Permit

Waste Management Plan			
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3	2.4 / 3.4	Updated text in section 2.4 and 3.4	September 2014	Environment Engineer
4	2.2.4 /4.3/ 10	Updated text	September 2014	Environment Engineer
5	2.3/ 2.2.4/ 3.9.3/ 4.5/ 10	New section 3.9.3	October 2014	Environment Engineer
6	2.2.2/ 2.3	Updated text to include mud gas separator/ and updated to powder polyacrylamide	October 2014	Environment Engineer
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Environmental Permit documentation is controlled by internal Cuadrilla Procedures. Submitted documentation to external agencies represents the current version of the document.

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1.0 Introduction

1.1 Background

Cuadrilla Bowland Limited (hereinafter “Cuadrilla”) is exploring for natural gas and intends to carry out temporary exploratory drilling, hydraulic fracturing and flow testing to identify and quantify the presence of natural gas trapped in the sub-surface reservoir rock.

Cuadrilla is specifically exploring for natural gas trapped in the Bowland Shale and Hodder rock formation, deep beneath Lancashire. The Bowland Shale and Hodder formation is referred to in this plan as the ’target formation’. The planned exploration operations include site construction, drilling, hydraulic fracturing, initial flow testing followed by extended flow testing and possible decommissioning of up to four exploration wells on a single pad. Each of the exploration wells will consist of an initial vertical borehole drilled from surface into the subsurface target formation, followed by deviation to a horizontal wellbore section.

Cuadrilla has received planning permission from Lancashire County Council (LCC) for the development of temporary exploratory drilling and testing facility. The planning application was supported by an Environmental Statement (ES).

1.2 Site location

The 1.55 ha well pad is situated at:

Preston New Road (PNR) Exploration Site

Preston New Road

Fylde

Lancashire

The national grid reference for the Site is E337408, N432744.

The surface site boundary (HSE-Permit-INS-PNR-010) and waste facility conceptual model (HSE-Permit-INS-PNR-002g) illustrate the extent of the proposed activities.

1.3 Scope of waste management plan (WMP)

Cuadrilla’s waste management plan has been developed to meet the requirements of Article 4 and 5 of the Mining Waste Directive 2006/21/EC (the ’Mining Waste Directive’):

1. *Pursuant to regulations implementing Article 4 of the Mining Waste Directive Cuadrilla is required to take the necessary measures to ensure that extractive waste is managed in a controlled manner without endangering human health or harming the environment.*
2. *Pursuant to regulations implementing Article 5 of the Mining Waste Directive Cuadrilla is required to prepare a Waste Management Plan for the minimisation, treatment; recovery and disposal of extractive waste, taking account of the principle of sustainable development.*

The process of exploring for natural gas will generate extractive waste which falls under the scope of the Mining Waste Directive and, as a result, an environmental permit is required under the Environmental Permitting (England and Wales) Regulations 2018 (as amended) (the ‘EPR’).

The plan is required to be updated at least every five years, or whenever a substantial change to the mining waste operation or the waste deposited occurs, in accordance with Article 5 (4) of the Mining Waste Directive.

2.0 Site facility classification and operations

2.1 Description of operations

The management of extractive waste at the site shall constitute a mining waste operation (under the EPR). The operation shall include two types of mining waste facilities (as defined in the EPR) as follows:

1. In respect of each hydraulically fractured well, a below ground non-hazardous mining waste facility for the accumulation of injected hydraulic fracturing fluid which has not returned back from the underground target formation; and
2. A single above ground hazardous mining waste facility surrounding the well heads (HSE-Permit- INS-PNR-011) being the area designated for the temporary deposit and accumulation of hazardous waste in storage containers as the wells are successively drilled.

No other surface area of the site will be used for the deposit, accumulation or storage of extractive waste beyond the relevant time period specified in Article 3(15) of the Mining Waste Directive.

The mining waste operation does not include the re-injection underground of waste. Flowback fluid will be captured and re-used wherever possible for re-injection as part of the hydraulic fracturing process.

The surface boundary of the mining waste operation is illustrated in HSE-Permit-INS-PNR-010 with a further surface hazardous mining waste facility drawing, HSE-Permit-INS-PNR-011 showing the position of the hazardous mining waste facility relative to the wells. A 2D conceptual model in HSE-Permit-INS-PNR-002g estimates the extent of the below ground non-hazardous mining waste facility for each well drilled and hydraulically fractured.

Table 1 below sets out the assessment and classification of the extractive waste that will occur during drilling, hydraulic fracturing and testing of the wells.

Table 1: Extractive Waste Stream Classification & Assessment

Waste stream	Assessment	Classification
Water based drilling mud (WBM) and cuttings	Returned WBM drilling fluids (commonly called muds) and cuttings will be temporarily accumulated on site and are waste in accordance with the Waste Framework Directive 2008/98/EC (the "revised Waste Framework Directive"). The composition has been assessed as non-hazardous.	Waste operation (M4)
Spoiled low toxicity oil based drilling mud (LTOBM) and cuttings containing LTOBM	LTOBM is intended to be sent offsite for re-use. Any spoiled LTOBM that cannot be dealt with in this manner will be classed as hazardous waste and sent to the hazardous mining waste facility. Any LTOBM lost to the target formation will be classed as hazardous waste. Returned drilling cuttings contaminated with LTOBM will be temporarily accumulated on site and are a waste in accordance with the revised Waste Framework Directive. The composition has been assessed as hazardous.	Waste facility (M2)
Spacer fluid	Returned spacer fluid will be temporarily accumulated on site. The fluid is a waste in accordance with the revised Waste Framework Directive. The composition has been assessed as non-hazardous in the case of WBM, and hazardous in the case of LTOBM.	Waste operation (M4) (or waste facility (M2) if LTOBM has been used)

Flowback fluid	Flowback fluid (exiting the well during the hydraulic fracturing stage) will be reused wherever possible. At the conclusion of the hydraulic fracturing stage, it will be temporarily accumulated on site as a waste. Flowback fluid (exiting the well during the post-hydraulic fracturing stages) will be temporarily accumulated on site as a waste. The composition has been assessed as non-hazardous The waste stream is also defined as radioactive waste in accordance with the EPR owing to the likely presence of naturally occurring radioactive material (NORM) at a concentration >1 Becquerel per litre (>1Bq/l).	Waste operation (M4)
Scale	Returned flowback fluid containing soluble minerals can potentially deposit scale within pipework and on-site equipment resulting in an accumulation of waste. Scale, if deposited, will be periodically removed as part of routine maintenance and will be temporarily stored on site. The composition of the scale will need to be determined from testing if the waste actually occurs. In case it should be found to contain any dangerous substances above the relevant threshold, scale has been classified as a hazardous waste stream as a precaution. There is a possibility that the waste stream will exhibit radioactivity and hence also be defined as radioactive waste in accordance with the EPR owing to the likely presence of naturally occurring radioactive material (NORM).	Waste facility (M2)
Sand	Returned sand temporarily accumulated on site is a waste in accordance with the revised Waste Framework Directive. The composition has been assessed as non-hazardous. There is a small possibility that the waste stream will exhibit radioactivity and hence also be defined as a solid radioactive waste in accordance with the EPR owing to the likely presence of naturally occurring radioactive material (NORM)	Waste operation (M4)
Natural gas	Surplus natural gas temporarily flared on site for disposal purposes is a waste in accordance with the revised Waste Framework Directive. The natural gas will be combusted within the flare stacks without being deposited or accumulated on site. The composition has been assessed as hazardous (highly flammable).	Waste operation (M4)
Retained hydraulic fracturing fluid	Once the hydraulic fracturing fluid retained in the target formation serves no further operational purpose it will be a waste in accordance with the revised Waste Framework Directive. The composition has been assessed as non-hazardous.	Waste facility (M3)

The activities which generate extractive waste are divided into multiple phases. The following section briefly describes the lifecycle of the exploration operation which will, at certain points, generate extractive waste.

2.2 Well pad construction and drilling

2.2.1 Well pad

The pad construction is consistent across the entire area of the site extending beyond the hazardous mining waste facility area as described below and in Chapter 4 of the Environment Statement. The site pad construction required top soil to be stripped and stored in a mound adjacent to the pad. The top soil will be reinstated during the site restoration phase of the project.

- The pad comprises of an area of approx. 1.55 hectares with a minimum depth of 300mm clean, compacted aggregate laid on a high density polyethylene (HDPE) membrane and geotextile layer with protective felt inter-layers. The top of the stone pad will lay at a level 50mm lower than the top of the outer perimeter ditch bund, thus providing 50mm air freeboard (creating a bath tub effect).
- A 1.0m deep, minimum 2.3m wide open trapezoidal drainage ditch will be constructed around part of the well pad perimeter to collect surface water and any spillages. The ditch will be isolated with double isolation valve preventing discharge to surface waters.

Construction of the well pad incorporating a HDPE membrane was designed to prevent pathways from the hazardous mining waste facility to soil, surface water and groundwater receptors. On completion of the well pad an integrity test of the membrane was conducted by a competent contractor. Any identified punctures will be repaired. Once a continuous seal across the pad has been validated by the competent contractor, the well pad will be commissioned for operations.

Surface water run-off attenuation will be provided by a perimeter drainage ditch system. Discharge of surface pad runoff water will be conducted in accordance with the prevailing permit conditions. A double isolation valve has been installed on the 150mm diameter storm water outlet pipe which outfalls to Carr Bridge Brook, north of the site. This outlet pipe will be restricted in diameter (using a throttle pipe diameter; an orifice plate stopper or similar) such that storm water runoff from the well pad is reduced to below greenfield rates.

During the construction process a construction quality assurance (CQA) validation report was produced to show the well pad was built to the correct standard and design specification as outlined in the detailed design. As an outline the CQA validation report covers the following elements:

1. Sub base;
2. Containment barriers;
3. Cellar;
4. Water collection/lagoon design;
5. Working surface; and
6. Monitoring systems (groundwater boreholes)

A series of groundwater boreholes have been located around the edge of the well pad to establish baseline groundwater quality conditions within the shallow geology. Drawings of the pad are detailed within HSE-Permit-INS-PNR-002a. The surface water discharge will flow through a 150mm diameter storm drain into Carr Bridge Brook to the north of the site.

2.2.2 Exploration Drilling

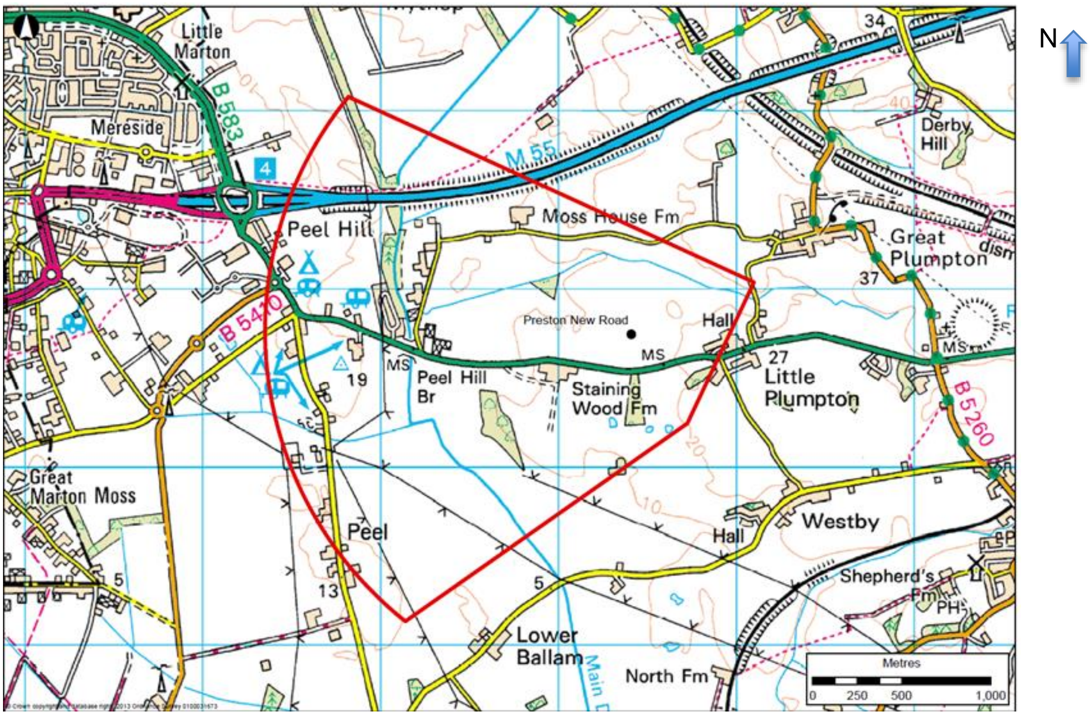
Up to four wells shall be drilled at the PNR well pad. Before each well is drilled, a WR11 notice of intent (Water Resources Act 1991) will be submitted to the Environment Agency serving notice of our intention to drill for minerals and setting out our methodology for protecting groundwater.

The wellhead cellars will be installed to accommodate the four wells at the site. The cellars will be constructed as an integral part of the site containment system and are subject to CQA assessment and validation.

Following initial appraisal it may be decided to drill laterals off the vertical section of an existing well rather than drilling up to four independent vertical sections. At no point will more than 4 wells be drilled at site in total under this current waste management plan and planning permission. This approach, if adopted, will enable the hydraulic fracturing and flow testing of multiple prospective horizons within the target formation while reducing the quantities of extractive and other wastes generated. The drilling of any such sidetracks will be separately detailed in an additional WR11 notice of intent in advance of the activity commencing. Such a sidetrack, if drilled will use an existing wellbore (e.g. PNR1z or PNR2) as a donor well. A bridge plug will be placed below the level at which the new sidetrack is to be drilled. Once drilling of a sidetrack has commenced, it progresses in the same way as the drilling of any other well. The existing waste management procedures will be utilised to correctly manage any extractive wastes arising.

All of the wells shall target natural gas reserves within the target formation. Figure 2 shows (edged red) the geographical area within which sub surface works will take place.

Figure 2: Directional area for subsurface works



The vertical pilot section of the first well to be drilled provided information to identify the most prospective zones for the horizontal laterals.

Each horizontal wellbore will be completed in preparation for multi-stage hydraulic fracturing, flow testing and extended flow testing.

Drilling these wells will produce a range of extractive waste in the form of drilling muds, drill cuttings, cement, and spacer fluid.

The extractive waste stream of drilling muds and cuttings is a result of an active mud management system whereby drilling mud is circulated down through the drill string and back up the wellbore and utilised for the following operational requirements:

- Drilled cuttings lifting capability;
- Providing primary well control via sufficient hydrostatic pressure to at least balance formation pressures;
- Stabilising the borehole;

- Providing lubricity to allow the horizontal targets to be reached with the drill string; and
- Cooling of the drill bit.

A mud gas separator is located on site as a potential source of venting during drilling. The safety critical equipment controls ’kicks’ (the buildup of gas in drilling fluids) in the well to separate gas from drilling fluids. Surface lines can be vented for maintenance if required.

A competent waste contractor will be appointed to manage the storage and offsite disposal arrangements for returning hazardous waste drill cuttings for each well. Drill cuttings contaminated with low toxicity oil based muds (LTOBM) will be temporarily stored in steel containers placed on the well pad, before being transported off-site for disposal at a permitted waste treatment facility. The contractor will be responsible for visual inspection of waste storage containers' integrity, and maintaining the storage containers to prevent spillages. Once drilling operations are completed, all drill cuttings are transported offsite for permanent disposal with no drill cuttings retained at site.

The drilling fluid plan is finalised prior to the start of each period of drilling operations. Table 2 provides an overview list of the drilling fluid additives which will be considered for use in specific wellbore sections depending on the formation and drilling conditions encountered. Each of these has been approved for use in writing by the Environment Agency in accordance with Table S1.1, activity A2 of the environmental permit (EPR/AB3101MW). A detailed breakdown of the available drilling fluid additives is appended in Appendix A.

Only drilling fluids which are non-hazardous to groundwater (water based/salt saturated polymer based muds (WBMs)) will be used in the upper section of the borehole when in contact with groundwater receptors including aquifers. LTOBM has significant operational advantages over WBM formulations, including greater lubricity and less interaction with the formations being drilled, resulting in reduced borehole washout and improved hole stability. Where reasonably practicable WBMs will be used, but where the use of LTOBM would be safer, result in better well integrity or less chance of loss of drilling muds to formation, LTOBM may be used instead. The decision to use LTOBM for one or more of those reasons will be made during drilling operations. Prior to the spudding of the first well, recent results of drilling Bowland Shale with LTOBM by other operators was reviewed to the extent information was available, and weighed against the alternative, WBM. If actual results from drilling the pilot hole (vertical hole) indicate a change from WBM is necessary, the fluid system will be changed for further drilling. This will be based on a number of parameters which will include borehole washout and uniformity, borehole stability as demonstrated by tripping, over-pull and reaming requirements, relative time spent maintaining the borehole versus drilling rates and torque measured during drilling.

