treatment facility. Accumulate peak flowback fluids at the treatment sites until they can be treated. Consider shutting off the well for a short period (ie stop flowback temporarily).		
Wastewater	Negligible Not significant	N/A	Negligible Not significant	Not applicable
Industrial wastewater	Slight Not significant	Cuadrilla shall regularly test the surface water from the pad to identify if it is possible send the surface water to the local watercourse. Use the surface water	Slight Not significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		in the hydraulic fracturing process.		
Extended well testing				
Construction				
Not applicable				
Operation				
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Flowback Fluid	Very substantial Significant	Identify additional appropriate treatment capacity with alternative treatment facilities. Discuss any issue relating to insufficient capacity with the EA and other stakeholders. Store flowback fluids onsite to reduce the impact at the treatment facility. Accumulate peak flowback fluids at the treatment sites until they can be treated. Consider shutting off the well for a short period (ie stop flowback	Very Substantial Significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		temporarily).		
Wastewater	Negligible Not significant	N/A	Negligible Not significant	Not applicable
Industrial wastewater	Slight Not significant	Cuadrilla shall regularly test the surface water from the pad to identify if it is possible send the surface water to the local watercourse; or use the surface water in the hydraulic fracturing process.	Slight Not significant	
Decommissioning and Restoration				
Inert Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of inert waste.	Negligible Not significant	Not applicable
Non-hazardous Solid Waste	Negligible Not significant	Identify opportunities for off-site re-use, recycling and recovery of non-hazardous waste.	Negligible Not significant	Not applicable
Hazardous Waste	Negligible Not significant	Hazardous waste would be correctly labelled, securely contained transported off site and disposed of by appropriately permitted waste carrier and disposal sites for hazardous	Negligible Not significant	Not applicable

Description of effect	Significance	Mitigation	Residual effect	Offsetting and enhancement
		waste.		

18 Transport

Chapter Summary – Transport

This chapter assesses the effects of the Project on transport. In particular it considers the potential effects of the Project on the transport networks serving the Site and surrounding area.

In the assessment the following potential effects from transport and traffic have been assessed:

- Driver delay;
- Pedestrian delay;
- Pedestrian amenity;
- Severance (the physical/perceived separation caused by highways/traffic);
- Accidents and safety; and
- Dust and dirt.

To inform the assessment existing data (e.g. accident records) have been reviewed and data collected (traffic surveys). Using data provided by Cuadrilla about the likely numbers of vehicle movements (including both heavy goods vehicles and light vehicles including cars and vans) the impact of the Project on the topic areas listed in the bullet points above has been undertaken.

The assessment has highlighted that over the lifetime of the Project the numbers of vehicle movements that will be generated will vary with peak movements being related to periods when equipment is being brought to or removed from to Site. These peaks generally only last for a few days (e.g. a week) before traffic movements reduce to a lower level during operations such as drilling, hydraulic fracturing and flow testing.

The assessment has considered all Project stages and although traffic levels on Preston New Road are increased slightly, this increase is not large enough, even during the peak of operations, to lead to a significant transport effect.

To reduce the impact of the Project on transport the following potential traffic management plan measures can be implemented, subject to consultation with LCC Highways:

- Use of specific access routes to and from the M55;
- Use of site management and housekeeping to minimise impacts on road users near to the Site and manage nuisance issues such as mud on the road;
- Providing drivers that travel to and from the Site with training about how they and when they should access the site;
- Monitoring the routes used including highway condition surveys; and
- Communicating with LCC Highways and drivers accessing the Site and providing a mechanism for residents and other road users to report issues or concerns,.

18.1 Introduction

1. This chapter assesses the likely significant effects of the proposed Project on transport. In particular, it considers the potential effects of the development on the transport networks serving the site and the surrounding area. A Transport Assessment (TA) has been produced for the Exploration Works and a Transport Statement (TS) for the Monitoring Works. These are presented in Appendices R1 and R2 respectively.

18.2 Key Development Issues

2. The key issues of particular relevance to transport are the delivery of plant, staff and materials to and from the site. A large proportion of the vehicles accessing the Site will be Heavy Goods Vehicles (HGVs). The effects of these vehicles on the highway network and public rights of way (PROW) have been considered in this chapter.

18.3 Scoping and Consultation

3. A Scoping Opinion has been obtained from both the Highways Agency (HA) (responsible for the Strategic Road Network) and Lancashire County Council (LCC) (the local highway authority). These scoping responses have informed the methodology and production of this chapter. Meetings have been held with officers of LCC and the HA to discuss the transport effects of the development.

Table 18.1: Transport scoping and consultation overview.

Consultee	Comment	Response
Highways Agency	The proposed approach and the key steps to be included in the process appear to be acceptable. With regard to traffic and transportation, we would expect to see the transport implications as outlined in the document to be included in a Transport Assessment. This should include an assessment of the potential impacts of traffic during the construction/mobilisation stage in addition to the usual daily operational movements.	Noted. The issues raised have been assessed in the TA and ES Chapter.
	We are most keen to see how the proposal will affect parts of the strategic road network that would be used to gain access to the site, which would at Junction 4 of the M55 motorway. It would also be advisable to include Junction 3 of the M55 as a potential access route.	
Lancashire County Council	LCC has confirmed that the details provided in the scoping report are sufficient to assure them that an appropriate Transport Assessment will be provided to assess the highway implications of the development proposals.	Noted
	The ES should be accompanied by a Transport Assessment (TA) that contains information on the likely traffic impacts of the construction of the site, drilling, testing and restoration operations. The TA should concentrate on the impacts of traffic using the local roads between the site and the primary road network including an examination of the likely impacts of HGVs and any abnormal loads that may be associated with the development, operation and restoration of the site.	A TA has been produced and is appended to the ES as Appendix R1 (for the exploratory works)

Consultee	Comment	Response
	The TA should include an analysis of expected vehicle numbers and sizes with a traffic management scheme demonstrating how vehicles will enter and leave the site and the routing of vehicles to and from the site to avoid local highway impacts. The TA should also consider the disposal of waste arising and water required for fracking operations and the traffic impacts associated with these aspects of the development.	This analysis is presented both in this chapter and in the TA at Appendix R1.
	The impacts on any public transport routes and passenger stops should be considered.	This analysis is presented both in this chapter and in the TA at Appendix R1.

18.4 Methodology

18.4.1 Introduction

4. The National Planning Policy Framework[434] (NPPF) sets out the Government's requirements for the planning system. NPPF states that "All developments that generate significant amounts of movement should be supported by a Transport Statement or Transport Assessment." The Department for Transport (DfT) has published Guidance on Transport Assessment[435] which includes (at Appendix B of that document) indicative thresholds for when a Transport Assessment (TA) is required. These thresholds are based on either the size or scale of land use (based upon land use classifications); or other considerations. As this type of development does not fall within the specified list of land use categories, these other considerations have been used to determine whether a TA is required. These considerations state that a TA will be required when the development:

- Is not in conformity with the adopted plan;
- Will generate more than 30 two-way vehicle movements per hour;
- Will generate more than 100 two-way movements per day;
- Proposes more than 100 parking spaces;
- Is likely to increase accidents or conflicts amongst motorised users and non-motorised users;
- Will generate significant freight or HGV movements per day or significant abnormal loads per year;
- Is proposed where the local transport infrastructure is inadequate (e.g. sub-standard roads); and
- Is proposed in a location within or adjacent to an Air Quality Management Area.

5. On the basis that the proposed development could be considered to meet (or may potentially meet) some of the criteria listed above, a Transport Assessment has been undertaken for the Preston New Road site exploration works (see Appendix R1 for

[434] National Planning Policy Framework, Communities and Local Government, 2012
[435] Guidance on Transport Assessment, Communities and Local Government & Department for Transport, 2007

details) and a Transport Statement has been produced for the monitoring works (Appendix R2). This will allow any transport effects to be identified and appropriate mitigation measures to be put into place.

6. It should be noted that, generally, the forecast volumes of traffic movements generated by Site development and operation fall below the quantitative significance criteria outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day and 100 parking spaces).

7. The DfT Guidance[436] also states that if the development requires a formal EIA, this should be cross-referenced in the TA. It is therefore considered that in order to provide a robust and consistent assessment of the effects of the development, a transport chapter should also be presented within the Environmental Statement (ES) that draws on the results of the TA. For completeness, copies of the TA and TS have also been included as a technical appendix to this ES (Appendicies R1 and R2).

18.4.2 Baseline Methodology

8. Traffic surveys have been undertaken at the closest junction to the Site (Preston New Road/Moss House Lane). This is the closest existing highway junction to the proposed site access and will therefore provide an indication of the current volume of traffic passing the proposed site. This survey was undertaken on Tuesday 08 October 2013 between 07:00hrs and 19:00hrs.

9. Accident collision data has been obtained from LCC. The collision data relates to the period from July 2008 to June 2013, the most recent five year period for which data was available at the time of it being requested (17 October 2013). The geographic study area for collisions extends from Peel Road in the west and east to Westby Road.

18.4.3 Assessment Methodology for Construction Effects

10. The effects of transport associated with the construction of the Project have been assessed under a number of headings. These are based upon the Institute of Environmental Management and Assessment (IEMA) Guidelines[437]. The IEMA Guidelines provide a checklist for headings within the assessment that is based upon the Design Manual for Roads and Bridges (DMRB) but excludes those headings that relate solely to new road construction and includes additional headings that may be relevant for an individual development.

11. The list of headings provided in the IEMA Guidelines is as follows:

- Noise*
- Vibration*
- Visual impact*
- Severance
- Driver delay
- Pedestrian delay

[436] Guidance on Transport Assessment, Communities and Local Government & Department for Transport, 2007
[437] Guidelines for the Environmental Assessment of Road Traffic, The Institute of Environmental Management and Assessment, 1993

- Pedestrian amenity
- Accidents and safety
- Hazardous Loads/Waste *
- Air pollution*
- Dust and dirt
- Ecological impact*
- Heritage and conservation areas*

12. Separate ES chapters have been produced for those headings with an *. This chapter therefore considers those headings that are not covered elsewhere within the ES.

13. The effects of Site traffic have been assessed under each of these headings on the basis that vehicles will travel to and from the site via the Strategic Road Network (SRN) from Junction 4 of the M55 from the west along the A583 Preston New Road and from Junction 3 of the M55 to the east along the A585 Fleetwood Road and the A583 Blackpool Road. These are the preferred routes for site traffic as identified in the TA.

14. Once traffic has reached the SRN it is considered that the effects of traffic generated by the development will not be significant given the very small proportional increase in traffic due to the development.

15. Information has been provided by Cuadrilla on the forecast traffic movements to and from the site. These forecasts have been derived from first-principles with regards to the plant and materials required to construct, operate and decommission the proposed facility. This methodology provides an accurate, site-specific estimate of the likely vehicle movements to and from the site. Further details of the proposed site operations and assumptions are presented in Appendix B of the ES.

16. Separate forecasts have been developed for heavy goods vehicles (HGVs) and light vehicles (cars and small vans). The HGVs will be predominantly articulated lorries. There would also be a requirement for some smaller HGV movements.

17. The net increase in traffic along the proposed HGV route has been forecast. An assessment has then been made on the impact of this increase in traffic (both in terms of HGVs and overall traffic) under each of the headings below.

18.4.3.1 Driver delay

18. Potential locations for delays to non-development traffic will include the Site entrance(s), the road passing the Site (i.e. Preston New Road), at key junctions elsewhere on the highway network, and from side roads onto Preston New Road due to a reduced ability for drivers to find gaps in traffic on the major road.

19. Table 2 of TA79/99[438] has been used to estimate the link capacity of the main routes to the site. These are presented in Table 18.2.

[438] TA79/99 Traffic Capacity of Urban Roads (DMRB Volume 5, Section 1), The Highways Agency, 1999

Table 18.2: Estimated link capacity of route sections

Route Section	Road Type	Total No. of Lanes	Carriageway Width	Capacity (busiest direction - 60/40 split)	Two-way Capacity
A583 Preston New Road	UAP2	2	7.3	1,470	2,650

20. The potential delay to drivers caused by traffic generated by the development has been assessed by adding the forecast traffic generated by the Site to the baseline flows on Preston New Road. Where the resulting net forecast traffic flows are close to, or exceed the values in Table 18.2 it is considered that there is a potential increase in delay to drivers.

21. Alongside the potential delays to drivers due to link capacity being exceeded, there is also potential for delays at junctions along the route due to increased traffic. An assessment has been made of the potential for additional delay at junctions along the route based upon the forecast increases in traffic.

18.4.3.2 Pedestrian delay

22. The effects on pedestrian delay have been assessed by identifying any PROW or pedestrian crossings that would be crossed by traffic generated by the Site. Where the proposed route for Site traffic crosses the path of a PROW or pedestrian crossing there is a potential for increases in pedestrian delay. The effect of these delays will be assessed based upon the increase in traffic levels and the likely levels of pedestrian demand on the route affected.

18.4.3.3 Pedestrian amenity

23. The term pedestrian amenity is broadly defined as ‘the relative pleasantness of a journey’. It is considered to be affected by changes in traffic flow, traffic composition and pavement width/separation from traffic. The effects on pedestrian amenity have been assessed by considering the changes in traffic flow, composition and pavement width/separation due to the development along the proposed route.

18.4.3.4 Severance

24. Severance is the physical or perceived division that can occur within a community when it becomes separated by a major traffic artery. It can occur due to difficulties in crossing a heavily trafficked road or due to impeded pedestrian access to essential facilities. The effects of severance have been assessed by considering the forecast increases in traffic along the route and the key pedestrian accesses to essential facilities in the area.

18.4.3.5 Accidents and safety

25. The number, severity and causal factors of accidents recorded in the baseline assessment have been used alongside the forecast traffic flow increases in order to assess the potential for increases in traffic accidents along the route.

18.4.3.6 Dust and dirt

26. Due to the nature of the processes proposed for the proposed development, and the use of HGVs to transport materials and plant to and from the Site, there is a risk of dust and dirt being generated and transferred to the highway network. Based upon information provided in the IEMA Guidance it is considered that dust and dirt are unlikely to occur at distances more than 50m from the road. The route will be assessed for the potential of dust and dirt to be transferred to the highway network and the effects that this may have on road users.

18.4.4 Assessment Methodology for the Effects from Installation of Arrays

27. Locations for the monitoring stations for the seismic arrays, including the traffic light system and microseismic arrays, have been identified based upon the technical specifications and monitoring requirements of the array.

28. Access routes to each of the monitoring stations from the highway network have been identified with a view to minimising the length of the route from the highway network and using existing highway access points where practical. It is proposed to use existing accesses for all monitoring stations.

29. Site visits were undertaken to review each proposed access point and identify any potential safety, capacity or operational issues associated with the proposed access.

30. The installation of arrays stage has been further subdivided into ‘traffic light system’ and ‘micro-seismic array’ sub-stages.

18.4.5 Assessment Methodology for Operational Effects

31. The assessment methodology for operational effects is the same as described for the construction stage. The operational stage has been further subdivided into ‘drilling’, ‘hydraulic fracturing’, ‘initial flow testing’ and ‘extended well testing’ sub-stages.

18.4.6 Assessment Methodology for Decommissioning Effects

32. Following the completion of the testing, the Preston New Road site would either be suspended and remain in its testing state, or be decommissioned. If the well is decommissioned then it will be restored as close as possible to its current condition.

33. The effects of the traffic generated by the Site during decommissioning have been assessed using the same methodology and headings as in the construction and operational stages described above.

34. If the Site is suspended, then transport conditions will involve occasional visits to check on security and to monitor and/or service the wells. If the site is abandoned and restored to its former condition then there will be a number of ‘construction’ vehicle movements associated with its removal. The number of vehicle movements required to undertake this work have been forecast and assessed.

18.4.7 Assessment Methodology for Overall Effects

35. There will be up to four wells within the Site and the peak traffic flows are likely to occur as a result of combined activities at more than one well. Construction of the well pad and access and decommissioning will only take place once at the start and the end of the process respectively.

36. There will be restrictions on which activities can take place simultaneously. Due to operational restrictions, there will not be any times whereby drilling and/or hydraulic fracturing is undertaken at the same time on the Site. The profile of traffic movements over the lifetime of the site therefore assumes that drilling of a well will only commence once fracturing of the previous well has ceased and that well has entered the initial flow testing phase. An assessment has therefore been made of the forecast total traffic movements that would be generated by the site as a whole over the testing period. This assessment has been undertaken using the same headings and methodology as the construction, operation and decommissioning stages.

18.4.8 Significance Criteria

37. In order to determine the significance of the effects identified using the methodologies described above, significance criteria have been used. The significance criteria are based on the Design Manual for Roads and Bridges Significance of Effect Categories[439]. These categories take account of the environmental value (or sensitivity) of a receptor and the magnitude of impact (or degree of change).

38. Environmental value is graded into five categories as follows:

- Very High (E1) – very high importance and rarity, international scale and very limited potential for substitution;
- High (E2)– high importance and rarity, national scale and limited potential for substitution;
- Medium (E3) – high or medium importance and rarity, regional scale, limited potential for substitution;
- Low (E4) – low or medium importance and rarity, local scale, and
- Negligible (E5) – very low importance and rarity, local scale.

39. The magnitude of impact is graded into five categories as follows for adverse impacts:

- Major Adverse impact (MA1) – loss of resource and/or quality and integrity of resource, severe damage to key characteristics, features or elements;
- Moderate Adverse impact (MA2) – loss of the resource, but not affecting the integrity; partial loss of/damage to key characteristics, features or elements;
- Minor Adverse impact (MA3) – Some measureable change in attributes, quality or vulnerability; minor loss of, or alteration to one (or more) key characteristics, features or elements;
- Negligible Adverse impact (MA4) – Very minor loss or detrimental alteration to one (or more) characteristics, features or elements; and

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- No change (MA5) – no loss or alteration of characteristics, features or elements; no observable impact in either direction.

40. The magnitude of impact is graded into five categories as follows for beneficial impacts:

- Major Beneficial impact (MB1) – large scale or major improvement of resource quality; extensive restoration or enhancement; major improvement of attribute quality;
- Moderate Beneficial impact (MB2) – benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality;
- Minor beneficial impact (MB3) – minor benefit to, or addition of, one (or more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of a negative impact occurring;
- Negligible Beneficial impact (MB4) – Very minor benefit to or positive addition of one (or more) characteristics, features or elements; and
- No Change (MB5) – no loss or alteration of characteristics, features or elements; no observable impact in either direction.

41. The environmental value and the magnitude of impact are then combined to rate the significance of the effect as shown in Table 18.3.

Table 18.3: Significance of Effects

Environmental Value	**Magnitude of Impact**				
	M(A/B)5 No change	**M(A/B)4 Negligible impact**	**M(A/B)3 Minor impact**	**M(A/B)2 Moderate impact**	**M(A/B)1 Major impact**
E1: Very high value	Neutral effect	Slight adverse/beneficial effect	Moderate adverse/beneficial effect	Large adverse/beneficial effect	Very large adverse/beneficial effect
E2: High value	Neutral effect	Slight adverse/beneficial effect	Moderate adverse/beneficial effect	Large adverse/beneficial effect	Very large adverse/beneficial effect
E3: Medium value	Neutral effect	Slight adverse/beneficial effect	Slight adverse/beneficial effect	Moderate adverse/beneficial effect	Large adverse/beneficial effect
E4: Low value	Neutral effect	Neutral effect	Slight adverse/beneficial effect	Slight adverse/beneficial effect	Moderate adverse/beneficial effect
E5: Negligible value	Neutral effect	Neutral effect	Neutral effect	Slight adverse/beneficial effect	Slight adverse/beneficial effect

42. For the purposes of this assessment, a significant effect is defined as an effect that is moderate, large or very large. Thus, neutral and slight effects are not considered to be significant.

18.5 Assumptions and Limitations

43. The key assumptions which form the basis of this assessment relate to the forecasts of traffic movements. These forecasts have been derived from first-principles with regards to the plant and materials required to construct, operate and decommission the proposed facility, and draws on the data set out in Appendix B. This methodology provides an accurate, site-specific estimate of the likely vehicle movements to and from the site.

44. As with any site-based testing/exploration, there is a risk of some variation to the planned activity durations and sequencing due to unforeseen events. For this reason, the forecasts for each stage are presented as ranges with minimum and maximum values for each stage and sub-stage. The assessment is therefore based upon the best available information at the time.

18.6 Baseline

18.6.1 Site Information

45. The site is located adjacent to the A583 Preston New Road. The entrance to the site will be located to the east of an existing lay-by on Preston New Road approximately 2.2km south-east of Junction 4 of the M55. This access will be used by nearly all vehicle movements associated with the Site.