Records of the decisions made will be documented in accordance with Cuadrilla’s procedural requirements. Any decision to use LTOBM will be fully documented within our internal management system and available to the Environment Agency upon request or inspection. However, LTOBM will not be used prior to casing and cementing off all potential groundwater receptors. At PNR, this translates to the use of LTOBM only after the surface casing has been set and cemented to isolate the Sherwood Sandstone formation.

Table 2: Summary and indicative drilling fluid options (to be finalised as part of the WR11 submission)

Indicative hole size (inches)	**Drilling fluid (Mud) options** ***(not in order of preference)***
24"-26"	• Polymer/NaCl+ water-based mud • Bentonite 'spud mud' • Air Drilled
16"-17.5"	• Continue with polymer/NaCl+ water-based mud • Continue with bentonite
12 ¼"	• Continue with polymer/NaCl+ water-based mud • LTOBM contingency
8 ½"	• Continue with previous polymer mud or replace with KCl-polymer • LTOBM contingency
8 ½" sidetrack	• Continue with previous polymer mud or replace with KCl-polymer • LTOBM contingency
6" Lateral	• KCl-Polymer mud with lubricant • LTOBM contingency
Production (cased) hole	• Completion fluid: fresh water + corrosion inhibitor and oxygen scavenger

2.2.3 Cementing

During the process of drilling, steel casing is cemented in the wellbore in a series of stages to protect groundwater receptors and maintain well integrity. Spacer fluid (to separate the mud from the cement) will be injected prior to cement being pumped in slurry form down the inside of the casing. The cement slurry rises up through the annular space between the drilled hole and the casing, and once in place sets hard. The spacer fluid and cement slurry displaces the mud both from the casing and the borehole, returning residual drilling muds to the surface. The process of replacing the residual drilling muds with cement slurry is designed to create a complete cement sheath for well integrity. The returning residual drilling muds (both WBM and LTOBM) and spacer fluid will wherever possible be reused or otherwise sent off site for disposal together with any excess cement slurry via an authorised waste carrier to a permitted waste disposal facility.

Table 3 summarises the cementing barrier plan illustrated in HSE-Permit-INS-PNR-002e. Cement slurry will be laboratory-tested as per American Petroleum Institute recommended practice prior to field application.

Table 3: Indicative well barrier and verification summary (to be finalised as part of the WR11 submission)

Casing (or Liner) type	Casing OD/hole size (inches)	Proposed low permeability strata set into	Proposed set depth (m MD)	Cement details	Purpose of casing/liner and cement barriers	Verification
Shallow conductor	36 – 42 casing / augered hole	Superficials	10 – 30	Grouted in place using Portland cement and solid admixes as shallow soils may require.	Provide structural support against weak unconsolidated soils. Protect shallow groundwater from well fluids during deeper drilling. Provide a permanent seal across the superficial deposits.	Confirmation of no loss of mud circulation upon drilling out the 30" shoe.[*] Applied cement volume per design and returns to surface as expected
	28 – 30 casing / up to 36 hole	Mercia Mudstone Group	50 – 70			
Deep conductor	18 $^{5}/_{8}$ – 20 casing / 24 – 26 hole	Mercia Mudstone Group	230 – 270	Light-weight/high-strength lead cement slurry with standard density tail cement.	Protect shallow groundwater from well fluids during drilling. Provide a permanent seal across the Mercia Mudstone.	Applied cement volume per design and returns to surface as expected. Pressure testing and FIT testing.
Surface casing	13$^{3}/_{8}$ casing / 16 – 17.5 hole	Manchester Marls Formation	1,150 – 1,250	Light-weight/high-strength lead cement slurry with standard density tail cement; specifications tailored to cementing across Sherwood Sandstone.	Protect the Sherwood Sandstone from well fluids during deeper drilling. Prevent fluids migration into Sherwood Sandstone from underlying units (for example, the Collyhurst Sandstone).	Applied cement volume per design and returns to surface as expected. Pressure testing and FIT testing. Wireline logging for monitoring purposes.
Intermediate casing	9 $^{5}/_{8}$ casing / 12.25 hole	Upper Bowland Shale	1,575 – 2,000	Gas blocking cement from base of 9 $^{5}/_{8}$" casing and high strength/ light weight cement up above the base of the 13 $^{3}/_{8}$" shoe. ECP installed close to 13 $^{3}/_{8}$" shoe.	Casing across Collyhurst Sandstone and Millstone Grit for well control purposes. Provides additional barrier between Sherwood Sandstone and well fluids.	Applied cement volume per design and top of cement is within surface casing. Pressure testing and FIT testing. LOT / XLOT testing. Wireline logging for verification purposes.
Production liner and tie-back[+]	7 casing / 8.5 hole	Target formation	2.300 – 3,600[+]	High resilience / high flexural strength cement designed to withstand the	Part of primary barrier preventing uncontrolled release of well fluids to adjacent	Applied cement volume per design and top of cement is above hydrocarbon-

Casing (or Liner) type	Casing OD/hole size (inches)	Proposed low permeability strata set into	Proposed set depth (m MD)	Cement details	Purpose of casing/liner and cement barriers	Verification
				hydraulic fracturing pressure cycles.	formations. Casing string for conducting hydraulic fracturing.	bearing zones to be isolated. Pressure testing and FIT testing. Wireline logging for verification purposes.
Production liner	4 ½ casing / 6 hole	Target formation	3,300 – 4,700^{+}	High resilience / high flexural strength cement designed to withstand the hydraulic fracturing pressure and perforations cycles.	Provides isolation within the lateral section to be hydraulically fractured.	Applied cement volume per design and top of cement provides adequate coverage. Pressure testing and FIT testing. Wireline logging for verification purposes.

2.2.4 Integrity testing

Pressure testing, formation integrity testing (FIT), and/or wireline logging (such as cement bond logs (CBL)) will be used to confirm cementation integrity, or identify anomalies from drilling muds if present, to verify that the integrity of the well system, as described in Table 3, is constructed and maintained during the exploration activities. This includes verification and pressure monitoring prior to and during hydraulic fracturing and flow testing operations. The process of integrity testing does not create extractive waste but provides assurance that the construction of the wellbore is sound, preventing pathways to receptors.

Hydraulic tests will be conducted on each drilled-out casing or liner shoe, once 1-3m of new formation has been drilled, to quality-control the cement job and verify zonal isolation around a casing shoe. This is a pressure test against the exposed new formation below a casing shoe achieved by pumping drilling fluid into the wellbore with a closed blowout preventer (BOP) to obtain the needed pressure at a low pump rate. Simultaneously the pumped volume and/or time are recorded during the injection and fall-off. The test takes three forms:

a) FIT: the test is terminated as soon as the specified pressure for a set equivalent mud weight (EMW) has been achieved, or as soon as formation breakdown occurs. The EMW specified is for the purpose of demonstrating the pressure integrity that will provide the necessary well control kick tolerance while drilling the next hole section.

b) Leak-off Test (LOT), approximately 1-2m^3: the leak-off pressure is found by identifying when the pressure starts to deviate away from its trend-line, and formation breakdown has been reached. The test involves initiating a very short, small fracture. The pumps are stopped immediately and the subsequent stabilised pressure establishes the maximum pressure that the borehole can be subjected to for kick tolerance calculations in the next hole section.

c) Extended Leak-off Test ("XLOT") approximately 5-10m^3: LOT results do not accurately represent the far-field stress or the fracture gradient. Consequently, extended LOT or XLOT (sometimes termed ELOT) will be used to extend a small fracture into the area controlled by the far-field stress. This requires a longer pump time and larger volume of fluid to be pumped to generate a longer fracture, and the recorded pressure decline data allows the calculation of the least principle formation stress. Volumes and rates to be used for the test would be determined at the stage of detailed programming.

Results of the integrity test will be recorded in line with Cuadrilla's internal processes and procedures.

Throughout the life of each well, the three annuli A, B and C are monitored using a digital gauge or equivalent method to download readings on annuli pressure. The frequency of monitoring will be dictated by the data being downloaded ranging from potentially daily to quarterly downloads.

2.3 Hydraulic fracturing

In order to release natural gas from the extremely low permeability target formation and allow it to flow towards the well, hydraulic fracturing must be undertaken. High volume hydraulic fracturing in shales is a proven technique to enable maximum gas production from an individual well, thus reducing the number of individual wells needed to be drilled to achieve the equivalent natural gas volume.

A steel well casing in the horizontal well may be installed with sleeved ports cemented in position which, when opened, allow the hydraulic fracturing fluid to enter the surrounding target formation. The ports are operated mechanically during fracturing so that only one section of a well is hydraulically fractured at any one time. Alternatively, the well casing may be installed as a solid steel tube and cemented in position. The perforations through the casing and into the target formation can be created in one of several ways, including the use of small shaped explosive charges or high pressure fluid jetting. These perforations typically penetrate less than 1m into the target formation and form an entry point for the hydraulic fracture fluid which subsequently generates the fractures.

Before undertaking the first hydraulic fracturing stage in each lateral well, a pilot hydraulic fracturing stage or 'mini-fracture' will be performed. This involves pumping smaller volumes of fracturing fluid (without proppant) into the well. We will also perform this procedure if we assess that there is a need to re-evaluate the injection pressure required to generate fractures in the target formation during the subsequent main hydraulic fracturing stages, or where otherwise required by the traffic light system for controlling induced seismicity with which we are required by OGA to comply with. The fracturing schedule will be modified as necessary to take account of the data gathered in the mini fracture. For example, if the observed pressure is higher or lower than expected, the injection rate may be modified, or the volume of sand and/or water altered to suit.

Once the fracturing schedule is finalised (but continually reviewed), the first stage is fractured with fluids injected into the formation at high pressure to overcome rock strength and pressures acting on the rock deep underground in order to create very small fractures in the rock. At the same time a proppant (sand) is injected into the induced and pre-existing fractures. The fractures connect the pore spaces and existing fracture networks of the target formation to the well. This creates a fracture network generally perpendicular to the horizontal well.

This process is carried out in a number of steps or stages generally starting at the furthest end of the horizontal section of the well and working back along its length towards the vertical section of the well. However, operational optimisation may alter the sequencing of stages. Where necessary, a well may be re-entered to optimise previous fractures created or to complete a fracture programme which may have been delayed or changed due to operational sequencing. Either way the re-entering of the well will be in accordance with the prevailing conditions of the permit e.g. injection rate per stage and overall quantity of hydraulic fracturing fluid per stage as well as associated hydraulic fracture plans.

The number of hydraulic fracturing stages to be used per exploration well is between ~approximately 30 stages and 45 stages with up to 765m^3 injected hydraulic fracturing fluid for each injection point. For wells 3 and 4 or a sidetrack well up to 100 frac stages will be installed with the same injection volume (765m^3 per injection point).

2.3.1 Fracturing fluids

Shale wells are treated with various types of fluids. The preferred option is 'slickwater'. This is a low viscosity fluid that creates a complex fracture network in the shale formation. Slickwater requires a high injection rate in order to carry the proppant down the wellbore and deep into the fracture network. In cases where it is difficult to place proppant or there are restrictions to injection rate, a more viscous fluid may be required. The higher viscosity fluid is able to transport the proppant at lower rates. It also reduces the complexity of the fracture network, which helps to initiate the fractures and increases the fracture width to allow more space for the proppant to enter. Hybrid systems are used that start with a high viscosity fluid in order to initiate the fracture network then transition to low viscosity fluid or start with a low viscosity fluid to create the main fracture network and finish with a higher viscosity fluid in order to maximize proppant concentration near the wellbore. All proposed constituents of fracturing fluids are non-hazardous to groundwater. All fracturing fluid components will be stored within bunded areas of the site in clearly labelled containers.

Slickwater

- Water and sand (approximately 99.95% by volume). The first hydraulic fracture stage will not use flowback fluid water. Subsequently we will, wherever possible, use all of the flowback fluid that is available, topped up with mains water where required.
- Friction reducer (concentration 0.05% by volume). The composition of the friction reducer (also known as polyacrylamide) will be agreed with the Environment Agency if not already approved. The friction reducer will be added to the water to minimise pressure loss incurred due to friction between the water and the well casings.
- An optimised concentrations of friction reducer of up to 1% by volume may be used in a hybrid system in order to increase the sand carrying capacity of the Slickwater fluid. As a result of this change in volume water and sand will reduce to 99%. The composition of the friction reducer (also known as polyacrylamide) will be agreed with the Environment Agency if not already approved.

Gelled water

- Water and sand (approximately 96% by volume). No reuse of flowback fluid will occur.
- Gelling agents (approximately 4% by volume). The constituent chemicals of a Gelled water formulation are outlined in Appendix F and will be agreed with the Environment Agency if not already approved. The gelling agents will be added to the water to transport the proppant along the length of the fractures.

Dilute hydrochloric acid (<10% concentration) is likely to be used in the event initial injection pressures are too high due to tortuosity, cement invasion or perforation damage/debris in the formation.

The purpose of using diluted hydrochloric acid is to facilitate entry of the fracturing fluid from openings in the production casing into the body of the target formation. It reduces fracturing pressure requirements and improves treatment effectiveness. The potential quantity of injected diluted hydrochloric acid is approximately 3 - 15m ^{3} per fracture stage but may be higher depending on operational requirements. Injection of the diluted hydrochloric acid will precede the 750m^3 hydraulic fracturing fluid per stage however at no point will the combination of hydraulic fracturing fluid and diluted hydrochloric acid be higher than 765m ^{3} in total per injection point.

Diluted hydrochloric acid will react with the shale (containing calcium carbonate materials) to produce salty water and carbon dioxide. The spent hydrochloric acid will mix with the injected hydraulic fracturing fluid down hole.

Spent diluted hydrochloric acid (salty water and carbon dioxide) will return to the surface within the flowback fluid. This plan identifies determinands which will be assessed in monitoring flowback fluid including chloride, sodium, dissolved solids and alkalinity.

2.3.2 Flowback during slickwater hydraulic fracturing & hybrid slickwater

Flowback fluid will be stored in tanks and reused in further hydraulic fracturing stages or removed for offsite for treatment and disposal as appropriate. In the unlikely event the concentration of dissolved solids in the flowback fluid exceeds the tolerance threshold specified by the manufacturers of the friction reducer, then further dilution with mains water will be required.

Flowback fluid has been assessed as a non-hazardous waste stream based on the results from Preese Hall and preliminary data from Preston New Road PNR1z well. The potential addition of further salty water and carbon dioxide within the flowback fluid (should diluted HCl be used) at such a small concentration and volume in comparison to the volume of injected hydraulic fracturing fluid will not have a material impact on the flowback fluid composition, or the resulting waste classification.

2.3.3 Flowback during gelled water hydraulic fracturing

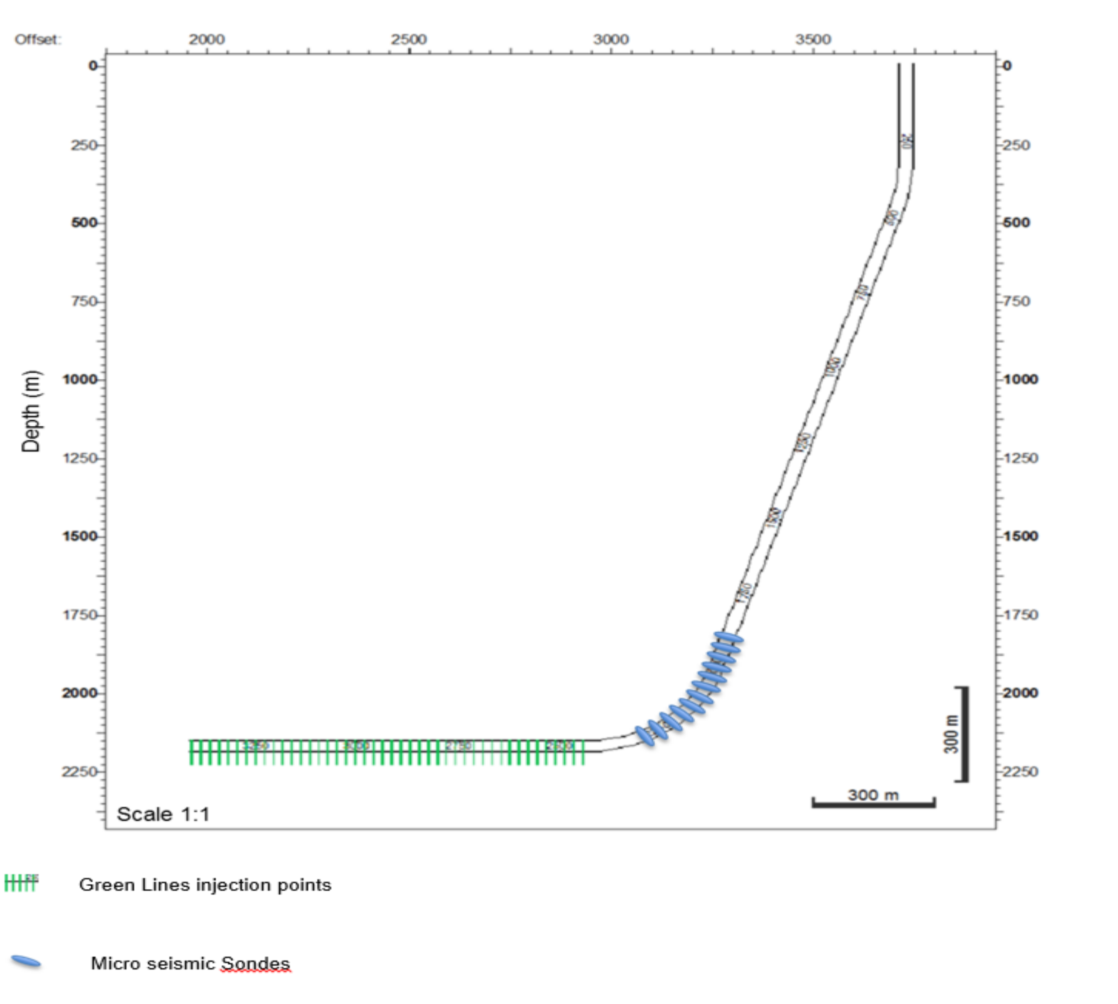
Flowback fluid will be stored in tanks within bunded areas on the site, however, unlike the slickwater composition, the fluid cannot be reused due to potential interference of returning gelling agents and breakers compromising the future injected fracturing fluid additives. There is no known proven, consented or tested technology that can reliably show, with specific and valid results of treating flowback fluid from the Bowland formation for the purposes of further hydraulic fracturing with gelling agents.