46. A second access will also be created to the west of the main access. This will provide very occasional access for National Grid to maintain their equipment installed at the compound connection point from the site to the gas grid. This access will be a 'farm gate' style and will only be used by National Grid for occasional maintenance of the National Grid facility.

47. Preston New Road is an 'A' classified single carriageway road with a footway on the south side of the road only in this location. The proposed site accesses are presented in Appendix R1.

48. The Preston New Road Site is currently in agricultural use and there are no uses on site that generate any traffic other than for farming purposes.

18.6.2 Traffic Flow Data

49. Traffic flow data has been obtained through a fully classified traffic survey which recorded vehicles passing junction closest to the Site in a twelve hour period. The survey was undertaken on Tuesday 8 October 2013 from 07:00hrs-19:00hrs.

50. TRADS provides traffic flow information for sites on the HA's SRN. The closest site for which data is available is on Fleetwood Road (A585) between the M55 and Thistleton Road (B5269). Data for the five-day period of 07 October-11 October 2013 has been interrogated in order to correspond with the survey data. The data is presented is Appendix R1 (Annex B). Table 18.4 shows the vehicle count and HGV count during various time periods on Preston New Road, adjacent to the site.

Table 18.4: Preston New Road two-way vehicle counts

Time	**Preston New Road**		
	Vehicle Count	HGVs	HGV %
AM Peak (08:00hrs-09:00hrs)	1,183	35	3.0%
PM Peak (1700-1800)	1,427	11	0.5%
12hr (07:00-19:00)	10,659	226	2.1%
18hr* (06:00-00:00)	12,621	246	2.0%
24hr*	12,981	257	2.0%

* 18hr and 24hr counts have been estimated by factoring the surveyed 12hr counts using the daily profile of traffic contained within the HA's Traffic Flow Data Service (TRADS).

18.6.3 Public Transport

51. The nearest train station is Kirkham & Wesham located approximately 4km from the site. There are hourly train services from Kirkham & Wesham calling at destinations that include Manchester Victoria, Blackpool (North and South), Preston and Liverpool Lime Street.

52. Bus service 61 runs along Preston New Road (A583) every 30 minutes during peak hours. The route is between Preston-Blackpool. There is a westbound bus stop approximately 100m to the west of the proposed site access (with a shelter). There is a corresponding eastbound stop on the opposite side of the road to the westbound stop.

18.6.4 Pedestrian and Cycle Infrastructure

53. There are no formal PROWs in the vicinity of the Preston New Road site access or along any of the potential access routes to the site from the SRN. The closest PROW is north of the M55.

54. There are no national or regional cycle routes which pass the site; however there is a 0.5km section of on road cycle route on Preston New Road (A583) at the approach to Junction 4 of the M55. There are some other small sections of cycle path proposed for the same area. There are advisory cycle lanes on both sides of the road either side of Preston New Road adjacent to the site.

55. Pedestrian footways are in place on one side of the road only on Preston New Road to the opposite side of the road to the Site. The proposed Site access will therefore not affect any footways on Preston New Road.

18.6.5 Accident Data

56. Accident data has been received from LCC and is presented in Appendix R1 (Annex C). The collision data relates to the period from July 2008 to July 2013, the most recent five year period for which data was available at the time it was requested (18 October 2013).

57. The study area covered the potential routes site traffic will likely use. The study area is a 2.3km section of the A583 adjacent to the site, including the western junction of Moss House Lane with the A583 and the eastern junction with Westby Lane and the village of Little Plumpton.

58. In the study area four accidents occurred in the last five years. All four accidents were reported as slight in nature. One accident involved a goods vehicle weighing under 3.5t, one involved a motorcycle and the other accidents all involved cars.

59. One of the four accidents occurred close to the proposed entrance to the development site. The reported cause of this accident was a private hire/ taxi vehicle pulling out without looking after it stopped at the side of the road.

60. The three remaining accidents were all reportedly caused by driver errors such as swerving, failing to look and health/ illness problems.

18.7 Assessment

61. This section sets out the forecast vehicle movements associated with each stage of the testing process. There will be four wells within the Site and the peak traffic flows are likely to occur as a result of the cumulative impact of activity at more than one well. Construction of the well pad and access and decommissioning of the Site will only take place once, at the start and the end of the process respectively.

18.7.1 Construction of Well Pad and Access

62. Construction of the well pad is forecast to take approximately two months to complete. Standard civil engineering plant will be used to construct the exploration site. This equipment will be brought to and from the site using HGVs.

63. The delivery of plant and other equipment to Site is anticipated to last approximately three weeks. This part of the construction period is forecast to generate between 0-14 two-way HGV movements per day.

64. The peak period of vehicle movements during construction relates to the import of the materials (predominantly stone) required to construct the pad. This peak period is anticipated to last for approximately three weeks. It is estimated that during this part of the construction period there would be up to 24 inbound and 24 outbound HGV movements per day. Peak HGV movements during this period are therefore forecast to be up to 48 two-way movements per day.

65. Following this peak period, the number of construction vehicles is forecast to reduce to less than 10 two way HGVs per day. This period of construction would last for approximately two weeks.

66. In addition to the movement of HGVs, there are also forecast to be approximately 12 two-way light vehicle movements per day associated with Site staff. This volume of traffic would be relatively constant throughout the construction stage.

67. On average over the two month period, construction would result in 12 two-way light vehicle movements and 22 two-way HGV movements per day. The forecast traffic movements for each stage are presented in Table 18.5.

Table 18.5: Forecast Traffic Generation (Construction) daily two-way movements.

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
1	A	Commencement of construction	3 weeks	12	0-14	12-26
	B	Materials to site	3 weeks	12	44-48	56-60
	C	Completion of construction	2 weeks	12	0-8	12-20
	All	**Average for construction stage**	**2 months**	**12**	**22**	**34**

68. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table18.6.

Table18.6: Forecast two-way traffic flows between 07:00-19:00 (Construction)

Route Section	Baseline flows (two-way)		With average construction stage site traffic (two-way)		With peak construction stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total
Preston New Road	226	10,659	248	10,693	274	10,719

18.7.1.1 Driver Delay

69. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.7.

Table 18.7: Estimated capacity along proposed route (Construction)

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	60

70. The forecast peak vehicle movements associated with the proposed development during the construction stage is 60 two-way vehicle movements per day. These movements will be spread throughout the working day depending upon the hours of operation of the development and the operational needs of the construction works.

71. From Table 18.7 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated during the construction stage will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road during the peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the Project. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

72. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 48 during construction. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay. The forecast volumes of traffic movements generated by the development are likely to fall well below the quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

73. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

74. The effect on driver delay is likely to be a **slight adverse effect**.

18.7.1.2 Pedestrian Delay

75. There are no PROWs located on or close to the routes proposed to be used by construction traffic. The proposed Site access does not affect any footways. The relatively

small forecast increase in total vehicles using the route as a result of the development will therefore not create any delay to pedestrians.

76. The environmental value of the area likely to be affected by pedestrian delays is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROWs are affected. The magnitude of the impact is considered to be MA5 (No Change) as the very small increase in traffic volumes is likely to have a negligible impact upon pedestrian delay crossing adjacent roads at any individual location.

77. The effect on pedestrian delay is likely to be **a neutral effect**.

18.7.1.3 Pedestrian Amenity

78. The forecast increase in daily traffic flows is very small and as such, it is not considered that pedestrian amenity would be affected due to an overall increase in traffic volumes. Similarly, the pavement width/separation from traffic will not change due to the proposed development. Due to the relatively small volume of traffic generated by the development in comparison to the existing flows on Preston New Road, it is not considered that there would be an observable change in traffic composition on the road.

79. The environmental value of the area likely to be affected in terms of pedestrian amenity is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be affected. The magnitude of the impact is considered to be MA5 (No Change) as the very small increase in traffic volumes is likely to have a negligible impact upon pedestrian amenity on Preston New Road.

80. The effect on pedestrian amenity is likely to be a **neutral effect.**

18.7.1.4 Severance

81. As demonstrated in Table18.6, the traffic generated by the proposed development will only result in a small increase in traffic on Preston New Road both in absolute and percentage terms. The traffic volumes that would be generated by the Site would not increase the difficulty in crossing Preston New Road or result in any increase in severance caused by the road, which already carries approximately 13,000 vehicle movements per day.

82. The environmental value of the area likely to be affected in terms of severance is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be affected. The magnitude of the impact is considered to be MA5 (No Change) as the low traffic volumes generated will not result in an observable change in severance.

83. The effect on severance is likely to be a **neutral effect**.

18.7.1.5 Accidents and Safety

84. The accident data demonstrates that there have only been four accidents in the vicinity of the proposed site access in the past five years. On that basis, and given the relatively small amount of additional traffic generated by the development, the risk of an increase in accidents on this road is considered to be low.

85. The proposed site access has been designed with appropriate visibility splays to the standards set out in the Design Manual for Roads and Bridges. This will ensure suitable visibility of oncoming traffic to allow Site traffic to enter and exit the site under safe conditions. A safety audit has been undertaken and only one matter was raised (the provision of double white lines on approach to the junction). This matter has been incorporated into the junction design.

86. The environmental value of the area likely to be affected by accidents and safety is considered to be E4 (Low Value) due to the local area over which the risk of accidents could potentially be affected (i.e. in the immediate vicinity of the junction). The magnitude of the impact is considered to be MA3 (Minor Adverse) as there may be a measurable change to the risk of an accident on the highway due to the creation of a new vehicular access onto a major road. However, the risk has been minimised as far as is practical through appropriate design of the junction and through a safety audit of the proposed access. The effect on accidents and safety is likely to be a **slight adverse effect.**

18.7.1.6 Dust and Dirt

87. Due to the nature of the processes proposed for the operational period of the Site, and the use of HGVs to transport materials to and from the Site, there is a risk of dust and dirt being generated. Due to the predominance of agricultural uses in the local area, the roads surrounding the Site currently experience the deposit of mud and dirt on regular occasions. The Site will be carefully managed to prevent material from being transferred to the highway network.

88. The environmental value of the area likely to be affected by dust and dirt is considered to be E3 (Medium Value) due to the regional nature of the roads potentially affected. It is considered that material will not be transferred to the SRN due to its distance from the site. The magnitude of the impact is considered to be MA4 (Negligible Adverse) as there may be a minor change to the local roads as a result of dust and dirt from the Site due to the fact that existing agricultural uses already result in dirt on the highway. The effect of dust and dirt is likely to be a **slight adverse effect**.

89. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.7.2 Installation of Surface and Buried Arrays

90. A separate Transport Statement will be submitted as part of the planning application for the surface and buried arrays (see Appendix R2).

91. Each of the array sites will be constructed using a rig that will be towed onto the site by a tractor or a similar type of vehicle. A further two support vehicles will also require access to the site. The construction is anticipated to take place during a few days only. Once constructed, each array site will require only occasional visits (principally to change batteries) that will generate a peak traffic flow of approximately 1-2 vehicles per week.

92. Existing farm gates and access points onto the highway network would be used for the construction and maintenance of all array sites.

93. Due to the low level of traffic forecast to be generated by the installation of the arrays and the use of existing highway access points, it is considered that the installation of arrays would have a **neutral effect** under all headings.

18.7.3 Drilling

94. The first operational stage (i.e. post-construction of the well pad) is drilling. The first well drilled at the site will consist of a vertical well drilled all the way through the rock formation, and then plugged back with cement and a horizontal well drilled out from that vertical well. This will take a longer period (c. five months including mobilisation/demobilisation) than the drilling of the remaining three wells (c. three months including mobilisation/demobilisation).

95. There will be an initial peak of traffic movements as the drilling rig and equipment is brought to the site. This mobilisation period will last for approximately one week. During this period there will be up to 40 two way HGV movements per day. There will also be up to 32 two way car movements associated with Site staff.

96. Following the mobilisation of the drilling rig, the number of traffic movements to and from the site will reduce. The main HGV movements in this period will be the transport of material to and from the site. During this period (which will last for approximately 20 weeks) there will be up to 36 two way HGV movements per day. There will also be up to 36 two way car movements per day associated with Site staff.

97. At the end of the drilling period, the drilling equipment would be demobilised. This is anticipated to take place over approximately one week. The number of two-way HGV movements would be up to 50 per day for this one-week period. There would also be up to 32 two-way light vehicle movements associated with staff.

98. On average, the drilling of the first well would result in 32 two-way light vehicle movements and 14 two-way HGV movements per day.

Table 18.8: Forecast Traffic Generation (Drilling of 1st Well) daily two-way movements

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
2	A	Mobilisation	1 week	24-32	26-40	50-72
	B	Drilling	20 weeks	32-36	2-36	34-70
	C	Demobilisation	1 week	24-32	24-50	48-82
	All	**Average for drilling stage**	**5 months**	**32**	**14**	**46**

99. The drilling of subsequent wells would have a shorter duration (approximately three months). However, the various periods and ranges of traffic generation would follow the same pattern as the first well. The vehicle forecasts for the subsequent wells are presented at Table 18.9.

100. On average, the drilling of the subsequent wells would result in 32 two-way light vehicle movements and 17 two-way HGV movements per day.

Table 18.9: Forecast Traffic Generation (Drilling of subsequent wells) daily two-way movements

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
2	A	Mobilisation	1 week	24-32	26-40	50-72

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
	B	Drilling	10 weeks	32-36	2-38	34-74
	C	Demobilisation	1 week	24-32	24-50	48-82
	All	**Average for drilling stage**	**3 months**	**32**	**17**	**49**

101. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table 18.10.

Table 18.10: Forecast two-way traffic flows between 07:00-19:00 (Drilling)

Route Section	Baseline flows (two-way)		With average drilling stage site traffic (two-way)		With peak drilling stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total
Preston New Road	226	10,659	243	10,708	276	10,741

18.7.3.1 Driver Delay

102. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.11.

Table 18.11: Estimated capacity along proposed route (Drilling)

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	82

103. The forecast peak vehicle movements associated with the proposed development during the drilling stage is 82 two-way vehicle movements per day. These movements will be spread throughout the day depending upon the hours of operation of the development and the operational needs of the site.

104. From Table 18.11 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated during the drilling stage will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road in the peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the Project. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

105. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 50 during drilling. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay. The forecast volumes of traffic movements generated by the development are likely to fall well below the

quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

106. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

107. The effect on driver delay is likely to be a **slight adverse effect**.

18.7.3.2 Pedestrian Delay

108. The effect on pedestrian delay remains the same as in the construction phase as the volumes of traffic generated are of the same order of magnitude.

109. The effect on pedestrian delay is likely to be a **neutral effect**.

18.7.3.3 Pedestrian Amenity

110. Effects on pedestrian amenity are considered to be the same as the construction phase as the traffic volumes are of the same order of magnitude.

111. The effect on pedestrian amenity is likely to be a **neutral effect**.

18.7.3.4 Severance

112. The effect on severance would be the same as in the construction phase as the traffic volumes are of the same order of magnitude.

113. The effect on severance is likely to be a **neutral effect**.

18.7.3.5 Accidents and Safety

114. The effects of site traffic on accident frequency and road safety are considered to be the same as in the construction phase as the traffic volumes are of the same order of magnitude.

115. The effect on accidents and severance is likely to be a **slight adverse effect**

18.7.3.6 Dust and Dirt

116. Site traffic during the drilling stage is considered to have a similar effect with regard to dust and dirt as the construction phase as the traffic volumes are of the same order of magnitude, although the completion and “bedding in” of the well pad and access road is likely to mean that any dust and dirt effects are very likely to be lower.

117. The effect of dust and dirt is likely to be a **slight adverse effect**.

118. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.7.4 Hydraulic Fracturing

119. The hydraulic fracturing stage will generate similar volumes of traffic to the construction and drilling stages. However, there are some differences in site traffic composition between hydraulic fracturing and construction/drilling processes, which could result in different effects due to site traffic. The assessment is based upon the first two wells being hydraulically fractured using a 30 stage process and the latter two wells using a 45 stage process.

120. During hydraulic fracturing the buried and surface arrays will be used and will require operatives to drive between array stations to remotely download data after each hydraulic fracturing stage. The light vehicles (private cars or vans) will only be used to get to the stations to download the data. It will only generate one vehicle trip to each array point and operatives will drive from one array station to the next sequentially. Given the number of vehicles that will be required it is concluded that this will have a negligible impact on any of the transport receptors and therefore is not assessed further.

121. By reusing a proportion of the flowback fluid for hydraulic fracturing operations, the number of HGV tanker movements during hydraulic fracturing as the flowback fluid generated between stages will primarily remain onsite and be used to make up part of the fracturing fluid for the subsequent fracturing stage.

122. The forecast traffic flows presented in this section include the effects of this flowback reuse. The hydraulic fracturing stage for each well would last for approximately one to two months.

123. The initial period of activity will involve the mobilisation of the hydraulic fracturing equipment on the site. This period will only last a matter of days. It is forecast that there will be up to 27 two-way HGV movements during this initial period. There will also be up to 22 two-way car movements associated with staff.

124. Once the fracturing equipment has been mobilised the number of HGV movements will reduce. For a period of approximately six to eight weeks the number of two-way HGV movements will be up to 24 per day. The number of car movements associated with staff will be up to 30 two-way movements per day.

125. The forecast two-way movements associated with hydraulic fracturing are shown in Table 18.12. On average, this stage would result in 25 two-way light vehicle movements and 10 two-way HGV movements per day.

Table 18.12: Forecast Traffic Generation (Fracturing) daily two-way movements

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
3	A	Mobilisation	1 week	16-22	0-27	18-43
	B	Fracturing	6-8 weeks	24-30	0-24	26-54
	All	**Average for Hydraulic Fracturing Stage**	**1-2 months**	**25**	**10**	**35**

126. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table 18.13.

Table 18.13**:** Forecast two-way traffic flows between 07:00-19:00 (Fracturing).

Route Section	Baseline flows (two-way)		With average hydraulic fracturing stage site traffic (two-way)		With peak hydraulic fracturing stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total
Preston New Road	226	10,659	236	10,694	253	10,713

18.7.4.1 Driver Delay

127. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.14.

Table 18.14: Estimated capacity along proposed route (Fracturing)

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	54

128. The forecast peak vehicle movements associated with the proposed development during the hydraulic fracturing stage is 54 two-way vehicle movements per day. These movements will be spread throughout the day depending upon the hours of operation of the development and the operational needs of the site.

129. From Table 18.14 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated during the hydraulic fracturing stage will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road in the4 peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the Project. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

130. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 27 during hydraulic fracturing. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay. The forecast volumes of traffic movements generated by the development are likely to fall well below the quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

131. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

132. The effect on driver delay is likely to be a **slight adverse effect**.

18.7.4.2 Pedestrian Delay

133. The effect on pedestrian delay remains the same as in the drilling phase as the volumes of traffic generated are of the same order of magnitude.

134. The effect on pedestrian delay is likely to be a **neutral effect**.

18.7.4.3 Pedestrian Amenity

135. Effects on pedestrian amenity are considered to be similar to that of the drilling phase as the volumes of traffic generated are of the same order of magnitude.

136. The effect on pedestrian amenity is likely to be a **neutral effect**.

18.7.4.4 Severance

137. The effect on severance would be the same as in the drilling phase as the volumes of traffic generated are of the same order of magnitude.

138. The effect on severance is likely to be a **neutral effect**.

18.7.4.5 Accidents and Safety

139. The effects of site traffic on accident frequency and road safety are considered to be the same as in the drilling phase as the volumes of traffic generated are of the same order of magnitude.

140. The effect on accidents and severance is likely to be a **slight adverse effect**

18.7.4.6 Dust and Dirt

141. Site traffic during the hydraulic fracturing stage is considered to have a similar effect with regard to dust and dirt as the drilling phase as the volumes of traffic generated are of the same order of magnitude.

142. The effect of dust and dirt is likely to be a **slight adverse effect**.

143. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.7.5 Initial Flow Testing

144. The initial flow testing stage is forecast to generate lower traffic volumes compared to the previous stages. There are also differences in site traffic composition, which will slightly alter the effects caused by site traffic. The initial flow testing process will last for approximately three months, though the total period will be slightly longer to account for mobilisation and demobilisation of equipment.

145. As with earlier stages, the initial period of mobilisation (and the demobilisation of the primary hydraulic fracturing equipment described above) will result in a short peak of vehicle activity. For this stage, the mobilisation is forecast to last for approximately one week. The number of two-way HGV movements during this time is forecast to be up to 23 per day. There will also be up to 22 car movements per day associated with staff.

146. During initial flow testing there will be up to 22 two way HGV movements per day for a period of approximately three months. There will also be 18 two-way light vehicle movements per day associated with staff.