2.3.4 Hydraulic fracturing monitoring

Monitoring of fracture growth will be captured by the temporary installation and operation of downhole micro-seismic geophones (sondes). The approach of drilling multiple wells before hydraulic fracturing subsequently means that an offset well, i.e. the well next to or in close proximity (on the same pad) to the well which is about to be hydraulically fractured, can be utilised to locate micro seismic geophones for the monitoring of fracture growth. Micro seismic geophones are lowered into the offset well at depth within the target formation before hydraulic fracturing occurs (see Figure 3). Data is then acquired and transmitted through wireline and collated at surface. The data will be processed to show event location, orientation and extent of induced fracture growth within the target formation.

Future wells which are to be hydraulically fractured can utilise an offset well for monitoring of their fracture growth using the same technique. This can be achieved in wells which have already been hydraulically fractured by plugging the well (using a bridge plug) and segregating the hydraulically fractured area from the micro seismic geophones which are lowered into the heel of the well. Check shots will be performed to calibrate the micro seismic geophones.

Figure 3: Illustrative figure of downhole micro seismic geophones



Potential propped fracture growth is detailed further in the ES Induced Seismicity chapter.

Between stages of hydraulic fracturing a mixture of injected hydraulic fracturing fluid and any produced fluid present, which we refer to together as flowback fluid, will return up the wellbore to the surface lifted by the release of pressure in the well. This flowback fluid will be collected in containers and subsequently reused wherever possible. Well flowback will be managed so as to minimise any releases of small quantities of natural gas entrained within the flowback fluid. The details of this process are contained in (HSE-Permit-INS-PNR-009).

Once all hydraulic fracturing activities are completed along one or more horizontal wells, hydraulic fracturing equipment may be removed from the pad and temporary flow testing of the well will commence. The duration of the hydraulic fracturing activities for each well will vary according to the total number of hydraulic fracture stages. It is expected to last one to two months per horizontal well, and may be repeated in future if required for operational reasons. Operatives 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 only be operated during planning permission hours.

2.3.5 Precautionary approach to deep groundwater receptors during hydraulic fracturing

As the Carboniferous Millstone Grit Group is adjacent to (directly overlying) the target formation, the prudent approach is to account for the highly unlikely potential of induced fractures creating a pathway for indirect discharge of fracturing fluids into the Millstone Grit Group. The conclusion is consistent with the Environment Agency's own risk assessment for the propagation of fractures beyond the target zone as a low residual risk (Environment Agency, 2013).

The Millstone Grit Group is characterised by low porosity and permeability. Although the Millstone Grit Group may be classed as a minor aquifer in some parts of Lancashire when present near the surface, in the region of the site the group consists of gas saturated sandstones, shales and gritstones which are characterised by low porosity (<10%) and permeabilities (<1.0x$^{10-1}$ millidarcy). The Millstone Grit Group above the target formation is not an aquifer as defined in accordance with the Water Framework Directive. Elsewhere, where the Millstone Grit Group has been classed as a minor aquifer, its porosity has been measured to be between 24% and 36% (Jones et al, 2000), which is significantly greater than that observed from well data obtained within the region of the site.

Induced hydraulic fractures have an extremely low potential to indirectly discharge into the poor quality Millstone Grit Group and hydraulic fracturing fluid used by Cuadrilla will contain non-hazardous additives. These facts combined with the absence of any environmental receptors, means that a release as a result of the project into the Millstone Grit Group would result in no perceivable environmental impact and hence could not be classed as the input of a pollutant.

Each hydraulic fracturing plan will include:

- A map showing faults near the wells and along the well paths, 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 micro seismic events and monitoring of local seismicity during the operations; and
- A description of the proposed real-time traffic light scheme for seismicity, and proposed method for fracture height monitoring.

Both the Millstone Grit Group and the target formation are isolated from the upper groundwater bearing units by the Manchester Marls Formation. The Manchester Marls Formation (which is anticipated to be approximately 170m in thickness at this location) underlies the Sherwood Sandstone Group and is a mudstone unit containing primary and diagenetic evaporite minerals. These result in reduced permeability that effectively forms a barrier to upward flow of gases and fluids. Data from deep wells across the Fylde (including Thistleton, and recent Cuadrilla wells) identified little to no hydrocarbons above the Manchester Marls Formation but significant hydrocarbons below, which is further evidence of the capping properties of the Manchester Marls Formation. Nevertheless, upper groundwater monitoring is to be carried out at the site and is described in more detail in section 9.10.

The hydraulic fracturing plan provides a series of measures to further mitigate the risk of induced hydraulic fractures creating a pathway for an indirect discharge into the Millstone Grit formation. The long term behaviour of retained hydraulic fracturing fluid is further described in section 5.8.

2.4 Well clean up

When opening up a well to remove liquids, if the well doesn't flow under natural conditions, nitrogen (N2) will be pumped to reduce hydrostatic pressure and enable water to flow upwards. This will allow the natural gas to come out of the formation and unload the well of liquids more quickly.

During this phase the gas mixture direct to the flare line after separation will have low rates of natural gas mixed with larger amounts of nitrogen, due to the artificial injection, which may produce an incombustible gas mixture.

The approved PO10 produced, as detailed in Table 5.1, requires the use of propane injection to aid combustion during slugging of the well after five minutes of flow. However, the addition of propane in this specific scenario after five minutes will not overcome the incombustibility of a nitrogen dominated gas mixture, leading to propane being vented.

During nitrogen lifting, or any gas flow to flare, the pilot lights will always be turned on. Subsequently, if the fluctuating gas composition (natural gas and nitrogen) becomes combustible, then flaring will automatically commence in accordance with PO10.

To prevent wastage and unnecessary emissions, flare support fuel will not be added during nitrogen dominated gas returns as it will not enable combustion to be achieved in these circumstances. At the earliest possible opportunity, as the returning gas compositions changes from being mostly nitrogen to including sufficient natural gas content to achieve combustion, our standard flaring procedures, including the use of support fuel will be activated as set out in PO10 (CORP-HSE-PLA-009).

A detailed BAT assessment has been undertaken which has concluded that nitrogen lifting is the best available technique for artificially lifting a well during well completion. A detailed air quality modelling and screening assessment has been undertaken of potential emission arising from nitrogen lifting using conservative assumptions. This exercise has concluded that no unacceptable impacts are predicted at any nearby receptor.

2.5 Initial and extended flow testing

Once the well is flowing under natural conditions the purpose of this phase is to remove a portion of the injected hydraulic fracturing fluid from the target formation, to enable natural gas to flow into the well.

To maintain full pressure control during the flowback process, and to reduce the pressure reaching the surface production equipment, the flow coming out of the well will be passed through a special device called a 'choke manifold', which reduces the wellhead pressure to the separator operating pressure as fluid is removed from the well. After the pressure reduction, the flow stream enters a separator. The purpose of this is to separate the water from the natural gas, and also to remove any sand that may be returned during the flowback. At the upstream (inlet) end of the separator there is a sand weir that removes the sand out of the flow stream, allowing mainly the natural gas and water to move onto the next stages of separation. A sand trap may be used instead of a sand weir. Typically 90% of the sand returning in the flowback water will be removed from the flowback fluid with the remaining sand flowing with the fluid into the storage containers. The wet sand that accumulates in the front stage of separation is periodically discharged to a disposal container being unsuitable for re-use (see section 4.4). A metering system is installed to measure and record the water that is sent to enclosed containers and the natural gas that is sent to the flare.

Flow test natural gas will be metered and then sent to the flare stacks to be combusted. The flowback fluid will be sent to flowback tanks for measurement and storage and re-use in the subsequent hydraulic fracturing process whenever possible. Once hydraulic fracturing is complete any flowback fluid and produced fluid will be removed to the designated permitted third party offsite treatment and disposal facilities with the capacity to accumulate and treat the waste stream. The third party offsite treatment facilities will be subject to duty of care checks by Cuadrilla prior to receiving the waste flowback fluid.

Once the flowback starts to produce mainly natural gas, and the flowback fluid in the flow stream steadily diminishes, the initial flow test will commence. It is not reasonably practicable to connect the potentially intermittent flow of extracted natural gas to the National Transmission System (NTS) during the initial flow tests. This is because the flow rates are unknown and the quality of the gas produced might not be compatible with NTS requirements without further processing. Natural gas will therefore be combusted via on-site enclosed flare stacks during the well testing stage.

The duration of flaring from the site has been assessed within the ADMS5 air quality model based on a conservative assessment scenario of flaring for 365 days continually in a 12 month period. The results included in Appendix E to this plan concluded that: *"the assessment has identified that the air quality impact of the development can be considered as not significant. As this assessment has determined that the operational phase impacts on local air quality are not significant, additional mitigation measures have not been recommended and the residual impacts are considered likely to be acceptable."*

The amount of data which can be gathered within the first 2,160 hours (90 days) of initial flow testing may be insufficient to verify that the natural gas arising will meet the requirements of the NTS for acceptance of natural gas into the gas network. For this reason it may be necessary to continue flaring at a given well for in excess of 2,160 hours (90 days) in total, but subject to a maximum aggregate of 8,640 hours (360 days x 24 hours) flaring for all wells at the site. However, the overriding objective of the initial flow test is to flare for the least time possible to gain the required date while reducing the amount of emissions generated.

Following on from the initial well test, a longer extended well test (EWT) may be conducted to produce natural gas from the well to gather data on the relationship between flow rates and well pressures, measure decline rates, and determine how much fluid will be produced over time with the natural gas. From the EWT data, Cuadrilla will be able to predict the future well performance over its potential working life should it go into production.

The duration of the EWT phase will last between 18-24 months. Providing the necessary gas licences and arrangements are forthcoming, a pipeline infrastructure connecting the well pad to the NTS shall transport natural gas during this period to the gas grid. At the well pad, the separation, dehydration (use of methanol) and filtration plant and associated storage vessels will be located in the open areas of the well pad and will separate the natural gas from produced fluid with potentially trace elements of injected hydraulic fracturing fluid. A small flare will be on site during this period and would only be used in rare circumstances during maintenance of the surface equipment or emergency scenarios. Once the exploration activities have been completed, the wells and associated surface works will either be suspended, or plugged and abandoned. The decision to suspend or plug and abandon will be made once the data from the exploration activities has been appraised.

2.6 Maintenance

Where a well is suspended for a prolonged period of time, it may be necessary to use small quantities (~ of m^3 per well) methanol downhole to help prevent the production of gas hydrates (an ice-like hydrocarbon) formation which can lead to operational difficulties. Methanol is a simple alcohol which can be used to lower the temperature at which liquids freeze. JAGDAG, the body which determines whether chemicals are hazardous or non-hazardous to groundwater have issued an interim determination in June 2018 indicating that methanol should be considered non-hazardous to groundwater. Subject to this determination being finalised, Cuadrilla seek to include methanol as a potential additive for downhole use. Further details on methanol are included in Appendix F.

It may be necessary periodically undertake a workover or other maintenance activities within a well at various points during its lifetime. This activity may be carried out using a work over rig or other appropriate equipment. It is not anticipated that this will be necessary on a regular basis, but is likely to be required on occasion over the full life of the well. All wastes generated during such activities will be of similar character to those produced during drilling. Before the start of the operation an estimated quantity of waste and method statement will be documented.

2.7 Plugging and well abandonment

If the wells are not to be taken into a longer term production phase (or alternatively at the end of their production life) they will each be plugged with cement and abandoned (decommissioned). Plugging and abandonment of the well shall be conducted in accordance with the planning permission and be conducted in conformance with the latest edition of the Oil & Gas UK Guidelines, UKOOG guidance and regulations in effect at that time. Further details are described in section 10.0.

3.0 Waste characterisation

3.1 Water-based drilling mud and drill cuttings

WBM has been assessed against the definition of 'inert waste' provided in Article 3(3) of the Mining Waste Directive. It has been concluded that the WBM do not fit this definition of inert waste as they contain natural substances that are capable of biodegrading.

Under the European List of Wastes, WBM is categorised as an absolute non-hazardous entry as follows:

- 01 05 04 freshwater drilling muds and wastes

Or if they contain chlorides:

- 01 05 08 chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06

The waste is therefore characterised as 'non-hazardous, non-inert' waste for the purposes of the Mining Waste Directive.

The waste drill cuttings have been assessed against the definition of 'inert waste' provided in Article 3(3) of the Mining Waste Directive. It has been concluded that the drilling cuttings do not fit this definition of inert waste as they may still be coated with a thin film of WBM which contain natural substances that are capable of biodegrading.

Under the European List of Wastes, drill cuttings contaminated with WBM are categorised as absolute non-hazardous entries as follows:

- 01 05 04 freshwater drilling muds and wastes

Or if they contain chlorides:

- 01 05 08 chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06

The waste is therefore characterised as 'non-hazardous, non-inert' waste for the purposes of the Mining Waste Directive.

3.2 Low toxicity oil based drilling mud and drill cuttings

Waste drill cuttings from drilling with LTOBM have been assessed against the definition of 'inert waste' provided in Article 3(3) of the Mining Waste Directive. It has been concluded that the drill cuttings do not fit this definition of inert waste as they may still be coated with a thin film of LTOBM.

Waste oil based drilling muds are listed as an absolute hazardous entry in the European List of Wastes:

- 01 05 05* oil-containing drilling muds and wastes

The waste drill cuttings are therefore also classified as 'hazardous' waste for the purposes of the Mining Waste Directive.

LTOBM is transported offsite for either direct reuse on another well site or return to the supplier at their storage depot for future use at other sites. However, any LTOBM lost to formation or spoilt such that it is not suitable for re-use is classified under the absolute hazardous category above.

To prevent the LTOBM being spoilt, monitoring and adjustment of LTOBM occurs at site to measure the oil to water ratio and quantity of low gravity solids to ensure the LTOBM remains within the supplier's specification managed by a competent mud engineer. LTOBM is managed onsite for fluid property maintenance using the same equipment as for WBM, including centrifuging and oil-water ratio adjustment. As a result the LTOBM can be reused and returned back to the supplier.

LTOBM coated on drill cuttings is spoilt and is subsequently sent off site for disposal.

3.3 Flowback fluid

Under the European List of Wastes flowback fluid is classified as an absolute non-hazardous entry:

- 01 01 02 wastes from mineral non-metalliferous excavation

In addition, although not required for the classification as non-hazardous waste, but acknowledging public concern, this waste stream has been assessed against the list of hazardous properties in Annex III of the revised Waste Framework Directive. The results of our analysis demonstrated that the fluid would not display any of the listed hazardous properties at or above relevant limit values (as set out in Environment Agency Technical Memorandum WM3, v1.1).

3.4 Surplus natural gas

Under the European List of Wastes we have classified natural gas which is to be flared as:

- 16 05 04* gases in pressure containers (including halons) containing dangerous substances.

Natural gas is however highly flammable and hence displays one of the hazardous properties listed in Annex III of the revised Waste Framework: H3A, fourth indent (highly flammable).

3.5 Scale

Under the European List of Wastes we have taken the precautionary approach of classifying scale as ‘other drilling wastes; under the appropriate mirror entry:

- 01 05 06* drilling muds and other drilling wastes containing dangerous substances

The actual composition of any scale that is found to be deposited will be sampled to determine whether it does in fact contain a dangerous substance(s) and if so which.