147. A significant proportion of HGV movements during the initial flow testing period are tanker movements associated with the removal of flowback fluid. This assessment has

been based on a 40% flowback scenario as set out in Appendix B which is considered to be conservative. Should flowback volumes be higher or lower than this estimate, the maximum and minimum daily two-way HGV movements are not expected to change significantly from that set out in Table 15 (maximum two additional movements per day). Should higher flowback rates be encountered, peak flowback production - and therefore peak HGV movements - will be sustained over a longer period. Overall however, HGV movements associated with HGV traffic during initial flow testing is forecast to generate lower HGV traffic flows compared to previous stages.

148. During the initial flow testing stage there may be a need for occasional servicing of the well (well servicing). Mobilising of equipment (including a service rig and coil tubing unit) would generate 4 two way HGV movements. After approximately one week, the well servicing equipment would be removed generating a further 4 two-way HGV movements. Well servicing would only need to be undertaken occasionally and the traffic movements generated by this process have been considered within the numbers presented in table 15 below.

149. Demobilisation of the initial flow testing equipment will take approximately one week. Two-way HGV movements over this period will be up to 11 per day. There will also be 18 two-way light vehicle movements per day associated with staff.

150. On average, flow testing would result in 18 two-way light vehicle movements and five two-way HGV movements per day.

Table 18.15: Forecast Traffic Generation (Initial Flow Testing) daily two-way movements

Stage	Phase	Description	Duration (days)	Light Vehicles	Heavy Vehicles	Total Vehicles
4	A	Mobilisation	1 week	18-22	14-23	36-45
	B	Initial Flow Testing	3 months	18	0-22	18-40
	C	Demobilisation	1 week	18	1-11	19-29
	All	**Average for initial flow testing stage**	**3-4 months**	**18**	**5**	**23**

151. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table 18.16.

Table 18.16: Forecast two-way traffic flows between 07:00-19:00 (Initial Flow Testing)

Route Section	Baseline flows (two-way)		With average initial flow testing stage site traffic (two-way)		With peak initial flow testing stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total
Preston New Road	226	10,659	231	10,682	249	10,704

18.7.5.1 Driver Delay

152. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.17.

Table 18.17: Estimated capacity along proposed route (Initial Flow Testing)

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	45

153. The forecast peak vehicle movements associated with the proposed development during the flow testing stage is 45 two-way vehicle movements per day. These movements will be spread throughout the day depending upon the hours of operation of the development and the operational needs of the site.

154. From Table 18.17 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated during the flow testing stage will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road in the peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the Project. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

155. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 23 during flow testing. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay. The forecast volumes of traffic movements generated by the development are likely to fall well below the quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

156. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

157. The effect on driver delay is likely to be a **slight adverse effect**.

18.7.5.2 Pedestrian Delay

158. The effect on pedestrian delay remains the same as in the hydraulic fracturing phase as the volumes of traffic generated are of the same order of magnitude.

159. The effect on pedestrian delay is likely to be a **neutral effect**.

18.7.5.3 Pedestrian Amenity

160. Effects on pedestrian amenity are considered to be similar to that of the hydraulic fracturing phase as the volumes of traffic generated are of the same order of magnitude.

161. The effect on pedestrian amenity is likely to be a **neutral effect**.

18.7.5.4 Severance

162. The effect on severance would be the same as in the hydraulic fracturing phase as the volumes of traffic generated are of the same order of magnitude.

163. The effect on severance is likely to be a **neutral effect**.

18.7.5.5 Accidents and Safety

164. The effects of site traffic on accident frequency and road safety are considered to be the same as in the hydraulic fracturing phase as the volumes of traffic generated are of the same order of magnitude.

165. The effect on accidents and severance is likely to be a **slight adverse effect**

18.7.5.6 Dust and Dirt

166. Site traffic during the flow testing stage is considered to have a similar effect with regard to dust and dirt as the hydraulic fracturing phase as the volumes of traffic generated are of the same order of magnitude.

167. The effect of dust and dirt is likely to be a **slight adverse effect**.

168. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.7.6 Extended Flow Testing

169. Following hydraulic fracturing of a well and completion of the initial flow test, an Extended Flow Test (EFT) may be undertaken.

170. An Extended Flow Test comprises allowing the gas to flow from a well for a period of up to 24 months in order to measure the change in the flow rate of the gas yielded from a well. From an initial peak, the flow rate of gas is expected to decline sharply initially and then level off (i.e. relatively constant flow with a very small month on month decline). The rate of this decline, and the flow rate achieved when flows have levelled off, provides important information to inform decisions regarding the commercial viability of shale gas production.

171. The EFT will generate minimal transport movements as follows.

- Security personnel – four car movements per day;
- Maintenance & monitoring personnel – two car movements per day;
- Minor maintenance – two small HGV movements per week;
- Propane deliveries – four small HGV movements per week;
- Removal of flowback fluid – two HGV movements per week.
- Well servicing – eight HGV movements on an occasional basis

172. It is during this stage that ad-hoc maintenance visits to the National Grid equipment will be required.

173. Given the small volume of traffic generated, the impact of traffic under all headings is considered to be a **neutral effect**.

18.7.7 Decommissioning and Restoration

174. The decommissioning and restoration process will last for approximately two months. Typical civil engineering plant will be used to remove the drilling site. This equipment will be brought to, and from, the site using HGVs.

175. The removal of plant and other equipment to Site is anticipated to last approximately three weeks. This part of the decommissioning period is forecast to generate up to 14 two-way HGV movements per day.

176. The main period of vehicle movements during decommissioning relates to the removal of the well pad. It is estimated that during this part of the decommissioning period there would be up to 24 inbound and 24 outbound HGV movements per day. Peak HGV movements during this period are therefore forecast to be up to 48 two-way movements per day. This peak period is anticipated to last for approximately three weeks.

177. Following this peak period, the number of construction vehicles is forecast to reduce to less than 10 two way HGVs per day. This period of decommissioning would last for approximately two weeks.

178. In addition to the movement of HGVs, there are also forecast to be 12 two-way light vehicle movements per day associated with Site staff. This volume of car traffic would be relatively constant throughout the decommissioning period.

179. On average, the decommissioning period would result in 12 two-way light vehicle movements and 22 two-way HGV movements per day.

Table 18.18: Forecast Traffic Generation (Decommissioning and Restoration) daily two-way movements

Stage	Phase	Description	Approx. Duration	Light Vehicles	Heavy Vehicles	Total Vehicles
6	A	Mobilisation	3 weeks	12	0-14	12-26
	B	Materials from site	3 weeks	12	44-48	56-60
	C	Completion of decommissioning	2 weeks	12	0-8	12-20
	All	**Average for decommissioning stage**	**2 months**	**12**	**22**	**34**

180. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table 19.

Table 19: Forecast two-way traffic flows between 07:00-19:00 (Decommissioning and Restoration)

Route Section	Baseline flows (two-way)		With average decommissioning and restoration stage site traffic (two-way)		With peak decommissioning and restoration stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total

Preston New Road	226	10,659	248	10,693	274	10,719

18.7.7.1 Driver Delay

181. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.20.

Table 18.20: Estimated capacity along proposed route (Decommissioning and Restoration)

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	60

182. The forecast peak vehicle movements associated with the proposed development during the decommissioning and restoration stage is 60 two-way vehicle movements per day. These movements will be spread throughout the working day depending upon the hours of operation of the development and the operational needs of the construction site.

183. From Table 18.20 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated during the decommissioning and restoration stage will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road during the peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the Project. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

184. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 48 during decommissioning and restoration. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay. The forecast volumes of traffic movements generated by the development are likely to fall well below the quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

185. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

186. The effect on driver delay is likely to be a **slight adverse effect**.

18.7.7.2 Pedestrian Delay

187. The effect on pedestrian delay and PROWs remains the same as in the construction phase as the volumes of traffic generated are of the same order of magnitude.

188. The effect on pedestrian delay is likely to be a **neutral effect**.

18.7.7.3 Pedestrian Amenity

189. Effects on pedestrian amenity are considered to be similar to that of the construction phase as the volumes of traffic generated are of the same order of magnitude.

190. The effect on pedestrian amenity is likely to be a **neutral effect**.

18.7.7.4 Severance

191. The effect of severance would be the same as in the construction phase as the volumes of traffic generated are of the same order of magnitude.

192. The effect on severance is likely to be a **neutral effect**.

18.7.7.5 Accidents and Safety

193. The effects of site traffic on accident frequency and road safety are considered to be the same as in the construction phase as the volumes of traffic generated are of the same order of magnitude.

194. The effect on severance is likely to be a **slight adverse effect**.

18.7.7.6 Dust and Dirt

195. Site traffic during the drilling stage is considered to have a similar effect with regard to dust and dirt as the construction phase as the volumes of traffic generated are of the same order of magnitude.

196. The effect of dust and dirt is likely to be a **slight adverse effect**.

197. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.8 Cumulative and Interactive Effects

18.8.1 Operations at the Preston New Road Site

198. The peak traffic flows are expected to occur as a result of the combined traffic associated with activity at more than one well. The total traffic flows used in the assessment are based on these conditions and are therefore considered to be robust.

199. Due to operational restrictions, there will not be any times whereby drilling and/or hydraulic fracturing is undertaken at the same time on the same Site. The profile of traffic movements over the lifetime of the site therefore assumes that drilling of a well will only commence once fracturing of the previous well has ceased and that well has entered the flow-testing phase.

200. The peak number of HGVs that would be generated by the site is 50 two-way movements per day. This traffic peak will be experienced for a short durations of less than a week at a time. Over the life of the site it is anticipated that up to eight of these short peaks would occur. The average number of two-way HGV movements forecast to be generated by the site during Stages 1-4 (approximately 28 months in total) is 10 per day.

201. In addition to HGV movements there may be up to 54 two-way light vehicle movements per day, with an average of 29 two-way movements per day. These totals have been

forecast by adding the forecast car trips for each stage of the process that it occurring simultaneously. In reality, it is likely that this figure will therefore include some double counting.

202. In order to assess the worst-case scenario, the selection of traffic routes and identification of impacts is based upon the peak traffic flows, despite their short duration.

203. Site traffic will be routed to and from the A583, which is the closest point on the primary road network. Traffic would be routed along Preston New Road. The forecast changes to traffic flows as a result of the development are set out in Table 18.21.

Table 18.21: Forecast two-way traffic flows between 07:00-19:00.

Route Section	Baseline flows (two-way)		With average site traffic (two-way)		With peak construction stage site traffic (two-way)	
	HGVs	Total	HGVs	Total	HGVs	Total
Preston New Road	226	10,659	236	10,698	276	10,763

18.8.1.1 Driver Delay

204. The spare capacity available on each section of the route to be used by site traffic during the peak highway hours is shown in Table 18.22.

Table 18.22: Estimated capacity along proposed route.

Route Section	Link capacity (peak hour)	Base flow (peak hour)	Peak increase in daily traffic
Preston New Road	2,650	1,427	104

205. The forecast peak vehicle movements associated with the proposed development during the construction stage is 104 two-way vehicle movements per day. These movements will be spread throughout the working day depending upon the hours of operation of the development and the operational needs of the site.

206. From Table 18.22 it is evident that the forecast increase in traffic due to the development will not result in any capacity issues on Preston New Road. The traffic that is forecast to be generated by the Site will only result in a small increase in daily traffic both in absolute and in percentage terms. On that basis, the additional traffic will not result in capacity issues on Preston New Road. The capacity currently available on Preston New Road in the peak highway hour of 17:00hrs to 18:00hrs greatly exceeds the total daily forecast flows generated by the site. Overall traffic flows are therefore forecast to remain well within capacity even with peak traffic flows from the Site.

207. Due to the nature of the development, a large proportion of these vehicles will be HGVs. The peak number of two-way daily HGV movements is forecast to be 50. Although this represents an increase on the baseline HGV flows in percentage terms, the absolute increase will not have an effect upon driver delay on Preston New Road. The forecast average volumes of traffic movements generated by the development are likely to fall well below the quantitative thresholds outlined above (i.e. 30 two-way movements per hour, 100 two-way movements per day).

208. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the very small increase in traffic volumes would result in a very minor change to traffic flows on Preston New Road.

209. The effect on driver delay is likely to be a **slight adverse effect**.

18.8.1.2 Pedestrian Delay

210. There are PROWs located on or close to the route proposed to be used by construction traffic. The proposed Site access does not affect any footways. The relatively small forecast increase in total vehicles using the route as a result of the development will therefore not create any delay to pedestrians.

211. The environmental value of the area likely to be affected by pedestrian delays is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW is affected. The magnitude of the impact is considered to be MA5 (No Change) as the very small increase in traffic volumes is likely to have a negligible impact upon pedestrian delay crossing adjacent roads at any individual location.

212. The effect on pedestrian delay is likely to be **a neutral effect**.

18.8.1.3 Pedestrian Amenity

213. The forecast increase in daily traffic flows is very small and as such, it is not considered that pedestrian amenity would be affected due to an overall increase in traffic volumes. Similarly, the pavement width/separation from traffic will not change due to the proposed development. Due to the relatively small daily volumes of traffic generated by the development in comparison to the existing flows on Preston New Road, it is not considered that there would be an observable change in traffic composition.

214. The environmental value of the area likely to be affected in terms of pedestrian amenity is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be affected. The magnitude of the impact is considered to be MA5 (No Change) as the very small increase in traffic volumes is likely to have a negligible impact upon pedestrian amenity on Preston New Road.

215. The effect on pedestrian amenity is likely to be a **neutral effect.**

18.8.1.4 Severance

216. Severance is the physical or perceived division that can occur within a community when it becomes separated by a major traffic artery. It can occur due to difficulties in crossing a heavily trafficked road or due to impeded pedestrian access to essential facilities.

217. As demonstrated in Table 18.21, the traffic generated by the proposed development will only result in a very small increase in traffic on Preston New Road both in absolute and percentage terms. The low traffic volumes that would be generated by the Site would not increase the difficulty in crossing Preston New Road or result in any increase in severance caused by the road.

218. The environmental value of the area likely to be affected in terms of severance is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be affected. The magnitude of the impact is considered to be MA5 (No Change) as the low traffic volumes generated will not result in an observable change in severance.

219. The effect on severance is likely to be a **neutral effect**.

18.8.1.5 Accidents and Safety

220. Accident data along the length of the route has been analysed as part of the baseline assessment. This data demonstrates that there have only been four accidents in the vicinity of the proposed site access in the past five years. On that basis, and given the relatively small amount of additional traffic generated by the development, the risk of an increase in accidents on this road is considered to be low.

221. The proposed site accesses have been designed with appropriate visibility splays to the standards set out in the Design Manual for Roads and Bridges. This will ensure suitable visibility of oncoming traffic to allow Site traffic to enter and exit the site under safe conditions. Safety Audits have been undertaken and the sole matter raised has been addressed in the junction design.

222. The environmental value of the area likely to be affected by accidents and safety is considered to be E4 (Low Value) due to the local area over which the risk of accidents could potentially be affected (i.e. in the immediate vicinity of the junction). The magnitude of the impact is considered to be MA3 (Minor Adverse) as there may be a measurable change to the risk of an accident on the highway due to the increase in the use of the access onto a major road. However, the risk will be minimised through appropriate design of the junction and through a safety audit of the proposed access. The effect on accidents and safety is likely to be a **slight adverse effect.**

18.8.1.6 Dust and Dirt

223. Due to the nature of the processes proposed for the operational period of the Site, and the use of HGVs to transport materials to and from the Site, there is a risk of dust and dirt being generated. Due to the predominance of agricultural uses in the local area, the roads surrounding the Site currently experience the deposit of mud and dirt on regular occasions. The Site will be carefully managed to prevent material from being transferred to the highway network.

224. The environmental value of the area likely to be affected by dust and dirt is considered to be E3 (Medium Value) due to the regional nature of the roads likely to be affected. It is considered that material will not be transferred to the SRN due to its distance from the site. The magnitude of the impact is considered to be MA4 (Negligible Adverse) as there may be a minor change to the local roads as a result of dust and dirt from the Site due to the fact that existing agricultural uses already result in dirt on the highway.

225. The effect of dust and dirt is likely to be a **slight adverse effect**.

226. Fugitive emissions of dust to the air are assessed in Air Quality (Chapter 6).

18.8.2 Cumulative Effect with Roseacre Wood

227. Similarly to the Preston New Road operations, the majority of traffic generated by operations at Cuadrilla's Roseacre Wood Site is expected to use the M55 as the principle access route to/from Site. The M55 is part of the national motorway network with high capacity. Given the relatively low volumes of traffic generated by both the Preston New Road and the Roseacre Wood developments, the cumulative impact of traffic generated by both developments on the M55 under all headings is considered to be a **neutral effect**.

228. It is expected that HGV traffic to the Roseacre Wood site will use Jn4 of the M55 to access the site, passing south along the A585 Fleetwood Road before turning east along A583 Blackpool Road/Kirkham Bypass. HGVs departing the site would use the same route, but in reverse. With one of the potential transport routes for Preston New Road development traffic being from Jn 3 of the M55, along the A585 Fleetwood Road and then turning west along the A583 Blackpool Road, there is a potential cumulative impact of Roseacre Wood HGV traffic and Preston New Road traffic on the section of the A585 Fleetwood Road from the M55 to the A583 Blackpool Road.

229. The traffic generated by the Roseacre Wood development will be a similar order of magnitude to that generated by Preston New Road. In the section above, the cumulative and in-combination effect of operations at Preston New Road on driver delay has been assessed as a *slight adverse effect* and the increase in daily traffic of 104 vehicles is well within the available capacity of the SRN. The additional traffic generated by the Roseacre Wood development is similarly small and will not take up available capacity during the peak periods.

230. This cumulative transport effect is further mitigated by the ability of Preston New Road traffic to use Jn4 from the M55 to access to/from site. This will reduce the magnitude of the cumulative effect of Preston New Road and Roseacre Wood traffic on the A585 Fleetwood Road.

231. The cumulative effect of traffic generated by both the Preston New Road and the Roseacre Wood developments on the A585 Fleetwood Road from the M55 (Jn 3) to the A583 Blackpool Road under all headings is considered to be a **slight adverse effect.**

18.9 Mitigation Measures

232. A traffic management plan will be developed and be formally agreed with the Local Highway Authority as part of the planning permission. The traffic management plan may include the mitigation measures presented in Table 18.23 to help manage the effects of site traffic on the local area.

Table 18.23: Potential Traffic Management Plan Measures

Measure	Description
Vehicle and route restrictions	Use of the Preston New Road Site preferred traffic route(s) for all HGVs to reduce the impact on local communities. This would be managed through a signage strategy to direct vehicles along agreed the agreed route with enforcement (and penalties) imposed as appropriate.
Site management	Sheeting of vehicles, damping down on site, wheel washing and other best practice measures will be implemented to reduce dust generation and transfer of mud to roads.
Driver Training and Education	Drivers of site vehicles would receive a code of conduct for travelling to/from site. This would include a limit on traffic speeds, and the need to adhere to the agreed route.
Monitoring	Monitoring of routes used and traffic flows to and from the site will be undertaken

	on a regular basis, the frequency of which would be agreed with LCC.
Communication and co-ordination	The Traffic Management Plan will be periodically monitored and reviewed. Should any changes to Plan be required, these would be reported to LCC for approval.
	Procedures for residents and the general public to report any drivers failing to adhere to this code of conduct would be established with disciplinary measures including fines and contract termination set out in the plan.

233. The site will be secured such that it will only be accessible to site workers and vehicles. This would be the case both when there is activity on-site, and also outside the operational periods. Accesses to the site would be gated and controlled. Large vehicles accessing the site would be supervised by a banksman. All vehicles waiting to enter the site will be provided with sufficient stacking space to wait off the road network to minimise disruption to local traffic. Where appropriate, swept path analysis of the construction accesses has been undertaken to ensure that vehicles can safely and efficiently manoeuvre in and around the site.

18.9.1 Installation of Arrays

234. No significant effects have been identified associated with the installation of arrays and therefore no mitigation measures are deemed to be required.

18.9.2 Decommissioning

235. The Environmental Management Plan (EMP) will also cover the decommissioning phase of the development. No additional mitigation measures are deemed necessary for the decommissioning of the site.

18.10 Residual Effects

236. The residual effects that will remain following the implementation of the mitigation measures are assessed below. This assessment has been undertaken for the total movements generated by the combined activities on site rather than for the individual stages.

18.10.1 Driver delay

237. Traffic movements would be planned to occur outside of the peak highway hours of 08:00hrs-09:00hrs and 17:00hrs-18:00hrs. This would reduce the effects of the site traffic on driver delay in the area.

238. The environmental value of the area likely to be affected by driver delay is considered to be E3 (Medium Value) due to the regional nature of the roads. The magnitude of the impact is considered to be MA4 (Negligible Adverse Impact) as the small increase in traffic volumes is likely to have a negligible impact upon driver delay on Preston New Road.

239. The residual effect on driver delay is likely to be a **slight adverse effect**.

18.10.2 Pedestrian Delay

240. Routes for construction traffic will be agreed with the local highway authority and signed appropriately to ensure that drivers accessing the site use Preston New Road to access the

SRN. This would avoid any effects on pedestrian movements along PROW in the area. The environmental value of the area likely to be affected by pedestrian delays is considered to be E4 (Low) due to the local scale of importance of pedestrian movements in this area and the fact that no PROWs or footways are affected. The magnitude of the impact is considered to be MA5 (No Change) as the very small increase in traffic volumes is likely to have a negligible impact upon pedestrian delay crossing adjacent roads at the points where the PROW terminate and at any other individual location.

241. The effect on pedestrian delay is likely to be **a neutral effect**.

18.10.3 Pedestrian Amenity

242. The forecast increase in daily traffic flows is very small and as such, it is not considered that pedestrian amenity would be affected by the development.

243. The environmental value of the area likely to be affected in terms of pedestrian amenity is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be directly affected. The magnitude of the impact is considered to be MA5 (No change).

244. The effect on pedestrian amenity is likely to be a **neutral effect.**

18.10.4 Severance

245. The low traffic volumes that would be generated by the site (in absolute terms) would not increase the difficulty in crossing Preston New Road. Pedestrian access to essential facilities would not be impeded by the development as the proposed routes for site traffic do not cross or affect any PROW in the area.

246. The environmental value of the area likely to be affected in terms of severance is considered to be E4 (Low Value) due to the local scale of importance of pedestrian movements in this area and the fact that no PROW will be affected. The magnitude of the impact is considered to be MA5 (No Change) as the low traffic volumes generated will not result in an observable change in severance due to Preston New Road.

247. The effect on severance is likely to be a **neutral effect**.

18.10.5 Accidents and Safety

248. Mitigation measures to manage and control the movements of HGVs to and from the site will help to mitigate the risk of accidents on the routes to and from the site. The proposed site access has been designed with appropriate visibility splays to the standards set out in the Design Manual for Roads and Bridges. This will ensure suitable visibility of oncoming traffic to allow Site traffic to enter and exit the site under safe conditions. A safety audit has been undertaken and the recommendations have been incorporated into the access junction layout.

249. The environmental value of the area likely to be affected by accidents and safety is considered to be E4 (Low Value) due to the local area over which the risk of accidents is considered to be affected. The magnitude of the impact is considered to be MA3 (Minor Adverse) as there may be a measurable change to the risk of an accident on the highway. The effect on accidents and safety is likely to be a **slight adverse effect.**

18.10.6 Dust and Dirt

250. A range of measures are proposed to limit the risk of materials being transferred onto the adjacent highways.

251. The environmental value of the area likely to be affected by dust and dirt is still considered to be E3 (Medium Value) due to the risk that dust and dirt may be transferred to Preston New Road which is of a regional scale of importance. Providing that suitable mitigation measures are implemented, it is considered that the magnitude of the impact can be reduced to MA4 (Negligible Adverse) by reducing the change to the local roads as a result of dust and dirt from the site to a minor change.

252. The effect of dust and dirt will remain as a **slight adverse effect.** This will be a temporary effect that will last for the period of the site operation only.

18.10.7 Installation of Arrays

253. The assessment concluded that the development would have a neutral effect on most receptors during the installation of arrays. The residual effects are also considered to be a **neutral effect**.

18.10.8 Decommissioning and restoratoin

254. The residual effects under each of the headings would be as per the operational unmitigated effects. The volume of traffic generated would be of the same order of magnitude in both stages and the proposed mitigation is the same.

18.11 Assessment Summary Matrix

Table 18.24: Transport assessment summary matrix.

Stage	Driver delay	Pedestrian delay	Pedestrian amenity	Severance	Accidents & safety	Dust and dirt
Construction	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Drilling	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Hydraulic Fracturing	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Flow Testing	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Extended Well Testing	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Suspension	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Decommissioning	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Installation of Arrays	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Cumulative Effects	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse
Residual Effects	Slight adverse	Neutral	Neutral	Neutral	Slight adverse	Slight adverse

255. None of the residual impacts are significant.

19 Water Resources

Chapter Summary – Water Resources

This chapter assesses the effects of the Project on water supplies and surface water runoff or drainage and the consequent impact on flood risk. The potential effects on surface and groundwater quality are assessed within Chapter 11.

The Site is currently a grass field used for grazing cattle. As a result there are no existing hard surfaces that could impede rainwater from entering the soil or exacerbate surface water flooding. The Site is not located within an area prone to flooding from rivers (the nearest watercourse to the Site is Carr Bridge Brook which is located 250m north).

The construction of the well pad will include the installation of an impermeable plastic membrane to be laid to prevent infiltration from the well pad through the underlying soils and water bodies. A min 300mm thick layer of crushed and compacted stone will be laid on top of the membrane. Ditches will be constructed around the perimeter of the well pad with the outer edge of the ditch raised 50mm above the well pad surface. The ditches provide the means to collect stormwater. The void space in the granular fill, ditches and the 50mm "air freeboard" provide a storage volume to attenuate drainage flows from the site.

An isolation valve is fitted to the discharge pipe from the site. During drilling and hydraulic fracturing operations, this valve will be closed preventing stormwater from leaving the site. During these periods stormwater will be removed by tanker to a licenced wastewater treatment works. At other times when the water quality in the ditch system meets the requirements of EA the site will drain freely to Carr Bridge Brook. An interceptor installed at the outfall will provide further security that discharges to watercourses will meet quality criteria.

The water requirements for the Project will be provided by a pipe connection to an adjacent United Utilities (UU) water main. Cuadrilla have consulted with UU to confirm that they can provide the quantity and flow rate of water needed for the Project. UU have confirmed that this supply will not affect their current customers (including residential properties).

With the measures described above in place the Project will not have a significant effect on surface water runoff, drainage or water supplies.

19.1 Introduction

1. The Water Resources assessment considers the Project's requirement for water as a resource (water use), surface water and drainage impacts, and assesses how the well pad containment and drainage system will function and how this may affect the Site and local surroundings. It also assesses flood risk relating to the implementation of the Project.

2. The disposal of flowback fluid from operational processes (aqueous waste) is addressed in the Resources and Waste Chapter (see Chapter 17 of this ES). The risks of contamination of groundwater and surface water associated with the Project are presented in the Hydrogeology and Ground Gas Chapter (see Chapter 11 of this ES).

3. Supporting calculations to this assessment are contained in **Appendix S**.

19.2 Key Development Issues

4. The assessment aims to assess the following key questions:

- What is the source of the water, where is it coming from and how much is required?
- What effect does this have on the local water supply/other water users?
- What is the well pad containment system, surface water drainage system and how is surface water managed?
- How does the Site impact on receiving field drains and the surrounding water environment? Are there any changes that would need to be addressed under the Water Framework Directive guidance
- Does the Site have an adverse, beneficial or neutral effect on flooding in the local area of the Site?

19.3 Scoping and Consultation

5. During the scoping phase, consultations were made with the following local authorities as listed in Table 19.1.

Table 19.1: Preston New Road scoping and consultation overview

Consultee	Comment	Response
Environment Agency	Obtain latest information with regards to flood risk mapping and specific issues relating to how the exploration sites should be viewed under NPPF regarding flood risk. Scoping opinion and to agree content of FRA	The Environment Agency's Flood Risk Technical Specialist stated that since the proposals are temporary, located within low Flood Risk Zones and the pad construction was generally granular, a formal flood risk assessment would not be required as part of the planning application for sites located in Flood Zone 1 if of 1ha or less. EA comments incorporated in LCC comments and are summarised below along with how the ES has responded.
United Utilities	Discuss water supply requirements for the Site (The disposal of return water is addressed in the Waste chapter).	Statement received confirming UU potable water network can meet anticipated demands (see Appendix S)

Consultee	Comment	Response
Lancashire County Council	The EIA will be expected to demonstrate how surface water run-off from the site will be disposed of to ensure that there is no increased risk of pollution to ground and surface waters, no detrimental impacts on aquatic ecology and no increase in flood risk off site.	This is addressed in the Project description (Chapter 4) and section 19.7.1 (Drainage Design).
	If it is intended to reuse/recycle flowback fluid following sufficient treatment at any time we feel that this option should be assessed through the EIA and the potential risks considered.	Reuse of flowback fluid to make up part of the fracturing fluid is proposed as part of the Project. The impact on water use has been assessed in section 19.7.5. Contamination risks have been assessed in Chapter 11.
	The impact on water resources will need to be given greater consideration. The EIA will need to consider water availability for hydraulic fracturing and where it will come from, i.e. mains or groundwater abstraction.	This has been assessed within this ES (see section 19.7.2 to 19.7.9). Water will be supplied from the mains supply (see also Appendix S)
	Demonstrate through the EIA how the use of mains water supply would affect the water company operations by approaching the undertaker(UU).	This is addressed within the assessment section of the ES (section 19.7.4 and 19.7.5) Details of discussions with UU is provided in Appendix S.
	A Flood Risk Assessment (FRA) will be produced and this should demonstrate that there will be no increase in the surface water run-off generated by the Site.	A FRA has been produced and submitted as part of the planning application for the Project.

19.4 Methodology

19.4.1 Introduction

6. This Water Resources assessment focuses on the Project's requirement for water as a resource (water use) and flood risk and surface water drainage impacts relating to the implementation of the Project. It assessed the following:

- The requirement for water, specifically during well drilling and hydraulic fracturing including the assessment of impact on water source, flows/volumes, transmission/transportation means, quantities and the percentage re-used during operation;
- The existing and proposed drainage regimes at the Site; and
- Flood risk from potential sources including local watercourse (fluvial), surface water, groundwater or any artificial water bodies.

7. The availability and capacity of facilities to treat waste water created by the Project have been assessed within Chapter 17 (Resources and Waste).

8. The assessment considered all relevant legislation and guidance. Specifically;

- National Planning Policy Framework 2012 and supporting Technical National Planning Practice Guidance[440];
- Fylde Borough Council Strategic Flood Risk Assessment (SFRA) 2011;
- Planning Policy Statement 25: Development and Flood Risk;
- Water Resources Act 1991 - http://www.legislation.gov.uk/ukpga/1991/57/introduction;
- Land Drainage Act 1991 http://www.legislation.gov.uk/ukpga/1991/59/introduction; and
- Flood and Water Management Act 2010 http://www.legislation.gov.uk/ukpga/2010/29/introduction.

19.4.2 Baseline methodology

9. The baseline for the Water Resources assessment was established through a desk study of available information, site visit and consultation. The well pad and well cellars are still to be constructed. Assessment effects were therefore made against the undeveloped or 'greenfield' state of the Site as the baseline for the subsequent assessment of effects during the project stages.

10. Baseline information was obtained from the following sources:

- Site visit walkover survey to identify key water features within the study area;
- Literature review of key documents regarding drainage and flood risk including Site levels, topography, any historic flood records, the Fylde Borough Strategic Flood Risk Assessment (SFRA) , sewer records and any relevant information obtained via the Hydrogeology and Ground Gas assessment. The SFRA was used to screen for sources of potential flooding and cross referenced in the assessment;
- Surface water features (watercourses, drains, ponds, wetlands, estuary, coastline) identified from ordnance survey mapping and Site reconnaissance with consideration of their interaction with the Site;
- The existing Site water usage, local surface water drainage regime and level of flood risk was used as the local environmental baseline for the Site;
- Description of the current European Water Framework Directive (WFD) surface water body status (quantity, quality and ecology);
- United Utilities Water Resources Management Plan, to provide data on the availability of mains water supplies to the Site http://corporate.unitedutilities.com/Water-Resources-Management-Plan.aspx
- Environment Agency Water Availability information/maps to provide data on the extent of water stress or scarcity in the wider environment (rather than in the mains supply) http://www.environment-agency.gov.uk/default.aspx

[440] Communities and Local Government (March 2012) "National Planning Policy Framework" and "Technical Guidance to the National Planning Policy Framework"

11. In order to assess the effects of the constructed well pad on surface runoff and drainage a greenfield runoff rate has been calculated using the Institute of Hydrology IH 124 "Flood Estimation for Small Catchments" methodology and used as the baseline (existing) case runoff rate. This has been used to predict existing runoff rates for various return period events up to and including the 1 in 100 year event (1% annual probability of exceedance), including an allowance for climate change.

12. As assessment of water stress/scarcity in the region has been made using water availability maps from the Environment Agency to understand if the volumes of water required during hydraulic fracturing could result in water stress.

19.4.3 Assessment methodology for the effects from installation of the monitoring works

13. Effects are assessed based on any water usage from installation activities and any increased runoff from the installation of the surface and buried arrays due to change in impermeable surface through alteration in ground surface / materials.

14. The assessment of the impact of the groundwater monitoring boreholes is encompassed within the assessment of the construction and operation of the well pad.

19.4.4 Assessment methodology for the effects from construction

15. The Site is currently in 'greenfield' state, therefore the well pad, drainage system, access track and well cellars are still to be constructed. Effects are assessed based on normal construction impact in terms of water usage from welfare facilities and any increased runoff from the development due to a change in impermeable surface/drainage regime.

19.4.5 Assessment methodology for operational effects

16. The operational[441] effects that have been assessed consists of:-

- Review of requirements for water use (well drilling and hydraulic fracturing process water), specifically during well drilling and the hydraulic fracturing operation, including the assessment of water source, flows/volumes, transportation means, quantities and the potential impact of re-use during operation. Water consumption during initial and extended flow testing has been excluded because this is likely to be limited to general site welfare and as such is insignificant.
- Review the proposed drainage regime at the Site which could become a pathway for contaminating neighbouring surface and groundwater receptors, or could increase flood risk either on or off-site.

17. Two scenarios were assessed when calculating the proposed runoff rates, and were then compared against existing runoff. One with the storm water outlet isolation valve open and one with it closed. Changes to the level of flood risk on and off Site and the potential effects on local area are assessed.

18. Proposed runoff estimates have been calculated for the Site by determining the attenuation effect of the well pad, gravel layer and perimeter ditches. Extreme rainfall depths for different return period have been estimated for the Site from the FEH rainfall

[441] Drilling, hydraulic fracturing, initial flow testing, extended flow testing and suspension

depth-duration-frequency (DDF) model, which enables estimates of design rainfall to be made at any location in the UK. The calculations use the containment volume of the pad, and once this capacity is taken up, then assume 100% of the rainfall falling of the pad could then runoff into adjacent areas, either through the interceptor (when the isolation valve is open) or by overtopping the trench bund when the perimeter ditches become full.

19. Predicted climate change allowances are taken as 5% on peak rainfall intensity and 10% on peak flow, in accordance with the National Planning Policy Framework (NPPF) and as shown in Table 19.2. These are based on a development timeframe up to 2025 (noting the application is for temporary consent of 6 years duration).

Table 19.2 - Climate changes allowances as recommended in NPPF (Table 5).

Recommended national precautionary sensitivity ranges for peak rainfall intensities, peak river flows, offshore wind speeds and wave heights

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	*+5%*	*+10%*	*+20%*	*+30%*
Peak river flow	*+10%*	*+20%*		
Offshore wind speed	*+5%*		*+10%*	
Extreme wave height	*+5%*		*+10%*	

19.4.6 Assessment methodology for decommissioning and restoration effects

20. The proposals for decommissioning the well pad and restoring the Site have been assessed in terms of water usage, drainage issues and any effects on the local flood risk during the temporary phases where the Site is restored to its original land use.

19.4.7 Assessment criteria and definitions

21. The magnitude, value of the receptor and overall significance of the predicted environmental effects relating to water resources are assessed in either a beneficial or adverse sense using the criteria set out in Table 19.3 (Water use) and Tables 4 to 6 (Flood risk and drainage) below. The predicted effects can be beneficial or adverse and range from negligible to major. For the assessment of water resource impacts an effect of **moderate or greater significance** is deemed a **'significant effect'** as defined in the EIA Regulations. These significance criteria have been developed based on the Design Manual for Roads and Bridges methodology.

19.4.7.1 Water Use

22. Only one source of water has been assessed (mains water supply) within the ES because of the proximity of an existing United Utilities water main which passes to close to the north west of the Preston New Road Site. Therefore to assess the significance of the Project's water use on the existing supply and available capacity the criteria in Table 19.3

have been used. Specific criteria for the sensitivity of the receptor [the water supply network] has not been used because only a mains water supply has been assessed.

23. The assessment also includes a comparison against equivalent household usage and compares water requirements against that used within the potable water network in the Northwest of England to give context, but these indices have not been used to define the overall significance which is based on the ability of the source to meet the required usage demands.

Table 19.3 - Water Use Significance criteria

Classification	Definition
None / Negligible	Water use – requirements are non-existent or not beyond typical construction site and welfare uses, or the impact is deemed to be 'negligible' or 'imperceptible' and is essentially indistinguishable from the existing situation
Minor	Water use – No restrictions in water supply source availability over 24 hours.
Moderate	Water use – Water supply source can meet the daily usage requirements without affecting other users, provided water is taken at certain times of day and flow limits are applied.
Major	Water use – Water supply source is unable to supply daily water demands over 24 hours period without affecting other users.

19.4.7.2 Drainage and Flood Risk

24. Assessment criteria for the impacts from the Project on drainage and flood risk receptors are presented below (Table 19.4 to Table 19.6).

Table 19.4: Magnitude of impact. assessment criteria

Magnitude	Criteria
None / Negligible	No discernible impact – Effects are non-existent or the impact is deemed to be 'negligible' or 'imperceptible' and is essentially indistinguishable from natural background variations.
Minor	Drainage – Minor change in surface water drainage flows leaving the Site or change to drainage regime in immediate vicinity only. Changes in flows offsite are within 5% of existing (greenfield) values for 1 in 100 year event (1% annual probability of exceedance). Flood Risk - Site is located in Zone of lowest flood risk (Flood Zone 1) and changes in surface water runoff from the Site are negligible. Minor change in flood risk that limited to immediate Site vicinity only. Duration: < 6 months. Extent: localised to immediate area. Reversibility: reversible.
Moderate	Drainage – Moderate change in surface water drainage flows leaving the Site or change to drainage regime in immediate vicinity only. Changes in flows offsite are between 5 to 20% of existing (greenfield) values for 1 in 100 year event (1% annual probability of exceedance). Flood Risk – Site is located in a zone of moderate flood risk (Flood Zone 2) and/or changes in surface water runoff from the Site are altered for return periods up to and including the 1 in 30 year event. Minor change in flood risk that limited to immediate Site vicinity only Duration: 6 – 12 months. Extent: local (moderate receptor sensitivity/value) or regional (low receptor sensitivity/value). Reversibility: reversible.
Major	Drainage - major change in surface water drainage flows leaving the Site or change to drainage regime. Changes in flows offsite are in excess of 20% different to existing (greenfield) values for 1 in 100 year event (1% annual probability of exceedance).

Magnitude	Criteria
	Flood Risk – Site is located in a zone of high flood risk (Flood Zone 3) and/or changes in surface water runoff from the Site are altered for return periods up to and including the 1 in 100 year event. Changes in flood risk may effect wider catchment Duration: > 12 months Extent: local (high receptor sensitivity/value) or regional (moderate receptor sensitivity/value). Reversibility: reversible (moderate/high value receptors), or irreversible (low value receptors or localised moderate/high value receptors).

Table 19.5 Sensitivity or value of water bodies or receptors.

Classification	Definition
Very Low	Drainage and Flood Risk - Site is located in Zone of lowest flood risk (Flood Zone 1) and receptor is a field drain or Ordinary Watercourse in an area where there is a low probability of flooding of residential and industrial properties.
Low	Drainage and Flood Risk - Site is located in Zone of lowest flood risk (Flood Zone 1) and receptor is field drain, Ordinary Watercourse or Main River in an area where 10 or fewer industrial properties are at risk from flooding.
Moderate	Drainage and Flood Risk - Site is located in Zone of moderate flood risk (Flood Zone 2) and receptor is an Ordinary Watercourse or Main River in an area where between 1 and 100 residential properties are at risk from flooding.
High	Drainage and Flood Risk - Site is located in a zone of moderate or high flood risk (Flood Zone 2 or Flood Zone 3) and receptor is an Ordinary Watercourse or Main River in an area where more than 100 residential properties are at risk from flooding

Table 19.6: Significance of effects matrix (Drainage and Flood Risk).