3.6 Spacer fluid

Under the European List of Wastes we have classified spacer fluid as an absolute non-hazardous entry:

- 01 05 04 freshwater drilling muds and wastes,

Or if it contains chlorides:

- 01 05 08 chloride containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06

However, if it contains LTOBM, it will be classified as absolute hazardous entry:

- 01 05 05* oil-containing drilling muds and wastes

3.7 Retained hydraulic fracturing fluid

Under the European List of Wastes we have classified retained hydraulic fracturing fluid as an absolute non-hazardous entry:

- 01 01 02 wastes from mineral non-metalliferous excavation

In addition, although not required for the classification as non-hazardous waste, but acknowledging public concern, this waste stream has been assessed against the list of hazardous properties in Annex III of the revised Waste Framework Directive. The results of our analysis demonstrated that the fluid would not display any of the listed hazardous properties at or above relevant limit values (as set out in Environment Agency Technical Memorandum WM3, v1.1).

3.8 Category A Assessment

3.8.1 Waste within the below ground non-hazardous mining waste facility

We are required by the Mining Waste Directive to provide sufficient information to justify why the non-hazardous mining waste facility below ground at each well drilled and hydraulically fractured will not require to be designated as a Category A mining waste facility in accordance with the criteria in Annex III of the Mining Waste Directive. The existence of accident hazards relevant to the waste facilities was considered as part of the environmental risk assessment. Based on the assessment of waste fluids from Preese Hall, which were classified as non-hazardous, we have no reason to suppose that the classification would be any different in relation to waste fluids at Preston New Road.

Annex III provides that a waste facility shall be classified under Category A if:

1. a failure or incorrect operation, e.g. the collapse of a heap or the bursting of a dam, could give rise to a major accident, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the waste facility; or

2. it contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold; or

3. it contains substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC above a certain threshold.

<u>1. Failure / incorrect operation</u>

Commission Decision 2009/337/EC provides that a waste facility shall be classified under Category A in accordance with number 1 above if the predicted consequences in the short or the long term of a failure due to loss of structural integrity, or due to incorrect operation of a waste facility could lead to:

a) non-negligible potential for loss of life;
b) serious danger to human health; or
c) serious danger to the environment.

The potential for the above effects to result from loss of structural integrity or incorrect operation of the mining waste facility for each well has been assessed. The risk is insufficiently high to fall within the description of a major accident above.

This is on the basis that:

i. With regard to a) above, given that the mining waste facility is to be located more than a kilometer underground and will not be accessible to people hence no relevant source-pathway-receptor chain exists.
ii. With regard to b) and c) above:

Well integrity will form a barrier to prevent escape of waste retained fluids via the wellbore from the mining waste facility. Well integrity is assured through compliance with the well examination regime and regulation by the Health and Safety Executive, and further through conformance to Oil & Gas UK and UK Onshore Operators' Group good practice guidelines for well design and construction. The hydraulic fracturing plan and the seismic monitoring programme submitted to OGA as well as operation of the traffic light system for monitoring of induced seismicity are designed to mitigate the risk of impacts from induced seismicity, including any potential for damage to well integrity.

The potential for fractures that are propagated by hydraulic fracturing to extend beyond the target formation has been assessed to be very low and the growth of fractures resulting from each fracturing stage will be assessed with the aid of the seismic monitoring geophones.

Cuadrilla will only use substances approved in writing by the Environment Agency as non-hazardous to groundwater as fracturing fluid additives. Polyacrylamide, which is intended to be used as a friction reducer additive, has been approved in writing as non-hazardous to groundwater and poses no serious danger to human health.

The detailed consideration of the subsurface geology that has been undertaken as part of the ES has assessed the potential for retained fluids within the shale rock to migrate upwards into contact with groundwater aquifers which may be a potential future source of drinking water. This outcome has been assessed as very low and with no plausible pathway (Hydrogeological and Ground Gas Chapter of the ES).

For this purpose we have considered, with regard to the structural integrity of the below ground non-hazardous mining waste facility, its ability to contain the waste within the boundaries of the facility in the manner for which it was designed, and all possible relevant failure mechanisms. Our evaluation of the consequences of a loss of structural integrity has also included the immediate impact of any material escaping from the facility as a consequence of the failure and the resulting short and long term effects, over the lifecycle of the facility.

For the purpose of considering the impacts from incorrect operation of the mining waste facility, we have included in our evaluation any type of operation which could potentially give rise to a major accident, and including insufficient design or faulty construction of a well.

The assessment of the release of contaminants resulting from incorrect operation has included both the effects of short-term releases as well as of the long-term release of contaminants, and has covered the operational period of the facility and as well as the period following closure. It has also considered whether any of the waste present is likely to be reactive and has concluded that it is not.

2. Hazardous waste above the threshold

The waste fluids present in the mining waste facility at closure of the mining waste operation at the site may contain naturally occurring radioactive materials and other dissolved minerals salts.

Regarding the threshold of hazardous waste, Commission Decision 2009/337/EC provides that it is calculated as the ratio of the weight on a dry matter basis of:

(a) all waste classified as hazardous in accordance with Directive 91/689/EEC and expected to be present in the facility at the end of the planned period of operation; and

(b) waste expected to be present in the facility at the end of the planned period of operation.

Waste assessed from the Preese Hall well has identified the waste stream to be non-hazardous and this is expected to also be the case at PNR.

3. Dangerous substances above the threshold

A waste facility is required to be classified as Category A if it contains substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC above a certain threshold.

Based on sampling results from the Preese Hall well, it has been assessed that no dangerous substances above the thresholds contained in Directives 67/548/EEC or 1999/45/EC are likely to be present.

3.8.2 Waste within the above ground hazardous mining waste facility

We are required by the Mining Waste Directive to provide a justification why the hazardous mining waste facility which is to be part of the mining waste operation does not require to be designated as a Category A mining waste facility in accordance with the criteria in Annex III of the Mining Waste Directive.

Annex III provides that a waste facility shall be classified under Category A if:

1. a failure or incorrect operation, e.g. the collapse of a heap or the bursting of a dam, could give rise to a major accident, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the waste facility; or

2. it contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold; or

3. it contains substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC above a certain threshold.

1. Failure / incorrect operation

Commission Decision 2009/337/EC provides that a waste facility shall be classified under Category A in accordance with criterion 1 above if the predicted consequences in the short or the long term of a failure due to loss of structural integrity, or due to incorrect operation of a waste facility could lead to:

a) non-negligible potential for loss of life;
b) serious danger to human health; or
c) serious danger to the environment.

The potential for the above effects to result from loss of structural integrity or incorrect operation of the storage area for hazardous mining waste streams (comprised in the hazardous mining waste facility) has been assessed. The risk is insufficiently high to fall within the description above. This is on the basis that:

i. With regard to a) and b) above, no people other than workers operating the facility that might be affected are expected to be present permanently or for prolonged periods in the potentially affected area.

ii. With regard to c), the presence of a well pad membrane around the hazardous mining waste facility means that there is no potential source-pathway-receptor relationship between the facility and environmental receptors.

For this purpose we have considered with regard to the structural integrity of the above ground hazardous mining waste facility, its ability to contain the waste within the boundaries of the facility in the manner for which it was designed, and all possible relevant failure mechanisms. Our evaluation of the consequences of the loss of structural integrity has also included the immediate impact of any material transported from the facility as a consequence of the failure and the resulting short and long term effects, over the lifecycle of the facility.

For the purpose of considering the impacts from incorrect operation of the waste facility, we have included in our evaluation any type of operation which could potentially give rise to a major accident, including the malfunction of environmental protection measures and faulty or insufficient design.

The assessment of the release of contaminants resulting from incorrect operation has included both the effects of short-term releases as well as of the long-term release of contaminants, and has covered the operational period of the facility and as well as the period following closure. It has also considered whether any of the waste present is likely to be reactive and has concluded that it is not.

2. Hazardous waste above the threshold

Before the end of operation of the hazardous mining waste facility, all of the hazardous waste contents will have been disposed off site to a permitted waste facility. Therefore the hazardous ,mining waste facility cannot be classified as a Category A facility on this basis.

3. Dangerous substances above the threshold

The waste contents of the hazardous mining waste facility are not envisaged to include any substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC above the applicable threshold.

3.8.3 Inspection of waste facilities

Cuadrilla has suitable plans in place for the inspection of both the surface and underground waste facilities. These are designed in line with the purposes of the Mining Waste Directive to allow Cuadrilla to monitor the integrity of the surface and underground facilities, as well as soil and water quality.

The underground mining waste facility at each well will be inspected through a combination of downhole micro-seismic, water, soil and well integrity monitoring techniques. Combining the data sets will give an overall downhole inspection of each underground mining waste facility. The surface facility will combine the inspection of waste containers, soil and water quality.

For the underground mining waste facility, throughout the life of the well, the three annuli; A, B and C are monitored using a digital gauge or equivalent method to download readings on annuli pressure (as per section 2.2.4). This will provide confirmation of continuing well integrity. Downhole micro-seismic monitoring will provide data on the extent and orientation of the fracture growth during hydraulic fracturing (see section 2.3). This data will provide evidence of the depth and formation of the fracture growth that has occurred.

For the surface mining waste facility as per section 5.1, the rectangular containers will be subject to annual thickness inspections and weekly visual inspections. Prior to drilling commencing, ancillary equipment which includes the containers shall be hydro tested for leaks or appropriately certified for integrity.

For both the surface and underground waste facilities, sections 9.10 and 9.11 describe the groundwater and surface water monitoring regime to determine surface water and groundwater quality and separately dissolved gas content for groundwater. The data will be compared to the baseline data to identify variations or confirm concurrence with the baseline. If a trend of continued and significant variation to baseline data is identified, the operations shall be immediately suspended, if operating, to investigate and address those causes if they are linked to the operations on site. Soil sampling as per section 9.13 has been collected to establish a baseline of soil conditions and is reported in the Site Condition Report (HSE-Permit-INS-PNR-003). Further sampling will take place once the site is restored to its original condition.

Information and data collected by the different sampling regimes or monitoring techniques will be communicated into a periodic mining waste facility inspection report in consultation with the Environment Agency.

4.0 Waste hierarchy

Article 5 of the Mining Waste Directive requires Cuadrilla to prepare a waste management plan (WMP) *for the minimisation, treatment, recovery and disposal of extractive waste, taking account of the principle of sustainable development.*

This section of the plan applies the waste management hierarchy to the design of the project and the site operations by examining for each mining waste stream the potential to eliminate, reduce, reuse, recycle and finally dispose of that waste stream from the site.

4.1 Drilling mud control

The well size will be optimised to reduce the amount of drilling mud required and the drill cuttings produced whilst maintaining a sufficiently adequate borehole diameter.

The drilling muds will be reused until spent or spoilt to reduce the continuous addition of fresh muds into the system and subsequent waste creation and continued use of virgin raw materials. A competent drilling mud engineer will be tasked to monitor and manage the muds to ensure efficiency of use and record the mud management in a daily mud report.

Any LTOBM that is recovered at surface will (unless spoilt) be returned to the supplier for reuse at the end of the operation. As a result, such LTOBM is not discarded and is therefore not classified as a waste.

When drilling mud is in contact with the permeable underground rock formation and there is greater hydrostatic pressure in the wellbore than in the formation, some mud filtrate is forced into the formation. The solids in the mud are ‘screened out’ at the wellbore interface, forming a filter cake, and a small amount of fluid (mud filtrate) enters the permeable formation. In order to minimize the loss of drilling fluid to the formation, the drilling mud is engineered with important filter cake building properties. Fluid loss control agents, generally starch-based (water-based systems) are added to the drilling fluids. These properties of the mud are measured onsite using an API Fluid Loss Test (mud filtration). Drilling fluid is designed so that the contained solids quickly form a very thin filter cake that has very low permeability. As filter cake thickens, the filtration rate decreases. When circulating, filter cake is constantly eroded and re- deposited, forming a dynamic filter cake of fairly constant thickness.

The filter cake is formed by design to minimise the invasion of drilling mud into permeable underground rock formations. Also, the materials which form filter cakes can reduce the uptake of water by clay minerals, thus contributing to wellbore stability. Typical filter cake thickness is approximately. 1-3mm.

Volumes of fluids pumped and returned will be monitored by two independent systems (the mud engineers and the drilling Pit Volume Totaliser (PVT) system) during the drilling operation. Circulating density is minimised when drilling weak or low-pressure porous formations. If there is indication of fluid losses into the surrounding formation, lost-circulation (solid/ fluid base) material will be deployed as soon as practicable to minimise leak-off. Monitoring will be in place to ensure mud loss is identified as soon as possible allowing measures to mitigate any further loss to be put in place.

Drilling into the target formation which has very low permeability (~1-100 nanoDarcy), filtrate loss is expected to be close to zero. For this reason, we do not expect there to be any significant loss to formation of LTOBM within the target formation.

Any losses experienced during drilling that are detected by the monitoring systems will be recorded by the drilling mud engineer on a daily basis.

Drill cuttings will be separated from the drilling mud, as far as reasonably practicable, at the surface so that the maximum amount of drilling mud can be reused on site. This is further explained in section 5.1.

4.2 Spacer fluid

Calculations will be made by Cuadrilla and a competent contractor accounting for borehole section and well design to estimate the amount of spacer fluid and suspension fluid required and the volumes will be measured to reduce the amount of waste generated by excess. Where possible, returned spacer fluid can be reused on site e.g. into the drilling muds. Otherwise, returned spacer fluid will be sent for disposal to a permitted waste management facility.

4.3 Sand

Returned sand cannot be reused as a proppant. It would require treatment to remove crushed or broken sand grains, sieving to the correct size and drying before further reuse. Treatment of this nature would require installation of additional infrastructure on site and additional energy usage, which we do not consider would achieve a net environmental benefit. Instead the sand will be sent off-site for recycling or disposal at an appropriate permitted facility.

4.4 Flowback between hydraulic fracturing stages

In order to minimise the overall quantity of fluid injected into the target reservoir to flow-test the well, a series of small hydraulic fracturing operations will be performed ahead of the main fracturing stages in order to assess fracture mechanics within the target formation. This will aid the design of later hydraulic fracturing and flow-testing, enabling the minimum quantity of fresh water and additives to be used in order to achieve optimum gas flow rates.

Flowback fluid may also be returned to the surface between hydraulic fracturing stages to reduce the risk of seismicity. In this scenario flowback fluid will be reused for future stages if using a slick water additive fracturing fluid. The flowback fluid consequently is not a waste at this stage. It is very unlikely that flowback will be disposed during this phase however, if due to operational requirements, the fluid will be disposed of then it shall be disposed of in accordance with this plan.

If a gelled fracturing fluid is utilised and flowback is required, then the flowback fluid will be disposed of in accordance with this plan. This flowback fluid cannot be reused due to the risk of interference from previous injected gels or dissolved solid content which could impact on the proppant placement, length and width of fractures in subsequent stages.

The flowback fluid will be stored at the surface in steel containers on top of the well pad membrane. The containers are a combination of open and closed top tanks. Flowback fluid will not be stored in pits or open lagoons during this phase. This is to prevent the uncontrolled release of flowback fluid into the environment.

Initially the flowback fluid will flow from the well towards a choke. The choke controls fluid rate and pressure and is supervised by a competent operative. The choke is configured appropriately according to the activity being undertaken. In most circumstances, all returning well fluids will be directed via the separator before being stored in tanks. In a small number of circumstances, where the risk of entrained natural gas in the returning fluid is highly unlikely or using the separator could damage it or inhibit its effectiveness, returning well fluids will be directed via the open topped tanks.

The primary purpose of the open topped tanks are two fold; to collect debris from well maintenance activities, or to manage substantial quantities of proppant returning during a short period of time during well circulation activities.

Debris within returning flowback fluid largely arises due to wellbore clean out runs (required after running tools and/or milling). Entrained gas returning during this activity is highly unlikely due to the overbalanced pressure in the wellbore and there being no contact between the fluid and the target formation.

A further activity which requires the use of the open topped tanks is well circulation to lift proppant, either following hydraulic fracturing or to resolve downhole screen outs. In such activities, large quantities of proppant or other solids will be returned in a short space of time, which would overwhelm the sand filter and subsequent separator. As with well maintenance activities, entrained gas returning during this activity is highly unlikely due to the well remaining overbalanced throughout.

The tanks are open topped to provide safety redundancy in the extremely unlikely event of an undetected build-up of gas flowing into the tanks, resulting in the risk of a potentially explosive gas / atmosphere mixture.