Risk Matrix		Magnitude of Impact			
		None/Negligible	Minor	Moderate	Major
Sensitivity of receptor	Very Low	Negligible Not significant	Minor Not significant	Minor Not significant	Moderate Significant
	Low	Minor Not significant	Minor Not significant	Moderate Significant	Moderate Significant
	Moderate	Minor Not significant	Moderate Significant	Moderate Significant	Major Significant
	High	Moderate Significant	Moderate Significant	Major Significant	Major Significant

19.5 Assumptions and limitations

25. The assessments in this chapter are based on the following assumptions and limitations:

19.5.1 Water Use

26. Estimates of daily water use during hydraulic fracturing activities are 765m^3/day, based on information provided by Cuadrilla gained at previously worked sites and their proposals for operations at this Site. During their planning work, Cuadrilla have refined their process as follows

- Reduced the requirement of water per hydraulic fracture stage to 765m^3/fracture stage by reviewing the fracturing process

- Reduce the planned number of hydraulic fracturing stages at the 4 no. wells from an initial 60-60-60-60 stage requirement to an anticipated 30-30-45-45 stage scenario which equates to a saving of 38% in the number of fracturing stages and hence the water requirements.

27. This has been taken as embedded mitigation within the EIA:

- Re-use of flowback fluid will be used to make up part of the fracturing fluid for the subsequent hydraulic fracturing stage to further reduce the requirement for incoming water. This has been considered in the assessment as embedded mitigation, such that the requirement for water from the UU mains will be further reduced from 765m^3/fracture stage to approx.600m^3/fracture stage. Flowback fluid will be subject to physical treatment using Ultra Violet UV disinfection to control bacterial growth.
- Cuadrilla will also consider the use of collected stormwater to make up part of the fracturing fluid volume (subject to water quality assessment). This has not been considered specifically in this assessment, but would make a positive impact by reducing mains water demand and reducing the transport of stormwater from the site.
- Calculations for on water usage have been derived for both the with and without reuse scenarios as summarised in Section 19.7.1.
- Comparisons to household water use are made against a housing usage of 182.5m^3/annum (typical), based on a consumption of 500 l/household/day[442]. This comparison has been provided to give context only.
- The use of a mains water supply negates the need to transport water to site by tanker thus reducing transport impacts.

Surface Water Drainage

- Infiltration to below ground soils and water bodies is prevented by the HDPE impermeable liner which is protected from puncturing by and underlay and overlay of non-woven fleece layers. The liner and protection fleece is lapped up the outside of the perimeter drainage ditch to a level 50mm above the well pad site level. This creates a fully contained site (a “bathtub effect”) with 50mm of air freeboard;
- The welded joints of the HDPE membrane will be verified and inspected upon installation. The membrane will be quality checked for thickness, tensile strength, puncture resistance and tear resistance in accordance with the manufacturers’ specification;
- It is assumed the high density polyethylene (HDPE) impermeable liner will be laid flat, with only small level changes resulting from construction tolerances during installation;
- Drainage calculations of flows off Site and comparisons to the greenfield runoff rates are made assuming initial dry conditions where the well pad storage is fully available for use. It is possible that surface water will be already present within the well pad and perimeter ditches which would result in higher resulting flow rates and volumes of runoff than those stated in Table 11 since some of the capacity would be already used up. However, the risk of consecutive high return period storm events over the temporary duration of the Project is low and there would also be losses from the well pad through evaporation which have also not been accounted for in calculations;
- During mobilisation, initial and extended flow testing, and subject to water meeting discharge quality criteria, surface water will be allowed to discharge from the well

[442] Source http://www.environment-agency.gov.uk/homeandleisure/beinggreen/117266.aspx

pad via the interceptor (isolation valve open scenario) to the adjacent watercourse. During well drilling and hydraulic fracturing, all stormwater collected on the well pad will be tankered off site to a suitably licenced wastewater treatment works.

- Discharge of water from the well pad to adjacent watercourses will not be made unless water quality testing has confirmed that any contaminant concentrations are at least 10% below Environmental Quality Standards (EQS) values, as per the terms of the Environment Agency Discharge permit. If these water quality standards are not met then all water from the well pad will be tankered off site for treatment at an appropriately licenced waste treatment facility;
- There is sufficient capacity within the pad drainage design to ensure any spillages will be contained within the Site if spilt on the pad (see also Chapter 11 for further assessment). In the event of spillage/leak operations the isolation valve would be immediately closed (if not already in the closed position) preventing off site migration of contamination.
- Runoff collected on the well pad will be tankered off Site promptly after a storm event.

Cumulative Impacts

- Cumulative impacts have been assessed on the basis of shale gas exploration works on-going at two Sites concurrently (Preston New Road and Roseacre Wood). Hydraulic fracturing operations would only be performed at one site at any one time.

19.6 Baseline

19.6.1 Water resource features

28. The shallow geology at the Site is shown on British Geological Survey (BGS) mapping to be formed of Glacial Till, which is a low permeability slightly gravelly, slightly sandy clay deposit. Nearby BGS borehole records indicate this material is up to 6 m thick. Consequently infiltration of surface water into shallow aquifers will be restricted by this material. This is described in further detail in Chapter 4 (Project Description) and Chapter 11 (Hydrogeology and Ground Gas).

29. The Carr Bridge Brook is situated approximately 250m to the north of the Site and flows into Main Drain which is located approximately 1.2km to the west. Main Drain is a large land drain classified as a Main River and flows south, discharging into the River Ribble estuary at Lytham St Annes.

30. Wrea Brook is located approximately 1.5km to the south, which also discharges into the Main Drain then ultimately into the Ribble at Lytham.

31. Numerous small marl ponds and drains are located within the agricultural land around the Site. These have a variety of uses including drinking water for livestock and wild animals, irrigation and the storage of slurry.

32. As required by the European Water Framework Directive (WFD) the EA has undertaken an assessment of ecological and chemical status of waterbodies across the North West, those nearest include the River Ribble and the Wrea Brook, assessed in 2012[443]. This states the River Ribble has a moderate ecological and good chemical status classed as

[443] Data source http://data.gov.uk/dataset/wfd-surface-water-classification-status-and-objectives. Last accessed 18/09/2013.

'very certain' and. The Wrea Brook has a moderate ecological status (chemical status not stated) classed as 'uncertain'. There was no chemical status listed for this watercourse. The current overall status for both watercourses was scored as 'moderate' with ecological objectives for both set as 'Good Potential by 2027'.

33. Table 19.7 below shows current status and objectives for each watercourse:

Table 19.7 - WFD status information (source Environment Agency).

WB Name	Current Overall Status	Ecological Status	Ecological Certainty	Chemical Status	Chemical Certainty
Wrea Brook	Moderate	Moderate	Uncertain	*Not Stated*	*Not Stated*
River Ribble	Moderate	Moderate	Quite Certain	Good	*Not Stated*

	Ecological Objective	Chemical Objective
Wrea Brook	Good Ecological Potential by 2027	*Not Stated*
River Ribble	Good Ecological Potential by 2027	High Chemical Status by 2027

19.6.2 Drainage

34. Topography dictates the area around the Site will generally drain north-westwards to the Carr Bridge Brook before entering the Main Drain and River Ribble to the south of the Site, at Lytham. The Site is part of the River Ribble catchment. The Ribble flows in a generally east-west direction before discharging into the Ribble Estuary.

35. This section of the River Ribble, into which the drainage ditches discharge, is part of the Ribble Estuary of Special Scientific Interest (SSSI), a Special Protection Area (SPA) and Ramsar Wetland Site Several marl ponds, small lakes and rivers including the Wrea Brook and Main Drain are located in the surrounding area.

36. The EA retain their responsibility and power with regards to regulation and consent over the Wrea Brook, Main Drain and the River Ribble. These terms are bound by the Flood & Water Management Act 2010 and the Land Drainage Act 1991.

37. The greenfield runoff rate for the Site has been calculated as 6.1 l/s/ha, or 14.6 l/s for the 2.39ha Site area (consisting of 1.55ha well pad and 0.84ha bunds / landscaping).

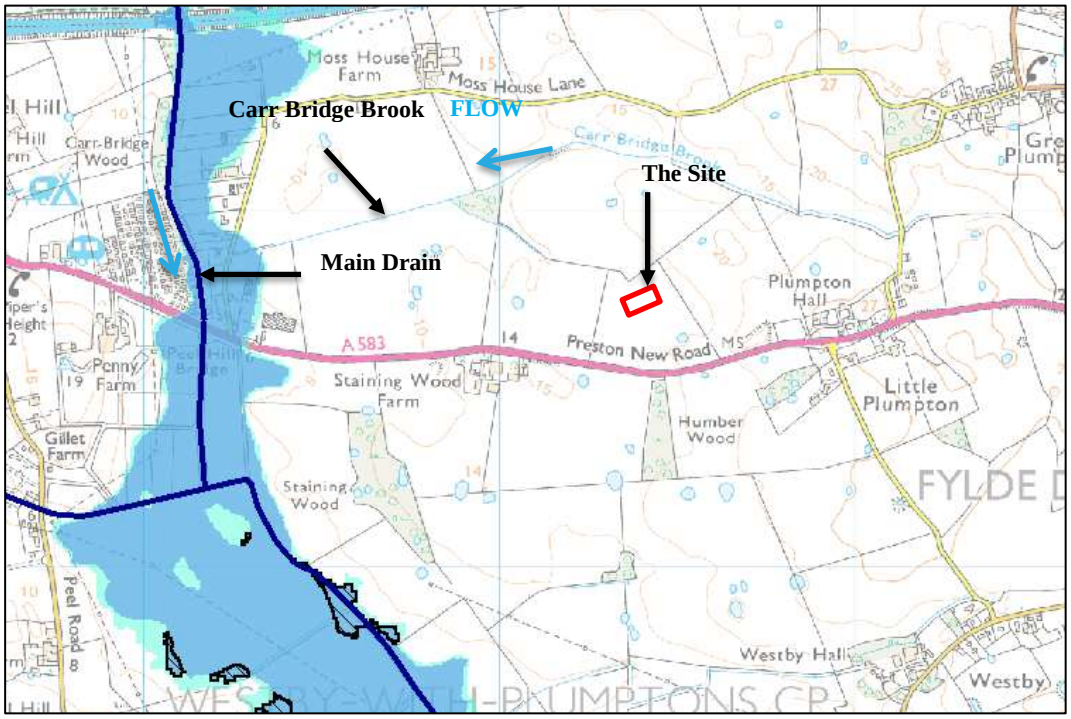
19.6.3 Flood Risk

19.6.3.1 Well Pad

38. The Site is located within the Environment Agency's Flood [4] Zone 1 (Figure 19.1)which is classified as Low risk: this zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding (<0.1%).

39. Approximately 1.2km to the west of the Site at Peel Hill, there is a small conurbation of houses, a farm and caravan site in an area that is classified within Flood Zone 3- High risk adjacent to Main Drain. Further downstream on this watercourse, there are several residential areas located within Flood Zone 3, some of which are shown as benefiting from constructed flood defences adjacent to Main Drain.

Figure 19.1 - Extract of the EA's Flood Map (from EA website) showing flood zones relative to the Well Pad *(Dark Blue: Zone 3 (1 in 100 years) flood risk. Light blue: Zone 2 (1 in 1000 years) flood risk).*



40. LCC and the Environment Agency have stated that the greenfield runoff rate for the Site should be identified to demonstrate that the development would not exacerbate flood risk off Site due to surface water runoff from the well pad. This is to ensure there is no increase to flood risk within catchments directly downstream of the Site.

19.6.3.2 Surface and buried arrays

41. The locations for the series of array stations around the Site have not been individually classified with respect to flood risk zones. They are small installations not susceptible to flooding. They do not alter ground levels nor would they alter the level of flood risk present locally.

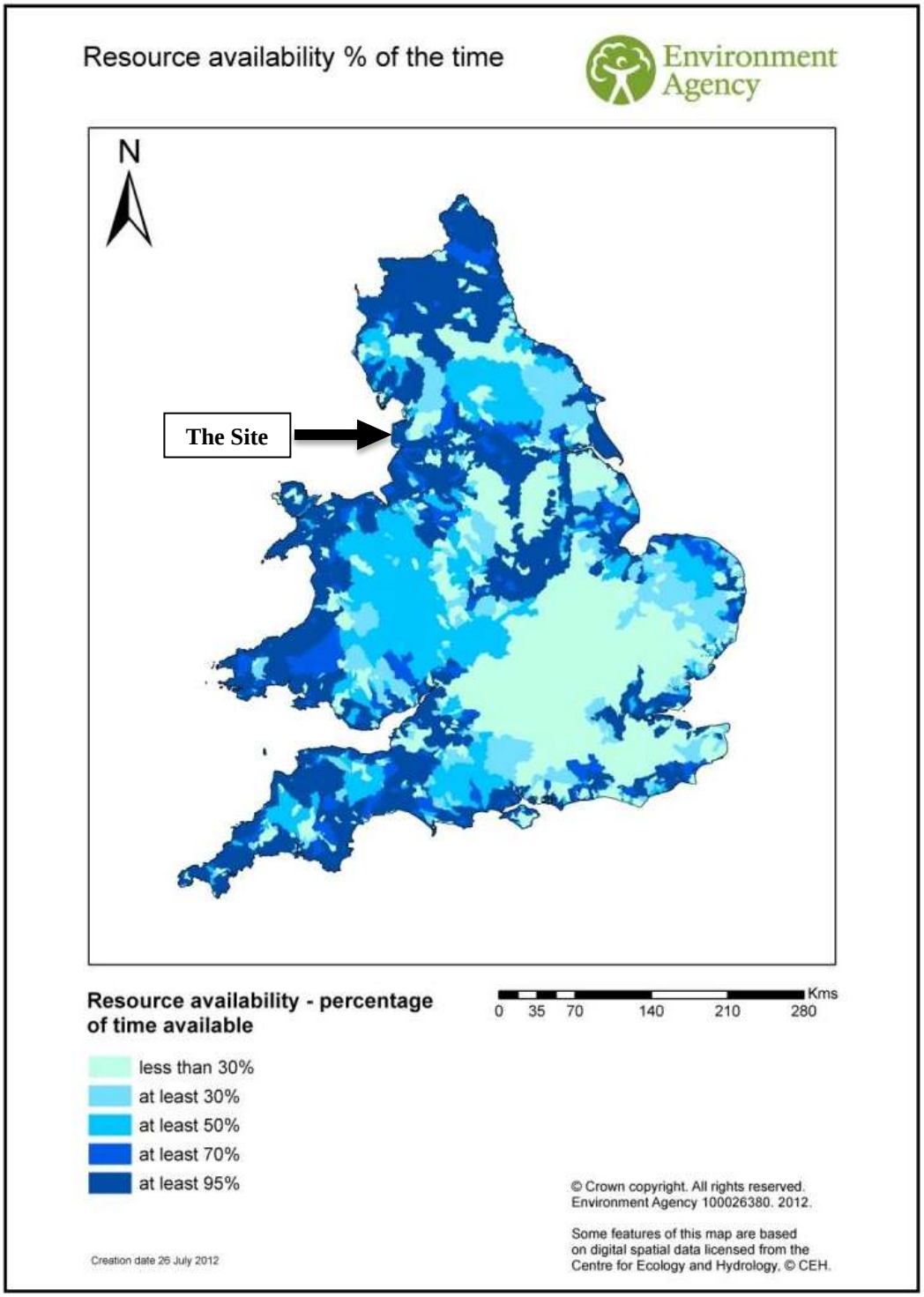
19.6.4 Water Use

42. Potable water supplies to the region are, in the majority, sourced from the Lake District and supplied via the United Utilities (UU) owned potable water network.

43. The Site currently does not take water from the UU potable water network. The Site is currently pasture and is not irrigated.

44. The Environment Agency (EA) has assessed water abstraction management throughout England & Wales and has assessed water resource availability. Figure 2 below displays the percentage of time water is available for abstraction across the country, which gives an indication of water scarcity. This shows the Site is located within a zone with high water resource availability, where water is available at least 95% of the time. This shows that generally, the region is not 'water stressed'.

Figure 19.2 - EA Resource Availability Map



45. The Site is located within United Utilities' "Integrated Resource Zone" supply zone. This means that water supplies are not fed from specific sources (i.e. an individual water treatment works), but are supplied via an integrated network of water mains and sources that are interconnected to maintain resilience of the network and flexibility of supply. United Utilities have indicated in their Water Resources Management Plan "headroom figures" within their supply capacity, i.e. the amount of daily spare potable water supply between typical demand and overall supply capacity. The target headroom value (with

allowances for climate change) for 2014/5 in this Integrated Resource Zone is estimated by United Utilities (UU) as 57.6Ml/d. This has been identified to allow a comparison with the demand by the Project, and the anticipated spare headroom that will remain to give context in the assessment and identify any significant effects.

46. The extent of the Integrated Supply Zone is shown below in Figure 3. UU are able to move water supplies around this region to meet demand. This helps UU to maintain adequate supplies to major areas of the Integrated Resource Zone in times of dry weather.

Figure 19.3 United Utilities' Water Supply Zones[444].(Not to scale).

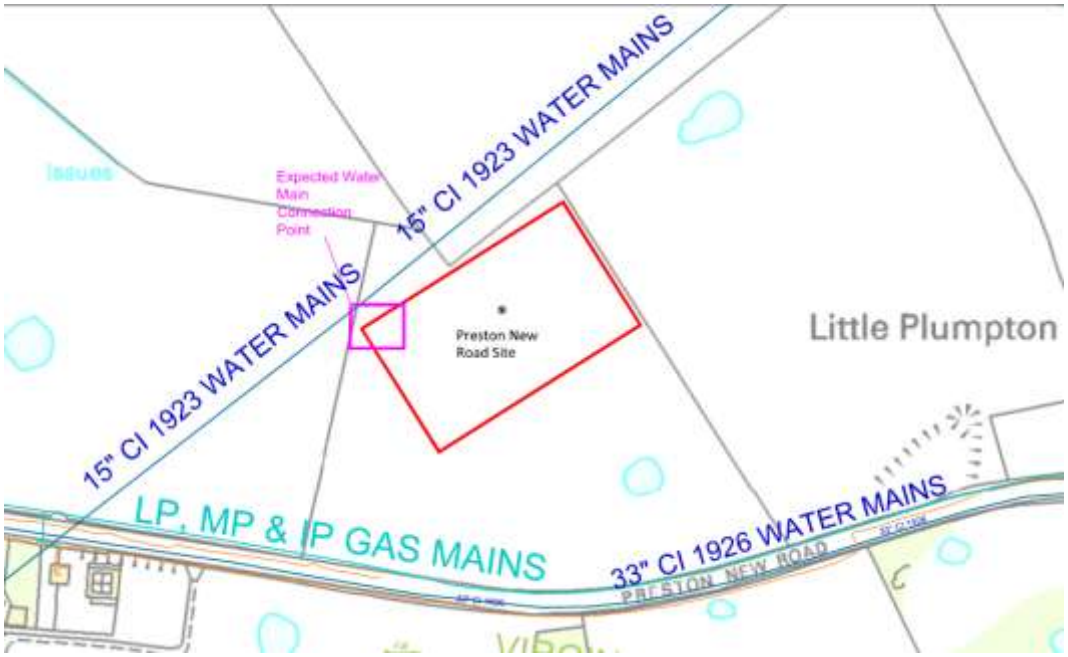
19.7 Assessment

19.7.1 Design

19.7.1.1 Water Use

47. A new 150mm dia HDPE water supply pipe will be constructed below ground to the northwest of the Site, to supply mains water as shown in Figure 19.4. This will be a metered connection with a shut off valve connecting from an existing United Utilities 15" cast iron potable water main in which runs close to the northern boundary of the Site. The supply pipe will terminate at the Site boundary where a meter and outlet valve will be located. UU have reported that the main has a history of bursts so installation of a pressure management valve (PMV) and flow meter would be required in order to reduce the risk of any future burst. UU have also stated it may be possible to re-zone their network so the Site would be the only user of the main. The works to construct the water connection and any other works to the existing water mains will be undertaken by UU.

Figure 19.4. Proposed water supply pipe route



48. The anticipated water usage figures required for the Project, supplied from the water supply pipeline are estimated in Table 19.8. Column 2 shows the overall water requirements per well irrespective of source, and Columns 3 to 6 show estimated requirements from the mains water supply, incorporating reductions resulting from the reuse of flow back fluid during hydraulic fracturing.

Table 19.8 - Estimated water usage

Stage	**Water demand per well**	**Water demand from UU mains per well (incorporates re-use of flowback fluid)**	**Total water demand from UU mains 4 wells combined (incorporates re-use of flowback fluid)**		
	Process Water (m^3)	**Process Water from UU mains (m^3)**	**Process Water (m^3) [No of Household equivalents[445]]**	**Welfare Water[446] (m^3)**	**Site Total (m^3)**
Construction of Well Pad, water supply pipeline and Access	N/A	N/A	Typical Construction usage and site welfare only	Negligible	Typical construction figures
Installation of Monitoring Works	-	-	Negligible	<1% of total water demand. Scoped out of the assessment.	N/A.
Drilling[447]	1,815	1,815	7,250 [40]	1,150	8,400
Hydraulic fracturing	765 per fracture stage, 22,250 to 33,725 per well	600 per fracture stage, 18,000 to 27,000 per well	90,000 [495]	430	90,430
Initial Flow Testing	Negligible, site welfare only	Negligible, site welfare only	Negligible, site welfare only	270	270
Extended Flow Testing	Negligible	Negligible	Negligible	330	330
Decommiss-ioning & Restoration	N/A	N/A	Typical Construction usage and site welfare only	Negligible	Negligible

[445] Comparisons to household water use are made against a housing usage of 182.5m^3/annum (typical), based on a consumption of 500 l/household/day.
[446] Welfare water usage is taken as welfare waste water /0.9, obtained via the British Water Code of Practise Flows and Loads publication based on a waste water figure of 60l/person/day. During construction and decommissioning, welfare water requirement assumption has been increased to 100l/person/day to allow for other construction site uses. Figures for Decommissioning and Restoration are assumed to be negligible at a nominal 25m^3.
[447] Data provided by Cuadrilla.

19.7.1.2 Surface Water Drainage to Well Pad

49. All assessment of effects determined in the Water Resources Chapter are made against the current 'Greenfield' state.

50. A detailed description of the well pad is given in the proposed development description in Chapter 4 and the example photographs showing construction of the well pad and drainage system. This is supplemented by the following information relevant to the water resources assessment.

51. The entire well pad area is to be constructed with a minimum 300mm depth Type 1 granular sub base material over a 30kN geo-grid over a fully welded 1mm thick HDPE impermeable liner protected by underlay and overlay of 300gsm non-woven protection membrane. The base of the well pad/liner shall be placed flat at c. 12.20mAOD, or 300mm below pad top level of approximately 12.50mAOD

52. A 1.0m deep, min 2.30m wide open trapezoidal drainage ditch will be constructed around part of the well pad perimeter and will be piped in other parts of the perimeter with a min 300mm pipe placed in the backfilled sections of the ditch base. The top of the stone pad will lay at a level 50mm lower (at 12.500mAOD) than the top of the outer perimeter ditch bund at 12.550mAOD, thus providing 50mm air freeboard (creating a 'bath tub' effect). This acts to provide an additional attenuation volume for rainwater storage within the pad area to cope with extreme storm events. An example of how this is constructed is shown in Figures 19.5 and 19.6. The liner will be continued through to line the ditches to create a containment system (Figure 19.6).

Figure 19.5. Perimeter ditch example during construction.

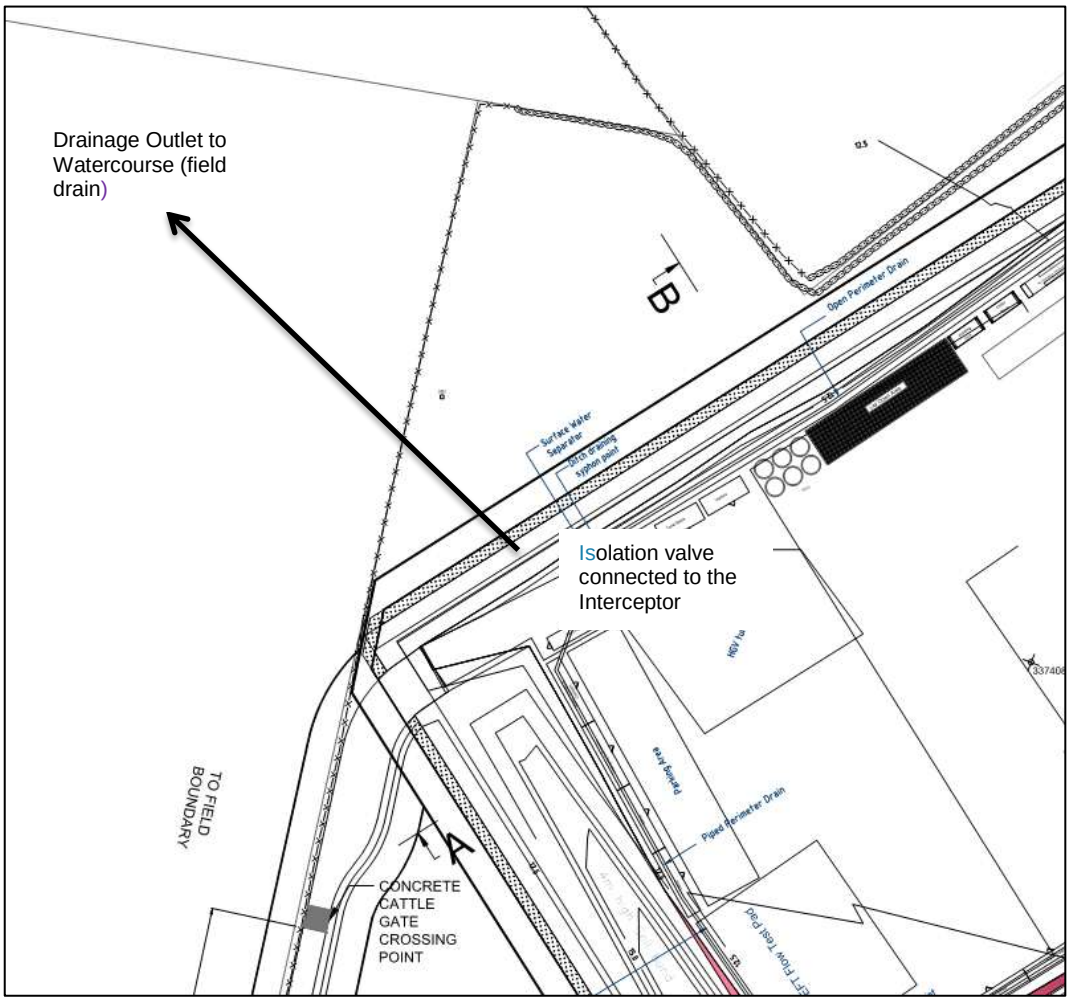
Figure 19.6. Perimeter ditch liner example during construction

53. An Interceptor shall be installed at the north western side of the perimeter drainage ditch which has an inlet level of approximately 12.05mAOD. This shall be appropriately sized for the drainage area. The interceptor removes liquid hydrocarbons that float on water such as spilt diesel and engine oil. The interceptor shall be operated, inspected and maintained in accordance with the manufacturers' guidance and Pollution Prevention Guidelines

54. Double isolation valves shall be installed on the 150mm diameter storm water outlet pipe which then outfalls to Carr Bridge Brook to the north of Site, as shown in Figure 19.7. The use of double isolation valves provides resilience in the system should one of the valves malfunction. The isolation valves shall be manually operated and the valve chamber accessed via a secure manhole cover.

55. This outlet pipe will be restricted in diameter (using a throttled pipe diameter; an orifice plate stopper or similar) such that storm water runoff from the well pad is reduced to below 'greenfield' rates, including an allowance for climate change.

Figure 19.7. Site drainage connections to adjacent field drainage.



56. The containment volume of the perimeter drainage ditches, voids within the stone layer and 50mm air freeboard has been calculated as 1,170m^3 over the well pad site area of 2.39ha (consisting of 1.55ha well pad and 0.84ha bunds / landscaping), as set out in **Table** 19.9.

Table 19.9 - Well pad containment volume estimate

	Stone (4% void ratio)	**Air Freeboard**	**Open Ditches/Pipe**	**Stoned Ditch**	**Total**
Storage Containment Volume (m^3)	185	775	190	20	1170

57. Should the stone layer become clogged with debris, spillages, historic rainwater or compacted reducing the void ratio, the containment volume of the open ditches and air freeboard alone is 965m^3. This volume has been used to assess drainage impacts in the isolation valve closed scenario (drilling & hydraulic fracturing stages) in order to provide a conservative assessment of impacts.

58. Extreme rainfall depths for different return periods have been estimated for the Site from the FEH rainfall depth-duration-frequency (DDF) model.

Table 19.10 - Rainfall depth estimations for 1 in 10, 30 and 100yr return period storm events

		Return Period (yrs) Rainfall Depth		
Storm Duration	**Storm Duration**	10	30*	100
Minutes	Hours	mm	mm	mm
15	0.25	14.4	20.5	30.4
30	0.50	17.8	25.0	36.3
60	1.0	22.0	30.2	43.1
90	1.5	24.9	33.9	47.7
120	2.0	27.2	36.8	51.2
150	2.5	29.1	38.9	54.0
180	3.0	30.7	41.0	56.5
240	4.0	33.5	44.3	60.6
360	6.0	37.8	49.5	66.9
480	8.0	41.2	53.5	71.7
600	10.0	44.0	56.9	75.7

*1 in 30 year values are interpolated using FEH Growth Factor Curves, Region 10

59. The design of the drainage system enables it to operate under two different scenarios – isolation valve open and isolation valve closed. This has been assessed as follows:

- **Isolation valve open** - The containment capacity of the well pad is assessed as able to retain a rainfall depth averaged across the c. 2.39ha well pad site equivalent to 9mm, before storm water starts to discharge off site by flowing through the interceptor and outfall pipe to Carr Bridge Brook.

- **Isolation valve closed -** The containment capacity of the well pad is assessed as able to retain a rainfall depth averaged across the c. 2.39ha well pad site equivalent to 40 mm, prior to storm water running off site by overtopping the Site perimeter ditch (overland flow). Rainfall events [depths] highlighted in green in Table 10 above would therefore be retained on the well pad, those shown as un-shaded would begin to runoff Site when containment capacity is exceeded.

60. The runoff rate from the well pad has also been compared to the greenfield site condition as reported in Table 19.11. Rainfall depth information has been taken for different return periods using data extracted from the catchment descriptors in FEH. This assumes that the pad is relatively dry initially, and once the containment capacity of the pad is taken up, then 100% of the rainfall falling of the pad would then runoff into adjacent fields as overland flow, eventually discharging into the Carr Bridge Brook. Runoff rates are controlled by the design of the storm water outlet pipe/orifice plate stopper which causes a throttling effect.

61. Table 19.11 identified how the proposed design attenuates storm water and has the effect of reducing storm water runoff rates compared with the baseline 'Greenfield Site'. This is a beneficial effect.

Table19.11 Storm water runoff estimates for greenfield and proposed well pad (2.39ha, including for well pad, bunds and landscaping).

Condition	Greenfield Site	Proposed Pad (Isolation Valve Open) [150mm∅ pipe]	Proposed Pad (Isolation Valve closed)**
Storm water runoff estimates			
Greenfield runoff rate (l/s/ha)	6.1	NA	NA
Greenfield runoff (l/s)	14.6	NA	NA
1 in 10 Year (l/s)	20.1	19.3 (4%)	2.1 (90%)
1 in 30 Year (l/s)	24.8	19.4 (21%)	Not determined- no growth curve available in FEH
1 in 100 Year (l/s)	30.6	19.6 (36%)	18.2 (41%)
1 in 100 Year +cc (l/s)*	33.6	24.7 (27%)	20.0 (41%)

*including a Climate Change allowance of +10%
% reduction over greenfield rates are show in brackets.

**runoff occurs only for storm durations where rainfall depth exceeds that of a 1 in 10 year return period event storm with a duration in excess of 6 hrs. Prior to that, runoff is contained.

Surface Water Drainage to Access Track

62. A new c. 170m long access track will be constructed to the south of the Site, from Preston New Road. For the majority of its length, this will be constructed for heavy vehicle use using a free draining stone surface (not tarmac). The last 20m of the track at the junction with Preston New Road will be tarmac to improve durability and control rutting for turning vehicles entering the Site.

63. Due to the free draining characteristics of the access track materials it is concluded that the surface will be permeable and will have a similar coefficient of runoff to the existing condition. There are no proposals to install active drainage or provide a tarmacked surface along the entire length which could otherwise increase the rate of surface water runoff during rainfall events. For the reasons stated above the impact of the access track on flood risk or drainage are not assessed further.

19.7.2 Construction of well pad, water supply pipeline and access

19.7.2.1 Water Use: Risk to Water Supplies

64. During construction, water usage would be limited to that of a typical construction site including plant cleaning, filling of bowsers, cabins and welfare facilities uses, estimated as c. 25m^3. The connection to the water main shall be installed but not available for use until the latter part of the construction period. The water requirements would be low and therefore the significance of the predicted environmental effects of water use during construction is assessed as **negligible** and **not significant.**

19.7.2.2 Surface Water Drainage: Risk of increased surface water runoff

65. Prior to the completion of the well pad and installation of the liner, there would be no increase in surface water runoff and the site will behave as per the 'greenfield case'(See Section 19.6.2)

66. Once the liner and outfall pipe have been constructed then the site drainage regime will operate in the same manner as during mobilisation (see Section 19.7.4.1). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.3 Installation of Monitoring Works

19.7.3.1 Water use: Risk to Water Supplies

67. There are no requirements for water supply for the installation and operation of the surface and buried arrays and consequently, the significance of the predicted environmental effects from water use have not been assessed. If water is required by the contractor it will be transported to Site in a bowser or similar container. This following assessment is for drainage related impacts only.

19.7.3.2 Drainage and flood risk: Surface array

68. The installation or operation of the surface array stations that form part of the mitigation against induced seismicity will not change ground levels and will not have a material effect on either the area of impermeable surfaces present or result in any significant consumption of water resources. As a consequence, the significance of the predicted environmental effects of water resources through the installation of surface arrays is assessed to be **negligible** and **not significant.**

19.7.3.3 Drainage and flood risk: Buried array

69. The installation or operation of the buried array stations will not change ground levels, will not have a material effect on the area of impermeable surfaces present or result in any significant consumption of water resources. As a consequence, the significance of the predicted environmental effects of water resources through the installation of surface arrays is assessed to be **negligible** and **not significant.**

19.7.4 Drilling

19.7.4.1 Mobilisation

19.7.4.2 Water use: Risk to Water Supplies

70. During mobilisation there are no requirements for mains water beyond typical site welfare uses. Consequently there would not be an impact on water use or a large requirement for water from the mains supply and no anticipated restrictions on availability. Consequently, the overall significance of the predicted environmental effects of water resources is assessed as **negligible** and **not significant**.

19.7.4.3 Drainage and flood risk: Risk of increased surface water runoff

71. During mobilisation, storms would result in the well pad liner and stone layer retaining water. The isolation valve would be open and flows would leave Site through the interceptor and outlet pipe discharging to the existing field drain to the north. The attenuation capacity of the well pad has been used in the assessment of the likely surface water runoff leaving Site during storm events up to and including the 100 year event, including an allowance for climate change. Table 11 shows that when the isolation valve is open, peak flows would be reduced for return period events up to and including 1 in 100 years by between 4% and 36% compared to existing greenfield runoff rates. The magnitude of the impact is assessed as *moderate* over the short duration (mobilisation takes <6 months)**,** the value of the receptor (field drain) is assessed as *very low*. The overall significance of the predicted environmental effects of reduced Site runoff is assessed as **minor beneficial** *(*because of a reduction in runoff rate) and **not significant.**

19.7.4.4 Drilling operations

19.7.4.5 Water use: Risk to Water Supplies

72. The Site will use an estimated 7,250m³ (7.25 ML) of process water total during drilling, an average of 0.02Ml/d. This amounts to 0.04% of the available headroom as determined by United Utilities and equates to 0.001% of the 1740 ML/d of potable water supplied by United Utilities within the Northwest of England. The demand for water from the mains supply is therefore not assessed as large and no anticipated restrictions on availability at these demand rates are anticipated. Consequently, the overall significance of the predicted environmental effects of water resources is assessed as **negligible** and **not significant**.

19.7.4.6 Surface Water Drainage: Risk of increased surface water runoff

73. With the isolation valve closed, the containment capacity of the well pad is assessed as able to retain a storm water depth equivalent to 40mm, prior to storm water running off Site. A comparison shows that this is sufficient to store water from a 1 in 100 year return period event, of c. 30 mins duration. Adequate containment is also provided for rainfall events of 1 in 10 year intensity for durations up to 6 hours. For short storm durations or low return period events (below 1 in 10 years), rainfall depths are predicted to be less than 40mm (see Table 10, values shown in green). Such rainfall events would therefore be retained within the well pad under these events.

74. During drilling, only very extreme return period storms of long duration would result in the attenuation capacity off the well pad being exceeded and flows leaving Site through overland flow. The attenuation capacity of the well pad is able to store water from rainfall events up to and including the 100 year event (including an allowance for climate change). Table 11 shows that when the Isolation Valve is closed, peak flows would be reduced for return period events up to and including 1 in 100 years by between 41% and 90%, compared to existing greenfield runoff rates. The magnitude of the impact is assessed as *moderate*, the value of the receptor (field drain) is assessed as *very low*. The overall significance of the predicted environmental effects of reduced Site runoff is assessed as **minor beneficial** and **not significant.**

19.7.5 Hydraulic Fracturing

19.7.5.1 Mobilisation

19.7.5.2 Water Use: Risk to Water Supplies

75. There would be limited water consumption for these works beyond plant cleaning, filling of bowsers, cabins and welfare facilities uses. The overall significance of the predicted environmental effects of water use during mobilisation is assessed as **negligible** and **not significant**

19.7.5.3 Drainage and flood risk: Risk of increased surface water runoff

76. The site drainage regime will operate in the same manner as during mobilisation of drilling (see Section 19.7.4.1). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.5.4 Hydraulic Fracturing

19.7.5.5 Water Use: Risk to Water Supplies

77. During hydraulic fracturing, water will be supplied to the Site via the new water supply pipe constructed using a metered connection to the United Utilities potable water main. The source of water is treated potable water (i.e. after treatment at the water treatment works) and United Utilities have conducted hydraulic modelling of their network based on typical demand scenarios.

78. The Site will draw up to an estimated 600m^3/d (0.60Ml/d) [excluding a nominal welfare water usage of c.2m^3/day] mains water during the fracturing process, which amounts to 1% of the available headroom figure of 57.6 ML/d, as determined by United Utilities. This equates to 0.03% of the 1740 ML/d of potable water supplied by United Utilities within the Northwest of England.

79. It is estimated that the hydraulic fracturing process at the Preston New Road Site will use in total c. 90,000m^3 (90ML) of water from the United Utilities water mains for all 4 wells over a 2-3 year period.

80. United Utilities PLC have confirmed through modelling that drawing up to 765m^3 over a 24 hour period from their 15" water main can be undertaken without flow restriction and will not adversely affect the supply to other users of their network, providing a Pressure Management Valve is installed to reduce the risk of bursts. The overall significance of the predicted environmental effects of water resources through the use of potable water for hydraulic fracturing is assessed to be **minor adverse** and **not significant.**

19.7.5.6 Drainage and flood risk: Risk of increased surface water runoff

81. The drainage system will operate in the same manner as during drilling operations (see section 19.7.4.2). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.6 Initial Flow Testing

19.7.6.1 Water Use: Risk to Water Supplies

82. There would be limited water consumption during initial flow testing beyond minimal uses in line with those of a typical construction Site, including plant cleaning, filling of bowsers, cabins and welfare facilities uses. The overall significance of the predicted environmental effects of water use during flow testing is assessed as **negligible** and **not significant.**

19.7.6.2 Drainage and flood risk: Risk of increased surface water runoff

83. The site drainage regime will operate in the same manner as during mobilisation of drilling (see Section 19.7.4.1). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.7 Extended Flow Testing

19.7.7.1 Construction of pipeline connection to the gas grid

Water Use: Risk to Water Supplies

84. There would be limited water consumption during extended flow testing beyond minimal uses in line with those of a typical construction Site, including plant cleaning, filling of bowsers, cabins and welfare facilities uses. The overall significance of the predicted environmental effects of water use during extended flow testing is assessed as **negligible** and **not significant.**

Drainage and flood risk: Risk of increased surface water runoff

85. The site drainage regime will operate in the same manner as during mobilisation of drilling (see Section 19.7.4.1). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.7.2 Operation

Water Use: Risk to Water Supplies

86. No fracturing is anticipated to be taking place during extended flow testing; therefore the requirements for water consumption are limited beyond normal construction uses and consequently, the predicted environmental effects are assessed as **negligible** and **not significant.**

Drainage and flood risk: Risk of increased surface water runoff

87. The site drainage regime will operate in the same manner as during mobilisation of drilling (see Section 19.7.4.1). The risk of increased surface water runoff is assessed as **minor beneficial** and **not significant.**

19.7.8 Decommissioning and Restoration

19.7.8.1 Extended Flow Test Infrastructure

88. The connection to the National Grid (NG) gas main would be isolated in accordance with NG standards and procedures. Equipment, tanks and materials associated with the EFT exploratory works will be removed from the Site. The overall significance effects of water use, drainage and flood risk during EFT abandonment are described under Exploration well, pad and access track are assessed as **negligible** and **not significant**.