In all other circumstances, after 'bottoms up' of the well, the open topped tanks will not be used as the primary fluid handling technique, with the separator being used preferentially. These activities include:

- Flowback for seismicity purposes
- Flowback between hydraulic fracture stages
- Flowback during well completion
- Flowback for well testing

The separator allows for gas and flowback fluid to be separated, and subsequently flared if sufficient gas volume and pressure is present. The liquid phase of the flowback fluid is then transferred to storage tanks. If there is insufficient gas volume or pressure to flare, the small quantity of gas present remains within the separator until future well activities yield sufficient gas volume or pressure to send the gas towards the flares. As an additional and/or alternative stage of gas separation (depending on flowback rate and gas breakout rate), a two stage pressurized surge tank is connected to the separator. Both the separator and the surge tank are independently connected to the flare system, with any gas separated being directed towards the flare once sufficient pressure is present, rather than emitted to atmosphere.

To minimise releases to the atmosphere, as required by the applicable BAT conclusion, an additional operational control will be put in place. During primary use of the open topped tanks (as outlined above), a monitor with the ability to detect methane at parts per million (ppm) resolution will be positioned to sample above the open topped tanks. When alerted by the monitoring equipment of the presence of small quantities of natural gas in the tanks, the choke operator will direct the returning fluid into the separator. These alerts will be triggered at a level of 7.1ppm, which is only marginally higher than the natural background level of 1-3ppm recorded at the Preston New Road site, and is in keeping with the approved EMMP which initially established the agreed notification levels.

Once the fluid has been managed and initially stored in the open topped tanks, the flowback fluid is reused for subsequent hydraulic fracturing, or transferred to the closed top (not sealed) tanks for storage or disposal.

Approximately 10%-40% of the injected flowback fluid for each fracturing stage is predicted to return to the surface between hydraulic fracturing stages if required to flowback to reduce the risk of seismicity or operational efficiency. The returning flowback fluid at the surface is expected be relatively clean, in comparison to produced water, as the fracturing fluid has been in contact with the target formation for only a short period of time e.g. hours up to days. With the relatively short period of time the dissolution of minerals and salts is expected to be low so the immediate flowback fluid will have relatively low levels of total dissolved solids (TDS) and total suspended solids (TSS).

Flowback fluid will be re-used for hydraulic fracturing wherever possible. In the event flowback fluid TDS is above 250,000mg/l (or where stipulated by the supplier of the friction reducer) then the friction reducer would not work to its designed tolerance. The flowback fluid would be diluted by mains water to reduce the TDS. If TDS remains above 250,000mg/l after dilution, which is very unlikely, then the flowback fluid would be disposed of. The reuse will involve utilising a closed loop system between hydraulic fracturing stages to ensure that all flowback fluid is captured and is available for re-injection into the target formation as part of the hydraulic fracturing process. Surveillance of flowback fluid will be conducted on a regular basis checking levels and integrity of tanks.

Flowback fluid shall be stored at the surface in steel containers on top of the well pad membrane within the perimeter fence line. As hydraulic fracturing will be conducted consecutively over a period of days the storage of the flowback fluid shall be temporary. To minimise the possibility of any residual natural gas remaining within the flowback fluid, and therefore minimise any vented emission from the flowback tanks, an onsite protocol (HSE-Permit-INS-PNR-009) will be used to manage flowback fluid to achieve this.

Flowback fluid at the surface will be subject to ultra violet (UV) disinfection prior to re-use to control bacterial growth. This is a precautionary approach to help maintain productivity of the fractures and reduce the risk of bacteria causing souring of the natural gas. UV disinfection has been selected to compliment the use of non-hazardous biocide (glutaraldehyde) additive. The decision to use UV and or glutaraldehyde will be dependent upon the effectiveness of the UV system as well test results from the fluid returning to the surface. The process does not create any further waste at the site. Details of glutaraldehyde, which has been determined as being non-hazardous to groundwater, is detailed in Appendix F.

4.5 Flowback fluid initial and extended well testing

During well clean up the flow from the well is anticipated to alternate from liquid (flowback fluid and produced water) and natural gas to predominantly natural gas flowing and produced water for the duration of the well testing period.

At this stage of the process there is no option for the flowback fluid or produced water to be reused unless there are additional wells which require hydraulic fracturing, depending on the hydraulic fracturing fluid composition (slick water or gels). If this option exists the flowback fluid and produced water can potentially be blended with hydraulic fracturing fluid to reinject back into the same formation. The flowback fluid and produced water will be stored in accordance with section 4.4.

Flowback fluid and produced water which no longer has a use the fluid will be disposed of. It is impossible to decouple the waste stream flowing back to surface in order to acquire the natural gas product. During the well testing phase of operations the fluid will be sampled, tankered and disposed at a permitted waste treatment facility. The fluid is stored in accordance with section 4.4.

4.5.1 Surplus natural gas

The requirement to flare natural gas is based on a need to collect natural gas data. The initial flow test purpose is to enable a continual uninterrupted flow from the well head to a flare. The uninterrupted flow of natural gas is required to provide the necessary data to measure the flow rate of natural gas and the initial decline rate of flow and pressure as well as the gas composition. This allows for the forecasting of potential future production flow from the well. Interrupting the flow, or the risk of interruption from utilising the natural gas on site, would impact the necessary data collection and ability to predict future decline curves of natural gas.

A site flaring limit of a maximum aggregate of 8,640 hours (360 days x 24 hours) for all the wells at the site provides operational flexibility to enable each well to be assessed on an individual basis. If there is uncertainty in the data being captured, the flexibility of the aggregate site limit means that a particular well can be flared for longer if required e.g. where flow is interrupted. Alternatively, in circumstances where data is quickly validated, flaring duration can be reduced for a well and the remaining hours then used in relation to another well. The overriding objective of the initial flow test is to flare for the least time possible to gain the required data while reducing the amount of emissions generated.

The flare system will be fitted with an 'hours run' gauge enabling accurate reading of flare time.

Once the initial flow test has established data, natural gas flowing from the well during the extended well test would be sent to the NTS rather than flaring. The extended well test is based on site specific information e.g. the gas composition and flow rates established during the initial flow test, to enable a connection into the gas grid.

Connection to the NTS costs several millions of pounds to approve and construct and approve. The intention of well testing is to extract the gas and evaluate (composition and flow rates) whether appropriate infrastructure access is available to ensure the product has a viable path to market before making an infrastructure connection. This approach is recognised in UKOOG guidelines (UK Onshore Shale Gas Well Guidelines, Exploration and appraisal phase, Issue 1 February 2013) and in the USA EPA.

Section 10 from the UKOOG guidelines states:

"10. Minimising Fugitive Emissions

Operators should plan and then implement controls in order to minimise all emissions. Operators should be committed to eliminating all unnecessary flaring and venting of gas and to implementing best practices from the early design stages of the development and by endeavoring to improve on these during the subsequent operational phases.

Emphasis should be placed on "green completions" whereby best practice during the flow-back period is to use a "reduced emissions completion" in which hydrocarbons are separated from the fracturing fluid (and then sold) and the residual flow-back fluid is collected for processing and recycling. However this approach will not always be practicable at the exploration/appraisal stage of a development where separation and flaring of natural gas should be the preferred option, minimising venting of hydrocarbons wherever practicable."

EPA Standards for Gas Well Affected Facilities states:

"Each well completion operation begun on or after January 1, 2015, must employ REC in combination with use of a completion combustion device to control gas not suitable for entering the flow line (we refer to this as REC with combustion). (EPA, Page 41, 40 CFR Part 63 Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews)

Once reliable data is validated from the initial well testing phase and reviewed by the infrastructure body (i.e. gas is suitable to enter a flow line), a connection to the NTS will be made for the extended well testing phase."

4.6 Scale

It is highly unlikely, due to the short term nature of exploration operations, that any significant scale will build up inside the pipes. The scale cannot be reused on site and will be sent off-site for disposal. A Radioactive Substances Regulation (RSR) permit has also been applied for to manage the accumulation and disposal of waste scale.

5.0 Site waste management operations

As a summary the following table identifies how the waste is going to be checked, monitored and sampled as well as detailing how the information will be taken into account for operations.

Table 4: Site waste management monitoring information

Waste	Monitoring frequency	Monitoring /sampling method	Recording document	Data usage
Muds/cuttings	Fluid and solid drilling waste will be sampled at the well site at the first available opportunity when drilling commences, or when there is a change in drilling mud composition, for chemical analysis and any other additional waste acceptance criteria that is requested by the offsite authorised waste facility. Following this initial sample, weekly samples alternating between solids and fluids will be taken for the remainder of the work programme. If the mud is taken off site in a combined slurry state then biweekly sampling shall be conducted.	Visual inspection. Chemical analysis.	Appended tabulated waste tracker to the Waste Management Plan (WMP) Environmental Management and Monitoring Plan ("EMMP")	Changes in the chemical profile of the waste will inform decisions concerning future waste management arrangements and environmental risk control measures, as well as sampling and testing frequency.
Flowback fluid	**The quantity of flowback fluid arising will be monitored and recorded, along with any quantities dispatched off site for disposal. Sampling of the waste flowback fluid will be taken at the first available opportunity for chemical analysis and any other additional waste acceptance criteria for the initial/extended flow testing stage. Flowback fluid shall be sampled (if available) during the hydraulic fracturing stage to confirm chemical and radiological composition.** **Routine sampling shall be conducted to monitor the composition of the flowback fluid due to the potential gradual compositional variation over time. Sampling of each flowback tank shall be conducted during initial flow testing and where required during extended flow testing during the accumulation of flowback fluid. Samples will be**	**Visual inspection.** **Chemical analysis.** **Radiological analysis.**	**WMP** **EMMP**	**The chemical profile of the waste will inform decisions concerning future waste management arrangements and environmental risk control measures, as well as sampling and testing frequency.**

	taken at different stages of the tank being filled with flowback fluid. Each sample will then be mixed together to create a bulk composite from each tank.			

Sands	Sand is removed from the flowback fluid within the high volume separator or sand filter. Residual amounts may accumulate in flowback tanks for disposal. The sand that accumulates during this stage is periodically removed to a disposal tank. The monitoring frequency is expected to be daily to weekly.	Visual inspection	WMP EMMP	Record quantity of waste generated.
Suspension fluid/ spacer fluid	Volumes of spacer fluid are calculated by competent contractors and the Mud Engineer. Tank dimensions and fluid levels can be taken to calculate fluid volume usage. Additional mud logging systems can also be used in conjunction to support this calculation.	Visual inspection combined with calculations by Cuadrilla and a competent contractor.	WMP	Record quantity of waste generated.
Surplus natural gas	Monitoring of the flare is conducted in two phases. The first phase is to monitor the feedstock flowing to the flare to ensure the natural gas quality. Within the initial first week of natural gas flow, sampling of the natural gas shall be taken on a daily basis. Samples are taken from the pipeline flowing from the separator travelling towards the flare. The samples are sent off-site to an independent accredited laboratory for chromatograph analysis. The first sample taken from the site shall be assessed and results turned around within 24 hours of the sample date. If the natural gas continues to show a homogenous nature after 7 days, sampling will be tapered down to 1 sample every 3 days for the next 14 days. Sampling shall continue after 21 days on a weekly basis. The flow rate shall also be monitored on a daily basis using a Daniel's Orifice or equivalent method for measuring the flow rate of natural gas.	Orifice	WMP EMMP	Flow rate determination key to establishing the economic viability of the well.
Scale	Significant scale volumes are not expected to be encountered. Scale monitoring will be conducted on a weekly basis with the monitoring	Visual inspection.	WMP	Record quantity of scale generated.

	frequency being flexible to adapt to changes during operations.			

The activities will be conducted so as to prevent waste production wherever possible, reduce the quantities generated and to protect human health and the environment. Where a waste stream is transported and disposed off-site this will be via an authorised waste carrier to a permitted waste facility.

5.1 Waste drilling muds and drill cuttings

Both WBM and LTOBM drilling muds containing cuttings returning to the surface are passed through a mechanical separation device which is used to extract solid drill cuttings. Further centrifugal treatment is used to remove finer drill cuttings from the muds. The drilling muds are then temporarily stored in dedicated steel mud tanks and reused within the further drilling process until no longer required or they have become spent.

The mud tanks are subject to annual thickness inspections and weekly visual inspections. Any waste drilling muds are removed by vacuum loading road tanker, or steel containers to an authorised waste treatment facility. It should be noted that the exact size and configuration of tanks and vessels for the storage of this waste may change to suit operational needs, but will remain of the same high standard. The waste tanks will be located on the well pad membrane.

Drill cuttings that are separated at the surface from the drilling muds, as described above, will be temporarily stored in a number of steel rectangular open skips with a capacity of up to 50m³. The cuttings will still contain residual muds and subsequently combined in the skips to form a slurry. The rectangular containers will be subject to annual thickness inspections and visual inspections. Prior to drilling commencing ancillary equipment, which includes the containers, shall be hydro tested for leaks or appropriately certified for integrity. The waste will be transferred onto containers or vacuum suction tankers and subsequently removed to one of several facilities that are appropriately permitted to receive, accumulate and treat industrial wastes. It is not feasible to dispose of the cuttings immediately back into the well as this would block the flow of gas. Furthermore, disposing of the drill cuttings into the well at the plugging and abandonment stage would not comply with the UK Oil and Gas guidelines (issue 4, 2012) minimum criteria for materials to successfully plug and abandon a well. Once the waste returns to the surface the waste does not undergo any significant changes due to above ground conditions.

Estimated quantities of bulk drilling muds waste are ~400m³ and drill cuttings are ~1400m³ (combination of polymer and salt saturated muds) per well.

Estimated quantities of both water-wet and oil-wet drill cuttings (cuttings containing residual muds) are ~1500m³ per well.

Estimated quantities of bulk drilling muds and drill cuttings waste are ~90m³ per sidetrack.

Appendix D provides indicative chemical characteristics of the waste drilling muds and cuttings.

5.2 Waste sand

Sand will be pumped into the target formation as part of the hydraulic fracturing fluid. Any sand returning within the flow back will be subsequently separated into a sand bin. The sand bin is located on the site well pad membrane. Once the waste returns to the surface it is not expected to undergo any significant changes due to above ground conditions. The estimated quantity of waste sand is 5-10 tonnes per well.

5.3 Waste flowback fluid and waste produced water

The overall quantity of waste flowback fluid and produced water generated during initial flow testing is estimated to be approximately 22,000m³ flowback fluid per site but may vary depending on geological conditions encountered during exploration period and hydraulic fracturing fluid composition (gel fractures cannot be reused). This is based on a 40% return rate. Once the waste returns to the surface it is not expected to undergo any significant changes due to above ground conditions.

As stated in section 5.7, the injected hydraulic fracturing fluid will mix with any produced water released from the formation by the fracturing process. If the well turns out to be predominantly water producing rather than gas (which is not expected at this site but remains a possibility), the combined volume of injected fracturing fluid and produced water flowing back to the surface could exceed the initial volumes of fluid injected.

The well is designed to prevent leaks into the surrounding receptors as well as formation fluid entering the well. Well integrity, as described in section 2.2.4, will be subject to integrity tests during drilling. The flowback fluid travels from the target formation via the wellbore into the surface pipework for reuse or temporary storage for transit to off-site disposal (if not needed for re-use in the fracturing process). Either vacuum suction tankers or road barrel containers transferred via a hose will transport the fluid from site storage containers into the haulage containers for offsite disposal.

The flowback tanks are monitored (see section 9.9) by gas detection equipment when receiving flowback fluid. The combined onsite storage capacity of individual flowback tanks equates to approximately 3000m³. The initial hydraulic fracturing phase shall require the overnight storage of fresh water, approximately 800m³ or less depending on the quantity of stored returning flowback fluid from previous hydraulic fractures stages.

Once the hydraulic fracturing stage is complete and initial flow testing phase begins, up to 3000m³ will be available for onsite temporary storage prior to off-site disposal at a permitted waste facility. The tanks are located on the well pad membrane and where possible secondary bunding providing further containment. The integrity of tanks and vessels is visually checked weekly and subject to annual thickness tests.

The well design incorporates a shut-off valve to immediately stop the flow of flowback water. A choke manifold will be used to reduce pressure to safe operating levels. Wellhead works design and procedures at the wellhead will be subject to HSE regulation.

We will visually monitor the level of fluid within the tanks and will shut off the flow when they reach their predetermined shut-off capacity.

Hoses and hose fittings will be regularly inspected to avoid detachment of hose assemblies during filling due to mechanical failure. Standard hose clamp fittings will be used for hose fittings to ensure secure liquid-sealed connection. Equipment will be hydro tested, or integrity tested, using clean water before initial operation to identify any leaks.

Flowback fluid samples will be analysed to assess naturally occurring radioactive material (NORM) and chemical concentrations. An RSR permit shall be applied for to manage the accumulation and disposal of NORM waste flowback fluid. Section 9.5.5 provides details of the chemical determinants which shall be tested.