19.7.8.2 Monitoring Works Infrastructure

89. There are no requirements for water supply for the installation and operation of the surface and buried arrays and consequently, the significance of the predicted environmental effects from water use have not been assessed. If water is required by the contractor it will be transported to Site in a bowser or similar container. This following assessment is for drainage related impacts only.

Surface Water Drainage: Risk of increased surface water runoff

90. There would be no change to surface type which would lead to an increase in storm water runoff. The overall significance of the predicted environmental effects of water use and of increased surface water runoff is therefore assessed as **negligible** and **not significant.**

19.7.8.3 Exploration well pad and access track

91. The restoration of the Site is described in Chapter 4 of the ES. The following decommissioning and restoration works are of relevance to this section. Concrete structures, e.g. drainage chambers, will be broken up and removed. Any voids created by Site clearance will be in-filled using subsoil from that stockpiled in the earth bund, ready for the Site to be re-graded to original contour levels. Any damaged land drains will be replaced and the subsoil and topsoil from the earth bund would be spread over the ground. If necessary a scheme of field drainage in the Site area will be prepared and agreed with the landowner and implemented at an agreed date.

92. Upon completion, the water supply pipe will be removed back to the meter location, capped off and the valve chambers are likely to be left in place.

Water Use: Risk to Water Supplies

93. There would be limited water consumption for these works beyond minimal uses in line with those of a typical construction site, including plant cleaning, filling of bowsers, cabins and welfare facilities uses, estimated as c. 25m^3. The overall significance of the predicted environmental effects of water use during decommissioning is assessed as **negligible** and **not significant.**

Drainage and flood risk: Risk of increased surface water discharge

94. Once Site activities have ceased, in water use, drainage and flood risk terms, the Site will behave as close to a greenfield baseline scenario and there should be negligible change to soil type or storm water runoff rates. Consequently, the magnitude of the impact is assessed as *negligible***,** the value of the receptor is assessed as very *low* and the overall significance of the predicted cumulative environmental effects on water resource issues are assessed to be **negligible** and **not significant.**

19.8 Cumulative and Interactive Effects

19.8.1 In combination effects within the Site

95. In-combination effects of drilling, initial flow testing and extended flow testing occurring together on the same well pad at the same time; and hydraulic fracturing, initial flow testing and extended flow testing occurring together on the same well pad at the same time will not significantly increase the daily or overall demand for water supply.

96. The drainage system will operate in the same manner during the identified in-combination scenarios. The risk increased surface water discharge to the adjacent watercourse does not change.

19.8.2 Cumulative Effects of Preston New Road and Roseacre Wood

19.8.2.1 Water Use

97. The Preston New Road and Roseacre Wood sites will have independent connections onto the United Utilities mains network. The connection points are far apart and do not draw from the same areas of the network. Hydraulic fracturing will not be undertaken simultaneously at both sites, therefore there will be no overlap in the water demands from hydraulic fracturing. Through discussion, United Utilities have confirmed that they can meet the demands of the Preston New Road and Roseacre Wood sites without affecting other users of their network. At Roseacre Wood, United Utilities have stated they would need to protect supplies to their existing customers by installing a pressure sustaining valve (PSV) on the connection to the Site and a new meter and Pressure Monitoring Valve (PMV). Once these mitigation measures are in place, the overall significance of the predicted cumulative environmental effects of water use at the two sites operating in concurrently is assessed to be **minor adverse** and **not significant.**

19.8.2.2 Drainage and flood risk

98. The Preston New Road site is located 7.5km south-west of the Roseacre Wood site. Preston New Road drains southwards towards Main Drain and ultimately into the River Ribble catchment. Roseacre Wood drains northwards into the River Wyre system. Therefore the sites are independent of each other in drainage terms and the cumulative effects of drainage and flood risk are assessed as ***negligible*** and **not significant**

19.9 Mitigation Measures

99. No mitigation measures are required for the:

- The construction of the well pad and access track;
- Installation of the Monitoring Works;
- Mobilisation of plant and equipment during drilling, hydraulic fracturing and flow testing;
- Drilling;
- Initial flow testing;

- Extended flow testing; and
- Decommissioning.

100. Over the duration of the project, the maintenance and inspection of the Interceptor will be conducted in accordance with manufacturer's guidelines and PPG3[448].

19.9.1 Hydraulic fracturing

19.9.1.1 Water use

101. To reduce the water demands some of the flow back fluid from the hydraulic fracturing process could be re-used in subsequent hydraulic fracturing stages (embedded mitigation). Depending on the availability and quality of flow back water the proportion of re-used water could be increased. This would reduce the total mains water demand. Cuadrilla should seek to maximise the reuse of flowback water for hydraulic fracturing operations.

102. Collected rainwater could also be used to make up part of the hydraulic fracturing fluid. This would further reduce the total mains water demand. Transport requirements to remove collected rainwater from the site would also be reduced. Cuadrilla should explore the potential to implement this at the Site.

United Utilities will install pressure management valve (PMV) in order to reduce the burst risk of the water supply main. UU have also stated it may be possible to re-zone their network so the site would be the only user of the main.

19.10 Residual effects

No other significant residual effects have been identified, after consideration of the original likely effects and the proposed mitigation measures.

19.11 Assessment Summary Matrix

103. The output of the environmental impacts of water resources as a result of the Preston New Road Shale Gas Exploration project are summarised below in Table 19.12.

Table 19.12: Water Resources assessment summary matrix.

Description of effect	Significance	Mitigation	Residual effect
Construction of the Well Pad, Water Supply Pipeline and Access			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant
Drainage and flood risk –increased runoff leaving the Site and entering the field drainage.	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Installation of Monitoring Works			

[448] Use and design of oil separators in surface water drainage systems: PPG3, The Environment Agency.

Description of effect	Significance	Mitigation	Residual effect
Drainage: Surface Arrays - changes to drainage regime or increased runoff due to change in impermeable surfacing	Negligible, Not significant	None	Negligible, Not significant
Drainage: Buried Arrays - changes to drainage regime or increased runoff due to change in impermeable surfacing	Negligible, Not significant	None	Negligible, Not significant
Drilling (mobilisation)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and Flood Risk – Increased surface water runoff resulting from the construction of the well pad.	Minor beneficial, Not significant	None	Negligible, Not significant
Drilling (Drilling)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and flood risk –increased runoff leaving the Site and entering the field drainage.	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Hydraulic Fracturing (mobilisation)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and flood risk –increased runoff leaving the Site and entering the field drainage.	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Hydraulic Fracturing (Hydraulic Fracturing)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Minor Adverse, Not Significant	More extensive reuse of flow-back water in the fracturing fluid to reduce water demand. Consider use of collected rainwater in the fracturing fluid to reduce water demand. Install PMV on network to reduce risk of bursts.	Minor Adverse, Not Significant
Drainage and flood risk –increased runoff leaving the Site and entering the field drainage.	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Initial Flow Testing			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant

Description of effect	Significance	Mitigation	Residual effect
Drainage and Flood Risk - increased runoff leaving the Site and entering the field drainage	Minor beneficial, Not Significant	None	Negligible, Not significant
Extended Flow Testing (Construction)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant
Drainage and Flood Risk - increased runoff leaving the Site and entering the field drainage	Minor beneficial, Not Significant	None	Negligible, Not significant
Extended Flow Testing (Operation)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant
Drainage and Flood Risk - increased runoff leaving the Site and entering the field drainage	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Decommissioning and Restoration – EFT Infrastructure			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and Flood Risk –increased runoff leaving the Site and entering the field drainage when compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant
Decommissioning and Restoration – Monitoring Works Infrastructure			
Drainage and Flood Risk –increased runoff leaving the Site compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant
Decommissioning and Restoration – Well, pad and access track			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and Flood Risk –increased runoff leaving the Site and entering the field drainage when compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant

Extended Flow Testing (Construction)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant
Drainage and Flood Risk - increased runoff leaving the Site and entering the field drainage	Minor beneficial, Not Significant	None	Negligible, Not significant
Extended Flow Testing (Operation)			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not Significant	None	Negligible, Not significant
Drainage and Flood Risk - increased runoff leaving the Site and entering the field drainage	Minor beneficial, Not Significant	None	Minor beneficial, Not Significant
Decommissioning and Restoration – EFT Infrastructure			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and Flood Risk –increased runoff leaving the Site and entering the field drainage when compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant
Decommissioning and Restoration – Monitoring Works Infrastructure			
Drainage and Flood Risk –increased runoff leaving the Site compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant
Decommissioning and Restoration – Well, pad and access track			
Water Use – Risk to availability of water supplies in mains network resulting from demand requirements	Negligible, Not significant	None	Negligible, Not significant
Drainage and Flood Risk –increased runoff leaving the Site and entering the field drainage when compared to pre-developed condition	Negligible Not significant	None	Negligible, Not significant

20 Public Health

1. This chapter describes how public health concerns associated with the Project have been considered in the different chapters of the ES, and summarises their conclusions.

20.1 Introduction

2. This Chapter provides an overview of potential public health issues considered relevant to the Project, the communities and groups of the population, rather than individuals, that might be affected and identifies how these have been assessed within the ES. This has also been informed by a summary of current community health issues in the vicinity of the Site. Additionally, the ES provides a summary of the key conclusions in relation to public health, and also considers broader wellbeing impacts relating to socio-economic issues and public perception issues.

20.2 Scoping and Consultation

3. In their response to the Preston New Road Scoping Report submitted to Lancashire County Council on 4th February 2014, and used as a basis for consultation, Public Health England (PHE) identified a range of health related concerns and requested that a section within the ES should set out how these concerns have been taken into account in the EIA process. PHE also requested that a section of the ES (this chapter) should indicate where public health related issues have been covered by the different sections of the ES (e.g. air quality, socio-economics and community and hydrogeology and ground gases).

4. PHE raised the following points (see Appendix D for full details).

   - Identification of where within the ES receptors that could be affected by health impacts are identified;
   - Highlighting where, within the ES, the impacts from construction and decommissioning have been assessed;
   - How potential health impacts relating to emissions to air and water have been assessed and where in the ES these are documented;
   - Specific issues concerning emissions to air;
   - Specific issues concerning emissions to water;
   - How potential health issues relating to land quality and contamination have been assessed;
   - How potential health issues relating to waste management have been assessed;
   - Other health related issues such as the management of pollution incidents, the regulation of the Site and how potential public stress and anxiety have been taken into account by the Project; and
   - The organisations that have been consulted regarding health related issues during the EIA process.

   A detailed signposting document responding to the points above can be found in Appendix T1.

In 2013 (PHE) also published a report, for comment, on the potential public health impacts from shale gas extraction[449]. The following recommendations (set out in bold below) are relevant to the exploration and appraisal activities that have been assessed within this ES. The way in which each recommendation has been addressed within the ES is described below:

- **Baseline environmental monitoring is needed to facilitate the assessment of the impact of shale gas extraction on the environment and public health.** Baseline environmental data is presented in each of the technical assessments and provides the basis for the assessment of the likely significant effects;
- **Effective environmental monitoring in the vicinity of shale gas extraction sites is needed.** The proposals for environmental monitoring have been identified within relevant assessment chapters. The specific parameters that will be monitored, monitoring methodologies and reporting will be set out in the Site specific Environmental Operating Standards (EOS) before works commence:
- **Consideration of broader public health and socio-economic impacts such as increased traffic and impacts on local infrastructure.** These broader considerations have been assessed within the ES and also within some of the other documents that have been produced to support the respective planning applications;
- **Disclosure of chemicals to be used within the hydraulic fracturing fluid.** These chemicals are described in Chapter 4, Chapter 11 and Appendix K (Section 5.3) as well as relevant permit applications;
- **The type and composition of the gas likely to be extracted.** The EIA has drawn on data regarding the composition of the gas that was sampled from the Preese Hall well and used this data to assess potential effects on atmospheric air quality and ground gas (see Appendix K Section 6.3.3 and 6.3.4); and
- **Characterisation of potentially mobilised natural contaminants including NORM and dissolved minerals.** These are identified and assessed within the Hydrogeology and Ground Gas chapter (11), the Air Quality chapter (6) and within Appendix K (Sections 5.4.2, 6.5.2 with respect to NORM and Section 5.4.2 Table 29 for dissolved minerals).

20.3 Community profile

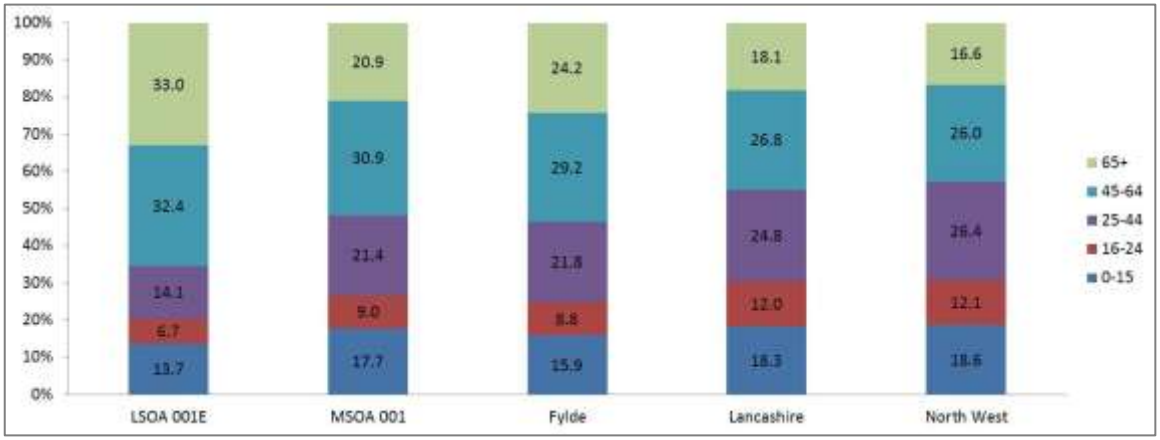
5. The purpose of the community profile, described below, is to provide an overview of the general health and wellbeing of the area. It also gives a context to the health issues described in section 20.5.

20.3.1 General

6. The nearest large nearby settlements of Kirkham and Blackpool have approximate populations of just over 7,000[450] and 142,000[450] respectively. The age makeup of the population based on figures from the 2011 census is shown in Figure 20.1 below.

[449] Public Health England, 2013. Review of the Potential Public Health Impacts of Exposure to Chemical and Radioactive Pollutants as a Result of Shale Gas Extraction.. http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317140158707
[450] Office for National Statistics: Census 2011.

Figure 20.1: Age profile for selected geographic comparator areas (Source: ONS, 2011 census).



7. The LSOA contains the highest proportion (33%) of residents over 65 out of all the comparator areas. This is 12% higher than the MSOA, 9% higher than Fylde, 15% higher than Lancashire and 16% higher than the NW. Similarly the LSOA contains the highest proportion of 45-64 year olds, approximately 2-6% higher than the other areas.

8. This higher concentration of older people, means that there are notably lower proportions of younger people in the area. The LSOA has a lower proportion of the population who are younger than 25, compared with the MSOA.

9. The Site is approximately equidistant from the centre of Blackpool (west) and Kirkham (east). Aside from the extensive agricultural land, other businesses exist in the surrounding area. These include, within 1km of the Site:

- A dog grooming business to the south;
- An aquatic superstore, pet centre and cafe (*World of Water*) to the west;
- A garden centre to the west;
- A nursery garden to the north west;
- A cattery to the west (Westby Cattery) and North West (Meadowgreen Cattery); and
- A large caravan park (including static caravans) to the east.

20.3.2 Deprivation

10. Deprivation is included in the community profile because it can be indicative of community health and wellbeing i.e. areas of greater deprivation tend also to coincide with poorer level of health than more affluent areas. The Indices of Multiple Deprivation (IMD) is a multivariate indicator set produced by government to aid and inform awareness of deprivation and approaches to improving the conditions (including health and wellbeing) in deprived areas.

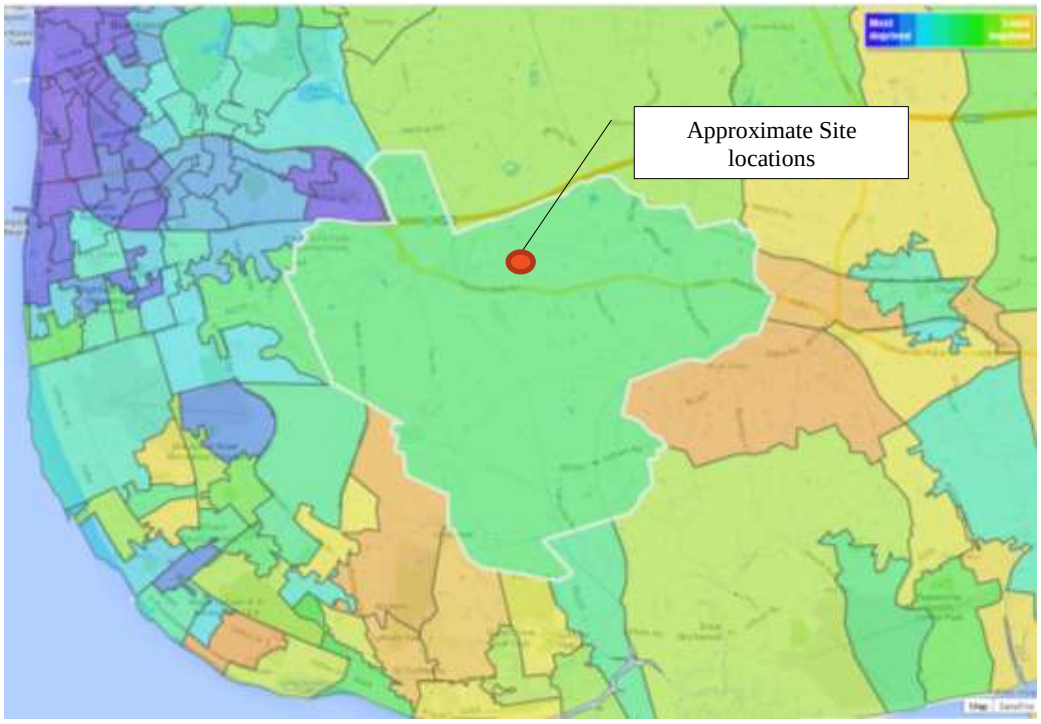
11. The Office for National Statistics holds data on this index. It states the following about the LSOA (defined in the IMD as a Neighbourhood) *All 32,482 neighbourhoods in England have been ranked on a range of deprivation topics. The most deprived neighbourhood in England has a rank of 1. These markers show the overall deprivation and the environment deprivation ranking for your area.*

12. The Figure below shows IMD mapping across Fylde and the neighbouring areas. At local authority level, Fylde's overall rank is 235 out of 326 districts, placing it in the top third least deprived areas. Fylde is also at the top end of the scale in Lancashire, with the least

amount of deprivation of any kind and the least amount of hotspots of deprivation. Compared with the region and national average, Fylde is 102 places higher than the North West average and 36 places higher than the national average.

13. The mapping below shows that the LSOA within which the Site sits is in the mid to low region of overall deprivation (official grade in 2010 was 17,130 out of 32,482, where 1 is most deprived).