5.4 Waste scale

The build-up of insoluble carbonate and/or sulphate scales inside pipes is a possibility due to a change in fluid pressure or temperature as the flowback fluid is brought to the surface. It is highly unlikely, due to the temporary nature of the operations that any or a material quantity of scale will build up inside the pipes. In the unlikely event that significant scaling of components occurs (and is identified via the proposed contamination monitoring regime), it shall be ensured that the pipework/component is capped/sealed to prevent release of material. Similarly, physico-chemical changes within the accumulating waters may lead to the formation of small volumes of precipitate, which could contain elevated concentrations of radionuclides. For the purposes of the Radioactive Substances Regulations (RSR) permit application, a worst-case scenario for low level waste (LLW) solids removal, which would partly constitute scale, has been calculated at $5m^3$ per well ($20m^3$ in total for the site). This material would be removed to a permitted waste facility.

5.5 Waste surplus natural gas

Flowback fluid initially bypasses the onsite separator before being temporarily collected in flowback tanks for measurement and storage until it can be reused in future fracture stages. In the unlikely event that the flowback fluid contains natural gas it will be diverted via the separator with any separated gas being sent to the flares for combustion in accordance with section 4.4.

The flare will be a fully enclosed steel design to incinerate waste natural gases. Depending on the manufacturer's requirements, up to two flares may be used on site. The flares will be subject to a 7 day commissioning period per well which would not count towards the site flaring limit of a maximum aggregate of 8,640 hours for all the wells at the site. The commissioning period starts when natural gas flows into the flare. The purpose of the commissioning phase is to allow the flaring system to be adapted to the natural gas composition, flows and pressures before the initial well test begins.

Since the feedstock is predicted to be clean natural gas, emissions from the flare are likely to be very low due to the use of best available techniques (BAT) as detailed in the Environment Agency sector guidance. The flare has been designed in principle to meet the standards described in section 3.5.2.6 of the guidance (BAT Reference Document cww_bref_0203 “Best Available Techniques in Common Waste Water and Waste Gas Treatment / Management Systems in the Chemical Sector), and with the intent that greater than 98% of methane will be converted to carbon dioxide, carbon monomers and water vapour.

The flare stack is a fully enclosed combustion chamber constructed of steel with a ceramic insulation to reduce heat loss and provide combustion silencing. Stack height is approximately 10 meters and is designed to operate unattended, however there will be 24 hour supervision on site.

It is anticipated that the flow rates per well of natural gas will be up to $130,000m^3$ per day. The retention time within the flare is 0.5 seconds for complete combustion. HSE-Permit-INS-PNR-002f provides examples of technical drawings of the proposed flare design. As the natural gas returns to surface the chemical composition of the natural gas does not change with exposure to above ground level conditions compared to below ground conditions.

An inlet pipe is connected to the flare with a main burner flame arrester and pilot flame for ignition. After the flare has been lit, air control is managed by louvres located on the side of the flare stack or equivalent air injection system. As the louvres open or air injection system circulates air, the flare fully ignites and the main gas valve will open.

5.6 Waste spacer fluid and suspension brine

Some spacer fluid may be incorporated into drilling muds for further use. The spacer fluid recovered at surface can normally be incorporated into the WBM system to the extent that the spacer has not become contaminated with the cement slurry behind it. The spacer fluid close to the interface with the cement slurry is therefore diverted to a separate tank for disposal.

When oil-based muds are used, a weighted, viscosified water-based spacer pill is not incorporated into the oil-based mud as it reduces the oil-water ratio of the emulsion and is subsequently disposed. However, when no longer required, spacer fluids returned to the surface are discharged into temporary steel storage tanks before off-site disposal. The storage tanks are located upon the well pad membrane. Once the waste returns to the surface it is not expected to undergo any significant changes as a result of exposure to above ground conditions.

The predicted quantity of surplus suspension brine has been estimated at 20-40m^3 per well.

The predicted quantity of surplus spacer fluid has been estimated at 20-40m^3 per well.

5.7 Retained waste hydraulic fracturing fluid

It is estimated that the volume of flowback fluid after each hydraulic fracturing stage returning to the surface will be in the range of 10-40% of the volume injected (Mitschanek et al, 2014). At this point the well should be producing predominantly natural gas and produced water from the formation.

It is possible that the vast majority of the injected hydraulic fluids will return to the surface over time. Equally it is possible that only a small proportion of the fracturing fluids will be returned and then the rest will remain in situ underground depending on the duration of operations. The injected hydraulic fracturing fluid will mix with any produced water released from the formation by the fracturing process. If the well turns out to be predominantly water producing rather than gas (which is not expected at this site but remains a possibility), the combined volume of injected fracturing fluid and produced water flowing back to the surface could exceed the initial volumes of fluid injected.

Some of the fluid remaining underground is expected to be reabsorbed into the rock within the target formation. The quantity that will remain in the rock is an estimate, largely due to the localised absorption rates within the target formation. However, the environmental risk posed by the retained non-hazardous hydraulic fracturing fluid is low as identified in the environmental risk assessment (HSE-Permit-INS-PNR-005). The retained hydraulic fracturing fluid becomes indistinguishable from connate water (water trapped in pores of the rock) already present in the target formation.

It is likely that a further proportion of the injected hydraulic fracturing fluids will remain inside the fractures created by the hydraulic fracturing process so long as they remain open or possibly in the well bore itself.

5.7.1 Accumulation of retained waste fluids

Whilst gas is allowed to flow, the water within the fractures and the well bore serves a useful purpose in allowing the gas to percolate out. However, at a point to be determined by Cuadrilla that flow testing operations at the well are to cease, the fluids remaining underground will be left in situ once the well is plugged and abandoned (including permanently sealing the well by insertion of a cement plug in at least part of the vertical section). The injected hydraulic fracturing fluid which has not returned to the surface will become waste when it no longer serves a useful purpose. It will remain permanently within the target formation.

It is not a practice in industry to attempt to remove the remaining fluids for disposal elsewhere and indeed no commercial solutions have been developed for this purpose. Indeed the depth and inaccessibility of the remaining fluids in the wellbore would make the cost prohibitive and there is no net environmental benefit of doing so.

By contrast, leaving the retained fluid deposited within the target formation presents a low risk to the environment. Each well will be plugged and abandoned by following prevailing industry guidelines (UKOOG guidance 2013, UK Oil and Gas guidelines for the suspension and abandonment of wells, issue 4, July 2012) and regulations (The Offshore Installations and Wells (Design and Construction) Regulations 1996, the Borehole Sites & Operations Regulations 1995). The ES contains further details on the plugging and well abandonment process.

Appendix C reviews options to remove or dispose of injected hydraulic fracturing fluid in accordance with BAT.

Permanently accumulating the fluid within the target formation is an environmentally sound option. Indeed, leaving the fluid retained in the formation is the best environmental option as there are no receptors of quality.

A number of studies have concluded that the potential for upward migration of hydraulic fracturing fluid that remains within the target formation is very low. Waste flowback fluid analysis from Preese Hall identified that the waste met the classification of a non-hazardous waste stream. The following literature extracts provide further evidence of why retained hydraulic fracturing fluid is a low risk to the environment:

- *If the formation minerals do not have sufficient water in their structure, they will trap and hold water from any available source until the minerals reach an irreducible water level. Water trapped in this manner may dry out again over geologic time through dry gas evaporation of the bound water, but is not likely to move during years of production. Water removed by dehydration will not transport chemicals, which will remain trapped in the rock. (King, 2012)*

- *Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine concluded that: As a result, upward migration of HF fluid and brine is controlled by pre-existing hydraulic gradients and bedrock permeability. We show that in cases where there is an upward gradient, permeability is low, upward flow rates are low, and mean travel times are long (often >10^6 years [10,000,000 year]). Consequently, proposed rapid upward migration of brine and HF fluid, predicted to occur as a result of increased HF activity, does not appear to be physically plausible (Flewelling and Sharma, 2013).*

For fluid to migrate via advection up to shallow groundwater along faults and discontinuities, the following conditions would be required which are absent from the site.

- *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). The potential for upward fluid migration is considered very low. In the worst case, fluid could migrate along the fault plane, but this would be limited due to the presence of impermeable formations above the Bowland Shale (Styles et al, 2012).*

Leaving the fluid retained in the formation is the best environmental option as there are no receptors of quality or pathways readily available for the fluid to create a risk to the environment.

5.7.2 Location of retained waste fluid deposit

Retained hydraulic fracturing fluid is subject to several geo-chemical influences of how fluid behaves in the target formation. Drawing HSE-Permit-INS-PNR-002g identifies a prudent area designated for disposal of retained hydraulic fracturing fluid.

Fluid and solids (sand) can be absorbed into the rock immediately surrounding the fracture or remain within the fracture itself. Due to the relative impermeability / conductivity of the target formation, the retained hydraulic fracturing fluid remains in close proximity to the fracture, a matter of feet. The fluid is unable to migrate and present a risk to environmental receptors due to the low permeability of the target formation.

5.7.3 Classification of the waste retained fluid

Retained waste hydraulic fluid to be accumulated underground is classified for the purpose of the Mining Waste Directive as non-hazardous. It will over time be indistinguishable from connate water already in the target formation.

In addition, to address public concern regarding the nature of fluids left underground we have considered the likely nature of the retained fluid and concluded that it is not likely to exhibit any of the hazardous properties listed in Annex III of the revised Waste Framework Directive.

We considered the ability of fluid to absorb methane. According to the International Union of Pure and Applied Chemistry, methane solubility in (pure) water at STP is 3.12 x 10^{-5} mole/mole (or mole fraction). This works out at 27.7 mg CH_4/litre of water, correcting for salinity would put this between 22 – 25 mg/l. As such this content of methane in the retained hydraulic fracturing fluid (accounting for brine or freshwater) would not render the retained fluid hazardous. As a result, if one litre of this fluid was taken to the surface it would contain 22 mg - 25mg of methane. If this methane was released into a litre of air it would still not burn as the lower flammable limit is 5% by volume (22 mg equates to about 0.002% in air by volume). Liquid substances and preparations would only be hazardous due to being flammable if they have a flash point equal to or greater than 21°C and less than or equal to 55°C. This fluid is therefore not flammable.

Our conclusion is also supported by the testing of flowback fluid containing the naturally occurring connate water from our Preese Hall site, which did not identify any of the hazardous properties listed in Annex III of the revised Waste Framework Directive. A screening exercise was undertaken which assumed (worst-case) that the natural mineral contaminants (see Appendix B) are present in their most dangerous form to people and in the aquatic environment. We then compared it with the aggregate, known quantity of these contaminants and compared the result with the lowest applicable threshold of 0.1% (1,000mg/l) above which they could render the waste hazardous. The total concentration of potentially harmful contaminants did not exceed 0.001% and therefore the waste was classified as non-hazardous.

5.8 Storage arrangements

Table 5 provides a summary of storage types, capacities and expected maximum volumes for each waste stream.

Table 5: Storage of waste types

Waste type	Estimated volume	Storage type	Capacity
Drilling muds / cuttings	2900m³ per well (400m³ spent drilling muds, 1400m³ drill cuttings and 1100m³ water wet and oil wet drill cuttings per well).	Steel containers (thickness testing with annual non-destructive testing inspection)	Subject to contractor selection multiple steel skips (~50m³) depending on rig selection and mud circulation system. Drill cuttings and spent mud wastes will be regularly removed to an offsite permitted waste facility.
Flowback fluid (not a waste stream due to reuse) Produced fluid	Up to 22000 m³ per site (during initial flow test period), 10m³ per day per well (during extended well test period)	Steel tanks subject to thickness testing with annual non-destructive testing inspection	Up to 3000 m³ on site any one time. Regularly removed to an offsite permitted waste facility. Up to 140m³ regularly removed to an offsite permitted waste facility.
Retained fracturing fluid	~16,000m³ to ~24,000m³	Geologic shale formation	Variable capacity based on geochemical influences.
Sands	5-10 tonnes per well	Skips or steel containers	Subject to contractor selection ~10-20m³ steel containers. Regularly removed to an offsite permitted waste facility.
Suspension brine/ spacer fluid	20-40m³ per well (suspension brine) 20-40m³ per well (spacer fluid)	Steel tanks subject to thickness testing with annual non-destructive testing inspection)	Storage capacity is flexible. Typically 5m³ storage tank up to larger 25m³ storage tanks. Removed to an offsite permitted waste facility
Surplus natural gas	Estimated 30,888 tonnes per year	Flared to atmosphere.	Maximum 130,000m³ per day
Scale	5m³ per well	Inside the pipe network.	Not applicable as scaled equipment is removed off site for treatment.

6.0 Competency

The management arrangements (HSE-Permit-INS-PNR-004) details the roles and responsibilities for onsite environmental management and monitoring. Cuadrilla's site supervisor has overall responsibility for ensuring that the operations conducted on the site are in compliance with environmental permits and other associated legislation and is the competent person who manages the mining waste facility.

The Environmental Manager is accountable for maintaining compliance with the environmental permit and ensuring that adequate and competent resources are in place to provide technical support and training to the site operations teams. The Environmental Manager has appointed an Environmental Advisor, to advise and support the Installation Manager that the conditions of the environment permit are adhered to.

'Competent person' qualifications will include the following:

- Academic qualifications;
- Professional qualifications e.g. membership of applicable institutions;
- External training qualifications / certification;
- Those with approved training to cascade training to other staff;
- Attendance / delivery of internal and external training courses; and
- Applicable industry work experience

based on Environment Agency guidance Control and monitor emissions for your environmental permit (on Gov.uk).

As part of Cuadrilla's competency framework, key posts have been identified within Cuadrilla and its supply chain that are either safety or environmentally critical. These roles have defined minimum competency requirements which are assessed during recruitment and developed through ongoing professional development.

A contractor will be selected to manage the day to day waste operation. Section 9.0 of the management arrangements sets out the commitment to train staff, contractors and consultants with the technical requirements and compliance arrangements for the permit conditions and environmental management.

Cuadrilla's employees, contractors and consultants will be provided with appropriate training that is relevant to their needs. The training needs are identified through risk assessment, role profiles and the requirements for delivering Cuadrilla's Environmental Policy.

Relevancy will be determined by reference to the Cuadrilla training matrix which has been developed to ensure the right person with the right competence is in the right role.

Where gaps are identified, a training needs analysis will be conducted, and the training matrix updated to reflect the changes. This will be reviewed and updated as required with refresher training. Records of training will be kept in accordance with Cuadrilla written management procedures.

7.0 Environmental risk assessment

7.1 H1 risk assessment

An environmental risk assessment (ERA) (HSE-Permit-INS-PNR-005) was prepared for the activity in support of the application for the environmental permit. These risk assessments have been reviewed and revised in line with the Environment Agency guidance on risk assessments for environmental permits (on gov.uk),

This qualitative risk assessment considered odour, noise, fugitive emissions, dust, air emissions, releases to water environment, waste, global warming potential, and potential for accidents and incidents as they relate directly to the activities.

The assessment concluded that with the implementation of the identified risk management measures, potential hazards from the activities would not be significant.

We will implement the identified risk management measures unless otherwise agreed by the Environment Agency or with any necessary modifications in the case of an emergency.

7.2 Guide to how we score risk in the context of our ERA

The ERA (HSE-Permit-INS-PNR-005) provides details of the activities and situations that could give rise to harm, and describes what this harm could be if no mitigation measures are in place – i.e. the worst-case scenario. It then goes on to score the risks with the planned risk control measures in place, where the initial risk rating is calculated as:

Likelihood that harm will occur x the severity of the Consequence if it does = Risk

Consideration is then given to implementing additional mitigation measures, and the residual risk rating is calculated – this is the remaining level of risk after all identified risk control measures have been implemented.

It should be noted that the aim is to reduce risks to an acceptably low level, but that it is not always possible to entirely eliminate risk altogether.

8.0 Risk mitigation

The ERA (HSE-Permit-INS-PNR-005) details the proposed risk control and mitigation measures that Cuadrilla will put in place at the PNR well pad.

9.0 Control and monitoring

The ERA (HSE-Permit-INS-PNR-005) coupled with the findings of the site condition report (HSE-Permit-INS-PNR-003), demonstrates that due to the nature of the waste to be generated and the proposed risk control and mitigation measures, there will be no significant risk from mining waste streams or any related emissions at the site.

9.1 General management

To ensure that the commitments and mitigation measures outlined within the waste management plan (WMP) are delivered on site, relevant management and operational staff, which includes contractors, shall be briefed on the requirements of the WMP and the ERA with the aim of preventing impacts from the mining waste activity.

Inspections shall be carried out in accordance with Cuadrilla's audit and inspection plan, these will include a combination of daily, weekly, monthly or annual inspections to document standards of compliance with the WMP in accordance with the prevailing operations at site.

The accompanying ERA and control procedures shall be updated in the event of a change in activities on site.

Construction and management of the underground mining waste facility at the site shall be to the regulatory requirements of the HSE (the Borehole Sites and Operations Regulations 1995 and the land-based requirements of the Offshore Installations and Wells (Design & Construction etc) Regulations 1996). In addition, the guidance set out by UKOOG entitled 'UK Onshore Shale Gas Well Guidance' will also be observed. The seismic monitoring programme and hydraulic fracturing plan prepared for the regulators will also be relevant to the integrity of the underground mining waste facility.

Training shall be provided for site personnel in the knowledge and skills required to ensure technical competence for the extractive waste management tasks for which they are responsible.

9.2 Security arrangements

The site is surrounded with a 4m high sound wall with anti-climb fencing and 24hr security who patrol the site.

Site security will be managed by a security contractor. Guarding arrangements will be in place to monitor and check the movement of vehicles and personnel accessing site.

In the unlikely event of a security breach, the Site Supervisor will follow the site shut down procedure to prevent unauthorised access to safety critical equipment and operational controls. This procedure will be available for inspection by the Environment Agency.

Cuadrilla operates in close co-operation with enforcement agencies to monitor and assess the risk of security to the site.

9.3 Environmental management and monitoring plan (EMMP)

The EMMP sets out the measures and processes for the management of environmental aspects of the project and to mitigate the potentially significant effects identified in the ES. The EMMP is a document which is intended to be used by site operatives to manage the environmental aspects of the project on a day-to-day basis. Records of monitoring and inspections will be kept within the EMMP alongside Cuadrilla's electronic management system.

The EMMP includes any management and monitoring requirements set out in the conditions attached to any planning consents. It also addresses the monitoring requirements of the environmental permits from the Environment Agency including groundwater and surface water, the interpretation of monitoring data and procedures in the case of abnormal monitoring results. All other relevant conditions imposed by OGA are addressed in the EMMP.

9.4 Environmental accidents

The potential for spillage on-site of extractive wastes or the unlikely potential of fire from flammable natural gas has been assessed as part of the ERA. Frequent checks of waste containers will be made by the operatives on waste containers with a view to preventing an overspill. Site HSE checks are also undertaken by the Site Supervisor and Site HSE advisor to assess for any damage to waste receptacles, as well as pipes and equipment handling extractive wastes. There will be a requirement to report any identified non-conformance that could lead to an extractive waste causing an accident as soon as possible to the Site Supervisor to action and close out the non-conformance. The action to close out the non-conformance shall be tracked using internal Cuadrilla procedures.

Additionally, the site is constructed with a large well pad membrane providing spillage containment. As the site is not situated in a source protection zone (with no potable water abstraction activities in the site boundary or immediately nearby) the ERA has concluded the risk of contamination of upper groundwater receptors to be low. As part of the site pollution incident plan, any spillages shall be documented to inform the future site restoration plan and sampling regime.

Integrity of the well pad membrane shall be checked during its installation by a competent contractor. The membrane is protected by an upper layer of protective felt and coarse gravel (Type 1). These barriers are designed to help prevent tears to the membrane. In addition no spikes or excavation work are permitted during operations without prior approval from the Cuadrilla Site Supervisor.

Although very unlikely, there is also the potential for the escape of natural gas between the wellhead and the flare when fluid is flowing back from the well post-fracturing. As required under the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002, any areas that have the potential for any unplanned leak of natural gas are protected within designated zones. Within the designated zone equipment and protective systems shall be used so as to prevent sources of ignitions. Additionally methane alarms are positioned around equipment containing or handling natural gas. If any alarm goes off, well site emergency procedures will be started and the well will be made safe to prevent further gas flow. Visual inspection of pipework and flow testing equipment will occur daily for leaks and damage during initial well testing and then moving towards a monthly/bi-monthly check during extended well testing.

The results of this monitoring will be recorded and the relevant sections of the site condition report (HSE-Permit-INS-PNR-003) will be updated accordingly and will inform the future monitoring for the site closure plan.

As part of Cuadrilla's environment management system, a site specific pollution incident plan (PIP) will be developed based on site specific activities and risk assessment in accordance with industry guidance and best practice. The ERA details a number of control measures to manage pollution incidents e.g. access to spill kits, emergency response contractors.

A range of scenarios detailed within a HAZID (HAZard IDentification) study will be produced and documented before operations begin. As contractors are selected, the HAZID and PIP documentation will be finalised based on site specific information.

Site specific emergency procedures and crisis management procedures are documented within Cuadrilla's management system should an event escalate beyond the capabilities of the site management.

9.5 Extractive waste monitoring

9.5.1 Drilling muds, drill cuttings

Every extractive waste load dispatched off site for disposal shall be documented and recorded. This data will be used to track and quantify extractive waste streams leaving site. Fluid and solid drilling waste will be sampled at the well site on the first day when drilling commences. Following this initial sample, samples alternating between solids and fluids or combination of solids and fluids (slurry) will be taken once during the top hole section (WBM) and once for the bottom hole section (LTOBM) for the remainder of the work programme. Further sampling maybe required if there is a change in process which could impact the classification of the waste stream. The chemical composition shall be submitted to a UKAS accredited laboratory for chemistry analysis. Changes in the chemical profile of the waste will inform decisions concerning future waste management arrangements and environmental risk control measures, as well as sampling and testing frequency.

9.5.2 Suspension fluid/spacer fluid

Every waste load dispatched off-site to an authorised waste facility for disposal shall be documented and recorded.

9.5.3 Sand

Every waste load dispatched off-site to an authorised waste facility for disposal shall be documented and recorded.

9.5.4 Flowback fluid

Sampling of the flowback fluid has been designed to ensure repeatable and representative samples are taken to inform re-use and off-site waste disposal. The sample location is taken post-separator. The sampling plan forms part of Cuadrilla's management system and will be updated depending on the configuration of the flowback tanks and operational phase. In summary the following principles will apply:

- The sampling plan will cover intermittent flow e.g. flowback during hydraulic fracturing, well slugging or nitrogen lifting (intermittent flow). Steady state flow when flowback is continually returning to the surface e.g. nitrogen lift (steady flow) or flow to flare.
- Sampling will take place at three horizons of the flowback tank
- Sampling will only take place once the tank(s) are full
- The quantity of sample will be subject to the laboratory requirements but as a guide approx. 8 liters per tank
- As a body of analytical data is created, as flowback is generated, it may be appropriate to increase the bulk volume of material from which the representative 8 litre sample is taken (weekly or monthly sampling), assuming that the physicochemical and radioactive properties are considered/expected to be uniform (i.e. no significant variation e.g. liquid hydrocarbons present or potential changes in operations which could affect the physicochemical and radioactive properties). This change (to weekly or monthly sampling) will be discussed with the Environment Agency before implementing.

The chemical composition will be submitted to an independent UKAS accredited laboratory for wet-chemistry analysis. See Table 6 for determinants. The results will be recorded and distributed to the permitted waste treatment facility and to the Environment Agency.

Table 6: Indicative flowback determinants

Determinants
Free ammonia
pH
Alkalinity as $CaCO_3$
Suspended solids
Dissolved solids
Chemical oxygen demand (COD)
Biological oxygen demand (BOD)

Determinants
Heavy metals
Fluoride
Chloride
Sulphate
Nitrate
Total volatile organic compounds (TVOCs)
Naturally occurring radioactive material (NORM)

9.6 Surplus natural gas

Emissions resulting from the complete combustion of natural gas include carbon dioxide and water vapour. Monitoring of the flare temperature and surrounding site ambient air quality shall be routinely undertaken before, during and after operations. The temperature of the flare shall burn above 800°C to ensure complete combustion.

9.6.1 Air quality

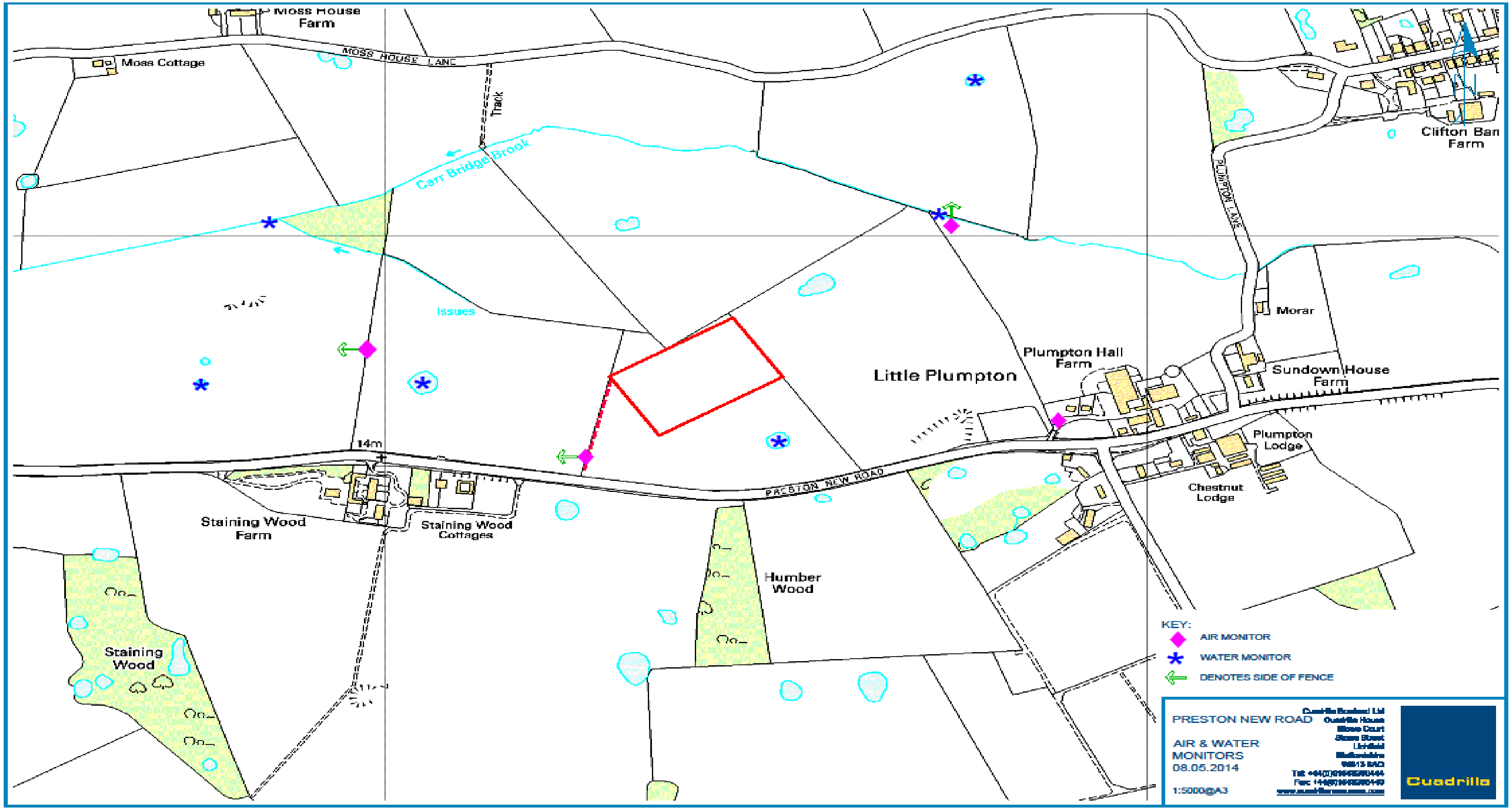
The temperature of the flare shall be monitored using thermocouples. The temperature data shall be recorded continuously during flow testing.

Temperature readings shall be wired from the thermocouples and recorded via panel indicator detailing the temperature of the flare. The panel shall be accessible at all times located at a suitable distance away from the flare so operatives have access to inspect the panel at all times.

A substantial body of representative monitoring data has been collated demonstrating no significant changes between baseline conditions and results gathered during active operations (including drilling, hydraulic fracturing and initial flow testing). As detailed in the site's EMMP (Version 5.1) an improved continuous monitoring regime has been implemanted at the site. The ongoing range of air quality monitoring undertaken around the site has been revised accordingly. A summary of the evidence justifying this measure is included in HSE-Permit-INS-PNR-014 Summary of environmental monitoring at Preston New Road (January 2019).

The sampling positions were selected based on independent consultation with Socotec (formerly known as Environmental Scientific Group (ESG)). The monitoring will incorporate the below determinants and locations illustrated in Figure 4.

Figure 4: Air quality and surface water monitoring points



Access to the sampling facilities shall be maintained throughout the baseline and operations to enable easy access.

The EMMP shall detail the monitoring requirements. In the event that the mobile monitoring equipment identifies significant changes to air quality from the baseline, more frequent sampling shall be conducted in consultation with the Environment Agency.

The following determinants in Table 7 below are to be monitored at the site.

Table 7: Air Quality Determinants

Determinant	Justification	Measurement method
Hydrogen Sulphide (H_2S)	Potential odour nuisance	Diffusion Tube
BTEX	Environmental accumulation potential and persistence Greenhouse gas Potential odour nuisance Precursor to ground level ozone Stratospheric ozone depletion	Diffusion Tube

As per the Cuadrilla EMMP (CORP-HSE-PLN-002) results shall be published on a monthly basis and will be available on the Cuadrilla website, as well as submitted to the necessary regulatory authority.

In the unlikely event of results indicating changes indicative of a potentially significant effect, there will be an immediate investigation into the reliability of the data as a first protocol e.g. checking calibration dates, tampering of samples, and deviations from laboratory procedures.

If further sampling indicates a trend of continued variation relative to baseline data and air quality standards then the operations shall be suspended to investigate and remediate the causes if they are linked to the on-site operations.

9.7 Odour

Based on prior experience, the extractive waste that will be generated is not malodorous and nor are any of the associated processes that will be performed.

9.8 Noise/Vibration

Road tankers visiting the site to collect extractive waste may be fitted with audible reversing alarms. Noise levels will be managed to ensure compliance with planning condition levels.

The assessment of noise is modelled within the ES assuming two temporary flares operating simultaneously. Noise from the flares is low (less than 20dBLAeq) at all dwellings, during both daytime and night time operation is therefore assessed as a not significant effect. Noise monitoring will be employed to ensure that noise emissions are controlled during operations.

9.9 Fugitive emissions

The following mitigation measures will be enacted to ensure that any fugitive gas emissions are reduced to as low as reasonably practical.

Prior to flowing natural gas, a hydro test is completed of all surface pipework. This requires the filling with water of all pipes and connections and applying hydraulic pressure to establish any leaks present. If the pipework or connections exhibit leaks then immediate maintenance is conducted to fix the leak. Only when the hydro test does not identify any leaks will the site supervisor accept the flow testing equipment.

The following table (Table 8) provides an overview of potential surface equipment which will be monitored during operations. Until the pad surface equipment is configured an assessment will be carried out to establish how the monitoring shall be implemented.

Table 8: Potential surface equipment to be monitored

Surface equipment	Determinant	Monitoring equipment
Well Head Pipe work and connections (e.g. flanges) Choke Manifold Separator Flow back tanks Flare system	Methane + higher chain Hydrocarbons	Infrared (IR)

Methane emissions shall be monitored using a (IR) monitoring device which measures to levels of 1ppm. The device shall be deployed in accordance with the EMMP during flow testing. The EMMP forms part of the Environment Operating Standards. If the results identify no significant changes to baseline levels for fugitive methane emissions the frequency of monitoring shall be reduced in consultation with the Environment Agency. The IR device shall be ATEX approved and MCERTS accredited, or equivalent.

The Environmental Risk Assessment has concluded any quantities are expected to be very minor and consequently pose a low environmental risk.

Access to the equipment will be available throughout flow testing subject to health and safety requirements.

The monitoring shall be performed in accordance with Cuadrilla's EMMP; the results shall be benchmarked against baseline results. In the unlikely event of significant elevated methane levels above baseline, there will be immediate investigation into the reliability of the data as a first protocol e.g. checking calibration dates, tampering of samples, and deviation from laboratory procedures.

If a trend of continued and significant variation to baseline data is identified, the operations shall be shut in or stopped to investigate the potential causes of the impacts. The results shall be documented in a monthly report and published on the Cuadrilla website.

9.10 Groundwater

The ERA, provides a three dimensional approach to identifying risk to groundwater (Source, Pathway, Receptor) based on DEFRA Greenleaves III guidance. Groundwater monitoring infrastructure was installed in July 2016 in order to monitor changes in water quality and natural gas levels.

Four monitoring wells have been installed along the site perimeter fence line and located targeting shallow groundwater formations. The design and execution of the monitoring wells are detailed within permit pre-operational measures PO4 and PO7.

9.10.1 Groundwater monitoring borehole installation summary

The previously submitted PO4 Groundwater Monitoring Plan (HSSE-PLN-SITE-001 PNR) (pursuant to the permit pre-operational measure) details the target horizons, depths and locations based upon the site conceptual model in section 4.0 of the Groundwater Monitoring Plan. A total of four boreholes have been installed at the Preston New Road site, of which three are dual installations and one is CMT (multi channel)

Table 9 below provides a summary of the boreholes installation (the references to sections are to sections in the Groundwater Monitoring Plan).