Figure 20.2: 2010 IMD rank mapping (image from www.http://opendatacommunities.org/)
Preston New Road



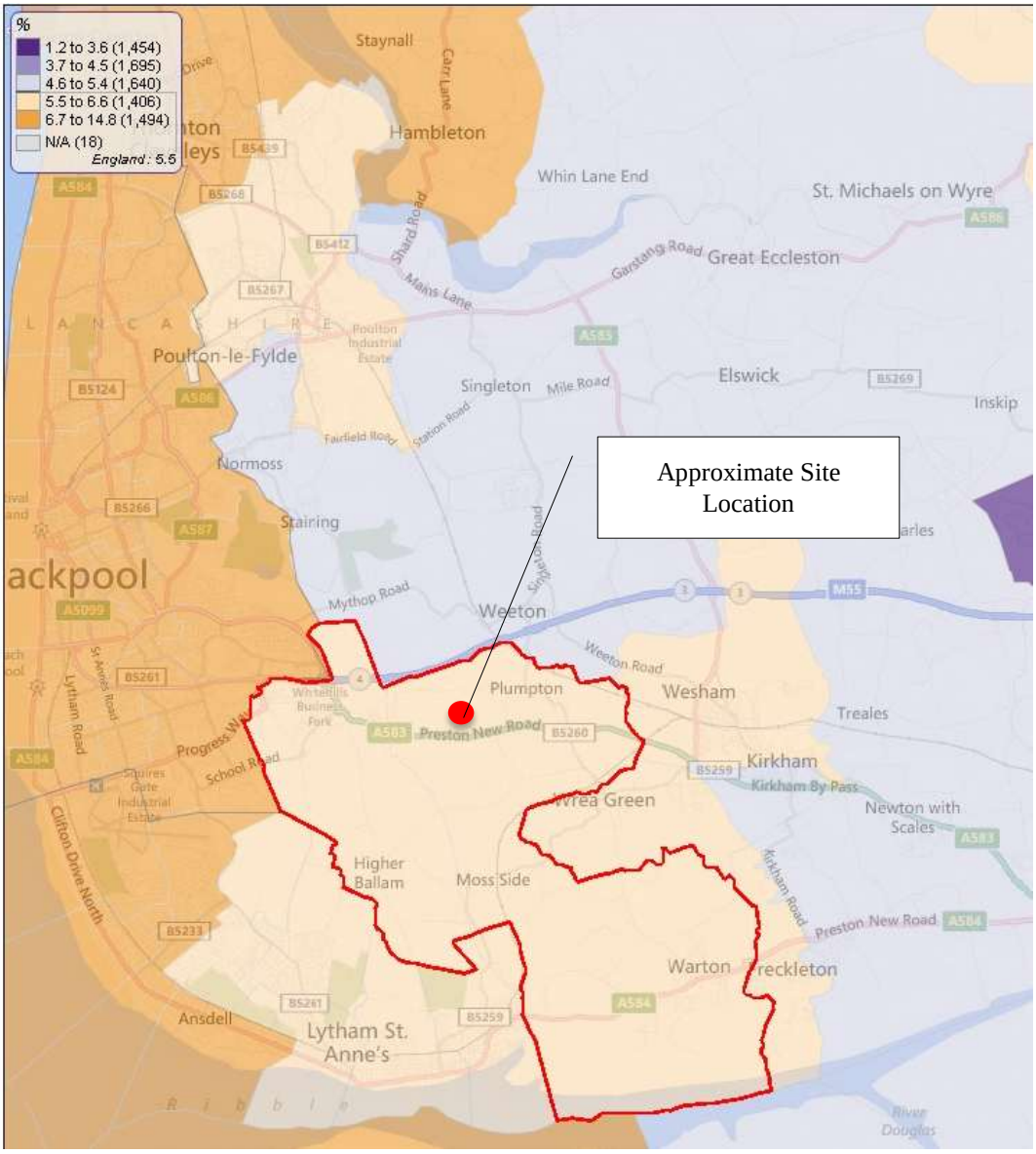
20.3.3 Health

14. The baseline health data for the Weeton and Westby Ward (in which the Site is located) shows that the ward has a relatively low proportion of its population that would describe themselves as being in bad or very bad health (6% compared with levels of 7.3 to 12.3% in parts of Blackpool) (see Figure 20.3) [451].

15. Life expectancies for both males and females at birth are similar to the average for England. Likewise the incidence of death from cancer, circulatory dieses, coronary heart disease, stroke and respiratory diseases do not differ, significantly, from the average for England[452]. This combined with relatively low levels of deprivation indicates that the general health and wellbeing of the local population is good.

[451] Public Health England. Local Health statistics for Selection: E05005205 - Warton and Westby Ward, Fylde, Lancashire.
[452] *Ibid.*

Figure 20.3: Percentage of people in bad or very bad health, 2011, at the Ward Level (Warton and Westby Ward).



©PHE – © Crown copyright and database rights 2012. Ordnance Survey 100020290 – ONS© Crown Copyright 2012 – Ward (2011)Estimates.

20.4 Health topics considered

16. The following health topics have been considered:

- Noise;
- Air quality;
- Water (surface and groundwater);
- Perception effects.
- Effects on community facilities and social networks; and
- Physical activity.

17. The ways in which these topics relate to health is set out in section 20.5 below.

18. Following a review of the proposals and the receptors present in the vicinity of the scheme, it has been concluded that there is no potential for health and wellbeing impacts to arise on the following and have not been considered further.

- **Effects on community facilities and social networks.** These have not been considered for the following reasons. Firstly, due to the small scale and temporary nature of the Project it will not result in a significant influx of new residents to the area that might have an impact on the availability of existing community facilities (e.g. doctor's surgeries). Secondly, the Project proposals will not have an impact on the ability of residents to access or use community facilities; and
- **Physical activity.** This has not been considered because the proposals are temporary and will not restrict or sever access to existing recreational or amenity facilities (e.g. public rights of way and playgrounds) that local residents may use for exercise and as part a healthy lifestyle. Likewise, the volume of traffic likely to be generated by Project is unlikely to deter cyclists or pedestrians from using the roads surrounding the Site.

20.5 Health issues

20.5.1 Noise

19. Noise impacts have been assessed in Chapter 16 and Appendix P of this ES.

Links to health and wellbeing

20. Direct health effects from noise are well established in terms of issues such as sleep disturbance and annoyance[453]. Associations have also been identified between prolonged noise exposure and cardiovascular effects as well as cognitive impairment of children at school.

21. In the case of cardiovascular effects[454] and cognitive impairment of children when at school[455], the evidence relates primarily to long term exposure to aviation noise and also road traffic noise, rather than temporary or construction noise. The noise effects from the Project are similar to those from a construction project comprising short to medium term exposure to varied levels of noise from construction activities and traffic. **There is no evidence to suggest that the type and level of exposure likely to result from the Project may be linked to cardiovascular effects or cognitive impairment.**

Summary of health effects from noise

22. The Site is located away from residential properties. The noise impacts of the Project have been assessed in the Noise Chapter (Chapter 16) which has concluded that **the Project will not have significant noise effects on the nearest residential properties.**

[453] Noise Policy Statement for England, Defra, March 2010. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69533/pb13750-noise-policy.pdf (last accessed 14/03/14).
[454] European Commission Research (2011) Scientists find links between stroke risk and road traffic noise. http://cordis.europa.eu/news/rcn/33064_en.html (last accessed 14/03/14).
[455] WHO Guidelines for Community Noise: A complete, authoritative guide on the effects of noise pollution on health 3. Adverse health effects of noise. http://whqlibdoc.who.int/hq/1999/a68672.pdf (last accessed 14/03/14).

Noise levels will be monitored so that Cuadrilla can manage operations to keep within the agreed noise limits.

23. No schools, community centres, places of worship or medical centres (including doctors, dentists etc.) were identified within 1km of the Site or along the route between the Site and the M55. **It is concluded that at these distances there is no risk of school children being adversely affected by noise from the Project.**

20.5.2 Air quality

24. Air quality impacts have been assessed in Chapter 6 and Appendix E of this ES.

Links to health and wellbeing

25. The ES provides an assessment of the likely significant effects on local air quality arising from the construction, operation and decommissioning of the Project, covering nitrogen dioxide (NO_2), fine particulate matter (PM_{10}), NORM, benzene and dust. The links between road traffic emissions and health are well established, with the main health damaging pollutants being particulate matter and NO_2[456].

26. PM_{10}, which is an important source of pollution with regard to health impacts, comprises atmospheric particles that are less than 10 µm in diameter. Road transport is a major source of PM_{10}, which is emitted from the combustion of vehicle fuels. Particulate matter maybe deposited in the lungs affecting lung function. [457]. Studies have also suggested that particulate pollution of various sizes may exacerbate pre-existing asthma[458].

27. The effects of road traffic related NO_2 on health are less well understood than the effects of PM_{10}, but it is thought to cause respiratory problems, with short term acute exposure having a greater adverse effect than a longer term exposure at lower concentrations[459].This is also supported by a research review undertaken by the Institute of Occupational Medicine (2004)[460].

28. Benzene is a common air pollutant which typically comes from vehicle emissions and the combustion of fuels, particularly gas used in the home for cooking and heating and the operation of petrol powered garden appliances like lawnmowers[461]. There is evidence that chronic exposure to benzene is linked to anaemia and leukaemia.

29. It is generally accepted that large particulate matter (dust) does not penetrate the lungs to cause respiratory health problems. It is particles in the PM2.5 – 10 range that are generally linked to health risks. However, dust can cause eye, nose and throat irritation

[456] *Ibid.*

[459] Douglas M, Thomson H, Jepson R, Hurley F, Higgins M, Muirie J, Gorman D (eds) Health Impact Assessment of Transport Initiatives: A Guide, NHS Health Scotland Edinburgh 2007. http://www.healthscotland.com/uploads/documents/5039-03686_NHSHIAGuideFinal1.pdf (last accessed 14/03/14).

[460] Searl A. 2004. A review of the acute and long term impacts of exposure to nitrogen dioxide in the United Kingdom. Institute of Occupational Medicine.http://www.iom-world.org/pubs/iom_tm0403.pdf (last accessed 14/03/14).

[461] Health Protection Agency (2007). Benzene Toxicological Overview. (page 3). http://www.hpa.org.uk/webc/hpawebfile/hpaweb_c/1194947391801

and lead to nuisance effects. There may also be health concerns if dust is made up from particles of heavy metals, asbestos and other pollutants[462].

Summary of health effects from air emissions

30. The predicted air quality emissions from the Project have been compared to Air Quality Objectives and Limit Values for the different pollutants likely to be emitted by the Project activities (Section 6.7 of the ES). These objectives and limit values are based on minimizing health effects as a result of acute or chronic exposure to potentially sensitive individuals.

31. As mentioned above dust from construction works and other activities that generate dust do not generally present a direct risk to health (i.e. inhalation or ingestion of dust). Given that the Site is located within an area of agricultural land and has not been subject to historical development **it is concluded that there is a negligible risk of contaminated dust being generated** during the construction of the well pad, access track, extended flow testing infrastructure, gas pipeline and the seismometer arrays.

32. Fugitive dust emissions can cause a nuisance and as a result be a source of annoyance for those affected. The risk to nearby receptors has been assessed. This assessment has concluded that there is a **negligible to low risk** of dust being created by the Project and it will not result in a significant effect. This is because there is sufficient distance between the Site and potentially sensitive receptors. Furthermore, the scale and duration of the Project activities (construction of the access track and well pad and decommissioning) will not be carried out over a long period of time (less than 2 months for each activity).

33. Emissions from fixed point sources (e.g. generators used on Site) **do not present a significant source of air pollution**. This is because the atmospheric emissions are within the limits or objectives set to protect air quality and health.

34. The Air Quality chapter of the ES (Chapter 6) includes a forecast and assessment of the potential quantity and effects of NORM in the form of gas (specifically radon) that may be present in the gas that is burnt in the flare stacks. These predictions have been compared to an annual dose limit of 300 microSv/yr for a single source[463]. The predicted emissions from the combustion of gas in the flares is 0.3 microSy/yr. This is one thousand times lower than ICRP limit. Therefore it is concluded that the levels of NORM emitted to the atmosphere by the Project **do not present significant risk to health**.

35. The flares that will be used to burn gas generated during initial flow testing are the main source of emissions to air associated with the Project. The concentrations and distribution of pollutants (specifically NO_2 and benzene) have been modelled so that the effect on air quality, and indirectly health, can be predicted at potentially sensitive receptor locations around the Site (residential properties). The air quality assessment concludes that the levels of NO_2 and benzene are well within the regulatory limits and therefore **do not present significant risk to health**.

36. In summary the air quality effects from the Project have been assessed for dust, NO_2, PM10, PM2.5, benzene and NORM. The assessment for all of these parameters has concluded that the emissions from the Project **will not be significant**.

[462] Holman et al (2014). IAQM Guidance on the assessment of dust from demolition and construction, Institute of Air Quality Management, London. http://iaqm.co.uk/wp-content/uploads/guidance/iaqm_guidance_report_draft1.4.pdf (last accessed 14/03/14).
[463] ICRP (1993) Board Statement on the 1990 Recommendations of the ICRP. Doc NRPB 4 (1)

20.5.3 Surface water and groundwater

37. Impacts of the Project on surface and groundwater quality have been assessed in Chapter 11 of this ES.

Links to Health and Wellbeing

38. For there to be a water-related health issue from the Project there needs to be a plausible pollutant pathway linking a potential source of contamination to a receptor that could be affected. A full description of the potential sources of pollution is provided within Chapter 11 of the ES. The potential exposure routes which could affect health are either via ingestion in drinking water or food that comes into contact with polluted water or contact with the skin.

39. In England around 99% of drinking water is provided by water companies whose supplies are monitored as it leaves the water treatment works and random samples in consumers' homes. These samples are compared against drinking water standards[464].

Summary of health effects relating to surface water and groundwater

40. As part of the analysis reported in Chapter 11 of the ES a review of potable water abstractions was undertaken. There are no surface or groundwater abstractions in the vicinity of the surface or below ground works that are used for potable water. This is based on a review of abstraction points registered with the EA and local authorities. Potable water within the vicinity of the Site is provided by United Utilities by their mains potable water supply.

41. The design of the wells, including multiple layers of containment through the shallow sections of the wells, and the characteristics of the geology below the Site means that there are no plausible pollutant pathways between the well and drinking water supplies. The well pad has also been designed to provide the level of containment required by the EA's Pollution Prevention Guidelines[465]. This, in combination with the implementation of the Environmental Operating Standards (See Appendix E), will minimise the risk of surface spills of potentially polluting materials affecting surface watercourses, soils, crops and animals.

42. For the reasons stated above it is concluded that the risk of a pollutant linkage being created that could then **impact on human health is negligible**.

20.5.4 Perception effects

43. This section considers the effects on health and wellbeing arising from public perceptions of the potential health impacts arising from oil and gas exploration and production, including hydraulic fracturing.

Links to health and wellbeing

44. Health effects may be exacerbated or triggered by the perceptions that people have about the Project and how they believe they may be affected by it rather than the likelihood of their exposure to it. This concern can affect mental, physical and emotional wellbeing[466].

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[464] 1998 European Drinking Water Directive.
[465] Pollution Prevention Guidance Notes 1 and 3.
[466] Luria, Parkins and Lyons (2009) 'Health Risk Perception and Environmental Problems: Findings from ten case studies in the North West of England'. Liverpool JMU Centre for Public

These could be in the form of health effects caused by changes in people's behaviour or as a result of increased anxiety from the perceived effects of the Project. In a review of case studies looking into health risk perception in the North West of England[467] it was concluded that fears can be allayed through:

- Information campaigns;
- Adequate and appropriate communication activities;
- Providing evidence on known risks;
- Making sure information provided is accurate, consistent and provided in clear non-technical language; and
- Ongoing programmes to monitor environmental factors that may be perceived to be a health risk.

Summary of health effects relating to Perception Effects

- The key health concerns raised by residents during the various consultation events prior to submission of the various planning applications are:
- Risk from radioactive materials;
- Risk from flammable gases;
- Risks from the presence of potentially hazardous materials at the Site;
- Risk from emissions to air (including flaring);
- Risk from induced seismicity;
- Risk of pollution to ground and surface water
- Road safety and traffic concerns; and
- Concerns regarding potential sensitive groups or individuals (e.g. children or people with pre-existing health conditions).

45. Concerns about the issues and receptors described above contribute towards perceptions in the local community relating to the perceived environmental hazard that the Project poses. In order to respond to this Cuadrilla have undertaken or will undertake the following:

- Provided information about shale gas exploration and the processes of drilling, hydraulically fracturing and flow testing wells;
- Undertaken early engagement with the wider community to allow them to communicate their concerns, to feed into the development of an Environmental Risk Assessment (ERA) and then the development of the planning applications for Roseacre Wood and Preston New Road;
- Provided evidence on known risks either as part of the ERA, the ES, othere documentation supporting the planning applications and applications for Environmental Permits;
- Develop a programme of environmental monitoring during the exploration works and mechanism to publicise the results and provide affected parties with a means to raise concerns and communicate with Cuadrilla throughout the life of the Project; and

Health & Health Protection Agency North West Office. http://www.cph.org.uk/wp-content/uploads/2012/08/health-risk-perception-and-environmental-problems--summary-report.pdf

[467] *Ibid.*

- Development of a framework for environmental management of the site, through implementation of a comprehensive Environmental Operating Standards (see Appendix E of this ES).

46. These are in line with the key points for consideration identified in the Health Protection Agency's summary report on Health Risk Perception and Environmental Problems[468].

20.5.5 Responses to issues raised by Public Health England

47. In their response to the Preston New Road Scoping Report submitted to Lancashire County Council on 4th February 2014, and used as a basis for consultation, PHE identified a range of health related concerns and requested that a section within the ES should set out how these concerns have been taken into account in the EIA process. PHE also requested that a section of the ES (this chapter) should indicate where public health related issues have been covered by the different sections of the ES (e.g. air quality, socio-economics and community and hydrogeology and ground gases).

48. PHE raised the following points (see Appendix D for full details).

- Identification of where within the ES receptors that could be affected by health impacts are identified;
- Highlighting where, within the ES, the impacts from construction and decommissioning have been assessed;
- How potential health impacts relating to emissions to air and water have been assessed and where in the ES these are documented;
- Specific issues concerning emissions to air;
- Specific issues concerning emissions to water;
- How potential health issues relating to land quality and contamination have been assessed;
- How potential health issues relating to waste management have been assessed;
- Other health related issues such as the management of pollution incidents, the regulation of the Site and how potential public stress and anxiety have been taken into account by the Project; and
- The organisations that have been consulted regarding health related issues during the EIA process.

49. A detailed signposting document responding to the points above can be found in Appendix T1.

[468] Luria, Parkins and Lyons (2009) 'Health Risk Perception and Environmental Problems: Findings from ten case studies in the North West of England'. Liverpool JMU Centre for Public Health & Health Protection Agency North West Office. http://www.cph.org.uk/wp-content/uploads/2012/08/health-risk-perception-and-environmental-problems--summary-report.pdf

21 Overview of cumulative and in combination effects

1. The cumulative effects associated with individual technical topic areas covered by the EIA are dealt with by each of the relevant chapters. The effects of the Project, in combination with the exploration project also proposed for the site at Roseacre Wood have also been assessed. A review of currently adopted land use plans and emerging local plans has also been undertaken to identify significant new development in the vicinity of the Site or along the key access routes.

21.1 Cumulative effects

2. Currently, there are no large planning applications (either granted or in determination) for development in the vicinity of the Site or nearby settlements. As a consequence, there is limited scope for the Project to result in cumulative effects with other developments. The other developments that are within 10km of the Site are not deemed likely to alter the magnitude of the effects assessed in this ES and create any new or additional significant effects. A review of the committed development and development currently in determination can be found in Appendix T.

3. Cuadrilla also intend to carry out well testing activities at two sites, Grange Hill and Becconsall as described in Chapter 5. The monitoring works will not have a cumulative effect with either this Project or Roseacre Wood because they are very minor works and are sufficiently distant from each other that they do not impact on the same sections or road (to get access to the M55) or communities.

4. The conclusion that can be drawn from these assessments is that the potential for the Project to result in significant cumulative effects is negligible (i.e. the Projects, when combined do not result in new significant effects that would occur if only one of the Projects were implemented). This is due to the following factors:

   - The separation distance between the two exploration sites is large enough that air quality, heritage, hydrogeological, seismic, water resources noise, visual and general disturbance impacts will not result in a cumulative effect. Likewise, the sites themselves are also separated enough from other development sites that these potential cumulative effects can be avoided;
   - There is sufficient separation between the two sites so that their operations will not have a combined effect on the same settlements. For example vehicles will use a different junction from the M55 and different local roads to access the Roseacre Wood site compared to those accessing the Preston New Road site; and
   - The different activities that will be carried out at the two sites will be synchronised so that, for example, when hydraulic fracturing is occurring at one site a different activity, such as drilling, is occurring at the other site. This will further reduce the risk of any cumulative effects from occurring.
   - The rate and quantity of flowback fluid generated from both this Site and Roseacre Wood can be managed using the mitigation measures set out in Chapter 17 (section 17.9).

21.2 In combination effects

5. Some of the impacts from the Project result in effects on more than one of the EIA topics. This includes:

- Air quality impacts on human beings and ecological receptors (nationally and internationally designated sites);
- Visual impacts on the setting of heritage sites and assets (e.g. Listed Buildings and Registered Parks and Gardens);
- Noise impacts on residential and ecological receptors; and
- Lighting impacts on residential and ecological receptors.

6. Due to the distance between the Sites, the dispersed nature of residential properties, topography and landscape features no in-combination effects are predicted.

21.3 Conclusion

7. The EIA process that is documented in this ES has identified the foreseeable impacts arising from the Project, and assessed whether or not they are likely to result in significant effects. Where significant effects have been predicted measures to avoid or mitigate these effects, so that where possible they are no longer significant, have been identified. Additional mitigation measures to further reduce the magnitude of potential impacts have also been identified within the assessment.

8. As a consequence of taking these measures the only residual significant effects (following the identification of mitigation measures) are the:

- temporary visual effects from the use of the taller pieces of equipment (e.g. the drilling rig and workover rig used during hydraulic fracturing);
- temporary sky glow and building luminance effects from night time exploration activities; and
- the short term use of the available waste treatment capacity, for flowback fluid, within 100 miles the Sites.

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