Table 9 - Boreholes Installation Details

Borehole designation (Reference)	Installation type	Gasclam® installed	Bladder pump installed	Levelogger ® and Barologger ® installed	Supporting information
BH01 (A)	Dual nested	Yes	Yes	No	Twin headworks design (see section 3.1)
BH01 (B)	Dual nested	Yes	Yes	Yes	Twin headworks design (see section 3.1)
BH02 (A)	Dual nested	No (see supporting information)	Yes	No	Artesian (limited headspace for GasClam®)
BH02 (B)	Dual nested	No (see supporting information)	Yes	No	Artesian (limited headspace for GasClam®)
BH03 (CMT)	CMT	Yes	No (see supporting information)	No	Not compatible with bladder pump systems
BH04 (A)	Dual nested	Yes	Yes	No	Twin headworks design (see section 9.2)
BH04 (B)	Dual nested	Yes	Yes	No	Twin headworks design (see section 9.2)

9.10.2 Deviations from PO4 Groundwater Monitoring Plan (HSSE-PLN-SITE-001 PNR).

During drilling groundwater strikes were identified in the Boulder Clay (Glacial Till), so boreholes BH01, BH02 and BH04 were completed as dual nested boreholes with individual downpipes (shallow and deep). The targeted response zones (RZ) and supporting construction information for each boreholes can be found in Table 10.

Borehole BH03 utilises the CMT system as detailed in the previously submitted PO4 Groundwater Monitoring Plan (HSSE-PLN-SITE-001 PNR) due to the encountered geology having multiple horizons to target. Subsequently this was favourable for the multichannel design of the CMT rather than a dual installation. The CMT system was installed within a single casing string with screened sections targeting the Middle Sands and

Boulder Clay (Glacial Till) along with a number of individual geological strata unique to this location. The design of the CMT system allows individual channels to be 'plugged' and isolated facilitating the targeting of specific RZs. The targeted RZs for BH03 (CMT) can be found in Table 10.

GasClams® have been installed within three of the boreholes (BH01, BH03 and BH04) to continually monitor headspace methane (CH_4) and carbon dioxide (CO_2) levels, as well as providing temperature, atmospheric and borehole pressure data. Boreholes BH02 does not have GasClams® installed due to its artesian nature with its potentiometric head being approx. 0.47m above ground level. Subsequently the amount of headspace between the GasClam® and the potentiometric head is significantly reduced for the GasClam® to monitor effectively.

Boreholes BH01, BH02 and BH04 have permanently installed bladder pumps to provide an undisturbed groundwater sample. Boreholes BH01 and BH04 have been redesigned in order to accommodate both GasClams® and bladder pumps in the above ground headworks.

BH01 (B) utilises a Barologger® which measures absolute pressure (water pressure + atmospheric pressure) and a Levelogger® which records conductivity, water level and temperature.

Table 10 – Response zones

Boreholes designation (Reference)	Response zone
BH01 (A)	Response zone (RZ) at: 9-12m bgl to target Glacial Sands.
BH01 (B)	Response zone (RZ) at: 27.0-30.0m bgl to target bottom of Middle Sands.
BH02 (A)	Response Zone (RZ) at: 9.0-11.3m bgl to target Glacial Sands.
BH02 (B)	Response Zone (RZ) at: 21.0-26.0m bgl to target mid to lower section of Middle Sands.
BH03 (CMT)	Response zones (RZs) at: Channel 1 port at 12.6m bgl - Targeting upper layer of dense sandy, clay and gravels. Channel 2 port at 13m bgl - Targeting lower layer of dense sandy, clay and gravels. Channel 3 port at 15.8m bgl- Optional sampling (see section 3.2.1.2) Channel 4 port at 16.3m bgl – Optional sampling (see section 3.2.1.2) Channel 5 port at 20.3m bgl – Targeting upper layer of Middle Sands Channel 6 port at 25.3m bgl – Optional sampling (see section 3.2.1.2) Channel 7 port at 26m bgl - Permanently Plugged (see section 3.2.1.2)
BH04 (A)	Response zone (RZ) at: 16.6-19.5m bgl to target upper sections of Glacial Sands.
BH04 (B)	Response zone (RZ) at: 22.0-24.8m bgl to target lower sections of Middle Sands.

9.10.3 Supporting information relevant to groundwater sampling

The below sections provide additional information relevant to the sampling programme and the interpretation of groundwater samples.

9.10.3.1 Sample programme BH03 (CMT)

The CMT system installed is designed to allow detailed discrete zone groundwater data to be obtained via the seven multichannel system. Following installation and development of the boreholes the defined sampling program has been formulated.

9.10.3.2 Sample programme BH03 (CMT)

The use of a peristaltic pump rather than a micro double value pump shall be used to obtain the required groundwater for analysis. This is a change to the original design due to the groundwater having high turbidity levels. Subsequently the micro double valve was ineffective in lifting the quantity of groundwater required for representative analysis.

However in the event that over a prolonged period of sampling the groundwater is identified (visually) to be running clear the use of a micro double valve pump remains an option to obtain future samples.

9.10.3.3 Sample programme BH03 (CMT)

The following sampling methodology will be used to gather groundwater quality data based on the geological formation being targeted.

In line with the PO4 Groundwater Monitoring Plan (HSSE-PLN-SITE-001 PNR) the priority is to sample from the Upper Gravels and Middle Sands. Such an approach provides consistency with the monitoring being undertaken at the remaining boreholes (BH01, BH02 and BH04) which utilise in-situ bladder pumps.

Upper Gravels (12-13.3m bgl)

Port 1: Dissolved gases only.

Port 1&2: Composite sample to gather groundwater quality data.

Upper Sands with Clay Lenses (15.1-19.2m bgl)

Port 3: Dissolved gases only, however previous attempts to flow from this port have not provided a suitable volume of water to sample effectively.

Port 3 & 4: Composite sample of groundwater quality only, however previous attempts to flow from these ports have not provided a suitable volume of water to sample effectively.

Due to the difficulty obtaining the required volume of waters from ports 3 and 4 further attempts will continue to be made until it is deemed impracticable to gather viable samples. Any such changes will be officially communicated via PO8 as detailed within Table S1.3 Pre-operational Measures (Permit EPR/AB3101MW).

Middle Sands (19.2- 25.4m bgl)

Port 5: Dissolved gases and groundwater quality.

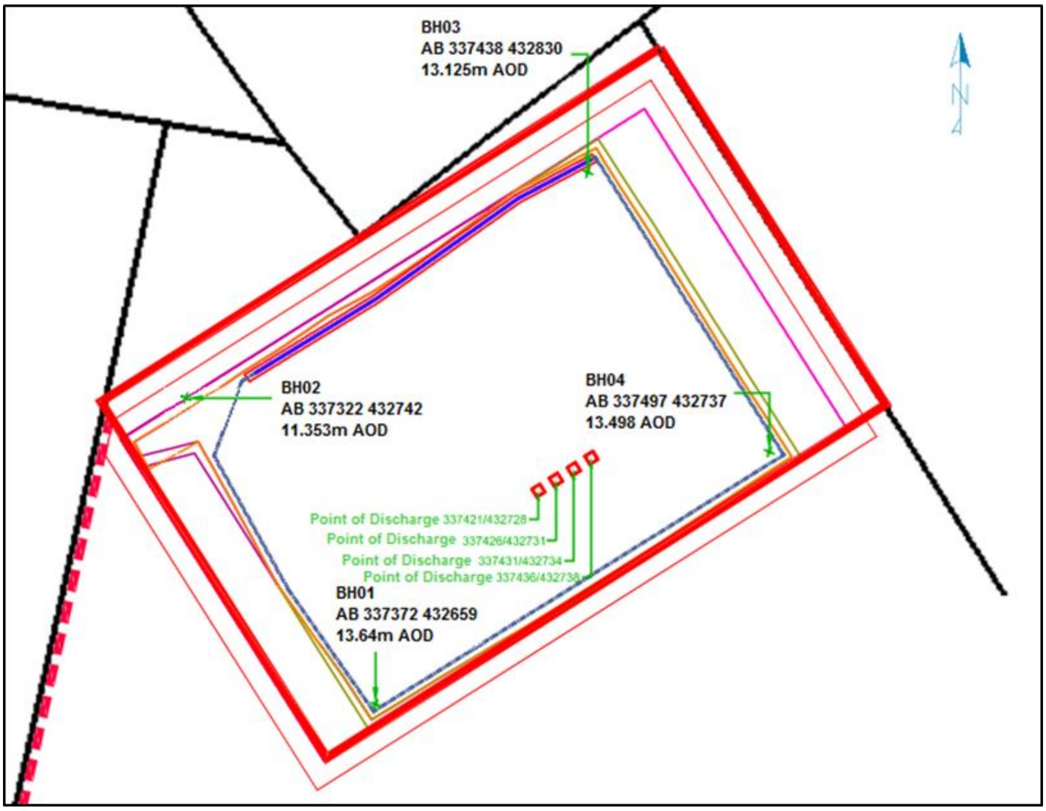
Port 5&6: Composite sample of groundwater quality only.

Due to the difficulty obtaining the required volume of waters from port 6 (as with Ports 3 and 4) attempts will continue to be made until it is deemed impracticable to gather viable samples. Any such changes will be officially communicated via PO8 as detailed within Table S1.3 Pre-operational Measures (Permit EPR/AB3101MW).

Boulder Clay (Glacial Till) (25.4 – 26.6m bgl)

Port 7: Has been permanently plugged due to the artesian flow. The CMT system does not allow the addition of a 'through flow adaptor plug' for the centre channel (channel 7).

Figure 5: Preston New Road Boreholes Locations, National Grid References and Elevation AOD



9.10.3.4 Groundwater monitoring borehole location summary

The locations, national grid references and elevations AOD for all four boreholes at the PNR site are identified in Figure 5 above. BH03 and BH04 designations and locations have been updated following the original submission of the Waste Management Plan (HSE-Permit-INS-PNR-006) due to the geological conditions encountered during installation. The point(s) of discharge from the site are also shown. Table 11 summarises this information.

Table 11: Borehole locations

Borehole Designation (Reference)	Easting	Northing	SD Grid Reference (As detailed within Permit EPR/AB3101MW)	Elevation (m AOD)
BH01 (A&B)	337372	432659	SD 37373 32666	13.64
BH02 (A&B)	337322	432742	SD 37487 32739	11.353
BH03 (CMT)	337438	432830	SD 37435 32820 (to be updated)	13.125
BH04 (A&B)	337497	432737	N/A	13.498

9.10.3.5 Borehole construction summary

Table 12 summarises the construction information for all four groundwater monitoring boreholes at the PNR site. Information includes details regarding casings/linings (lengths, diameter, material, type of grout or filter media and whether slotted or plain).

Table 12 Borehole construction summary

			BH01		BH02		BH03	BH04	
			Shallow	Deep	Shallow	Deep	CMT-7	Shallow	Deep
		unit							
Borehole diameter	300mm	m	none		none		7.0	4.0	
	200mm	m	19.0		7.0		19.0	16.5	
	150mm	m	33.0		30.0		26.6	25.8	
Final depth		m	33.0		30.0		26.6	25.8	
Casing/liner/ well	Material		HDPE	HDPE	HDPE	HDPE	CMT-7	HDPE	HDPE
	OD/ID Diameters	mm	63/51	63/51	63/51	63/51	43 (OD)	63/51	63/51
	slotted/screen length (0.75mm slot)	m	9.0-12.0	27.0-30.0	9.0-11.0	21.0-26.0		16.5-19.5	22.0-24.8
	plain length	m	gl-9.0	gl-27	gl-9.0	gl-21.0		gl-16.5	gl-22.0
	annulus fill - Mikolit	m	gl-8.5	12.0-26.5	gl-8.5	11.0-21.0	Remainder of hole	gl-16.0	19.5-21.5
	annulus fill - filter sand 1-	m	8.5-12.0	26.5-30.0	8.5-11.0	20.5-26.0		16.0-19.5	21.5-24.8
	collapsed	m		30.0-33.0		26.0-30.0			24.8-25.8
	response zone 4 (filter sand 1-	m					12.2-13.5		
	port 1	m					12.6		
	port 2	m					13.0		
	response zone 3 (filter sand 1-	m					15.4-16.7		
	port 3	m					15.8		
	port 4	m					16.2		
	response zone 2 (filter sand 1-	m					19.7-21.0		
	port 5	m					20.3		
	response zone 1 (filter sand 1-	m					23.6-26.0		
	port 6	m					25.3		
	port 7	m					26.0		

Groundwater monitoring borehole unlined sections

All four boreholes at PNR were constructed with no unlined sections.

Strata encountered

Borehole logs detailing the strata encountered at all four boreholes at the PNR site can be found in Appendix B (section 10.0). Appendix C provides the site lithology which is relatively consistent with the predicted site conceptual model in PO4 identifying an upper layer of Boulder Clay and deeper Middle Sands receptor.

Groundwater ingress and groundwater levels on completion

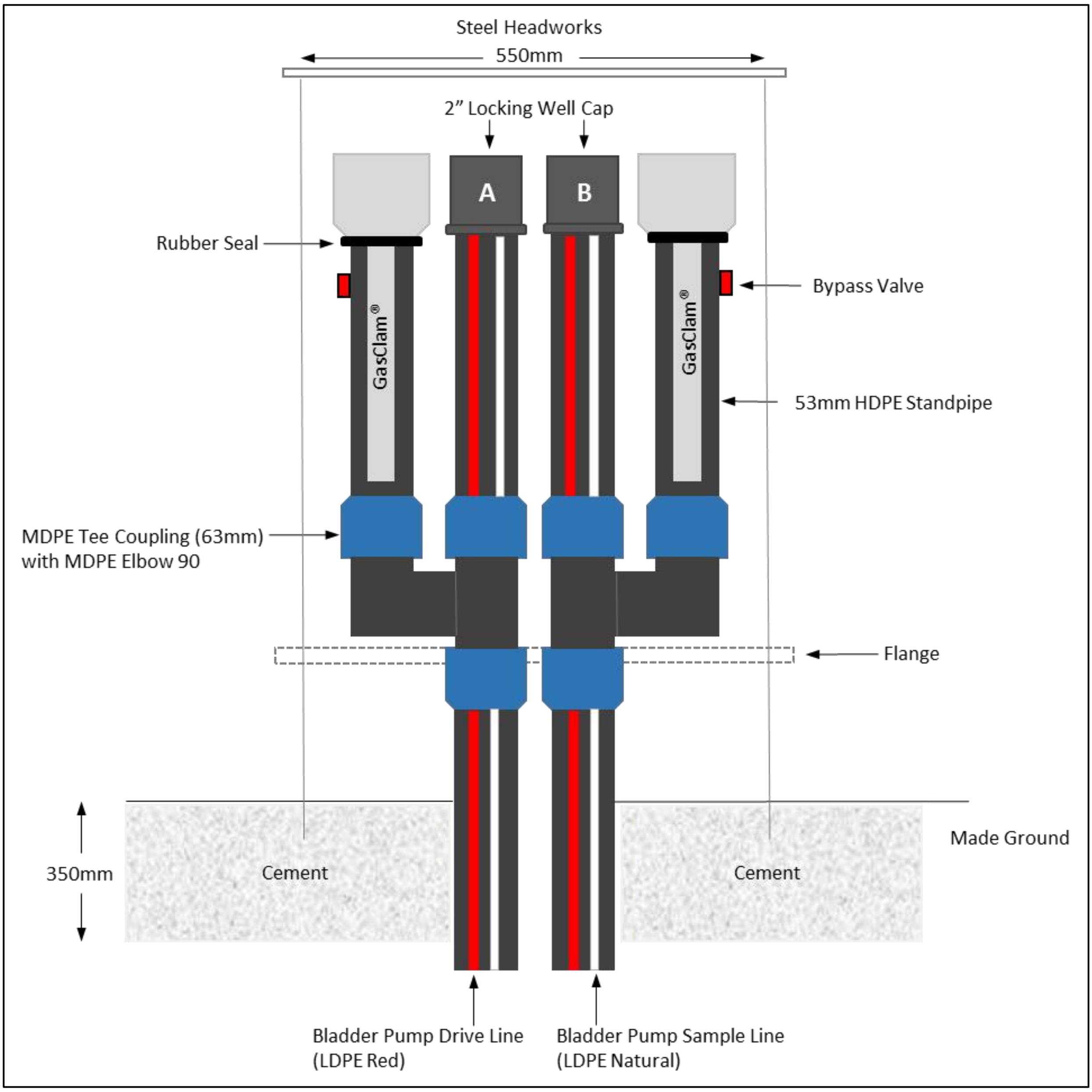
Table 13 details groundwater ingress (strikes) during construction along with standing groundwater levels post completion.

BH02 potentiometric surface is approximately 0.48m AOD and is deemed to be artesian.

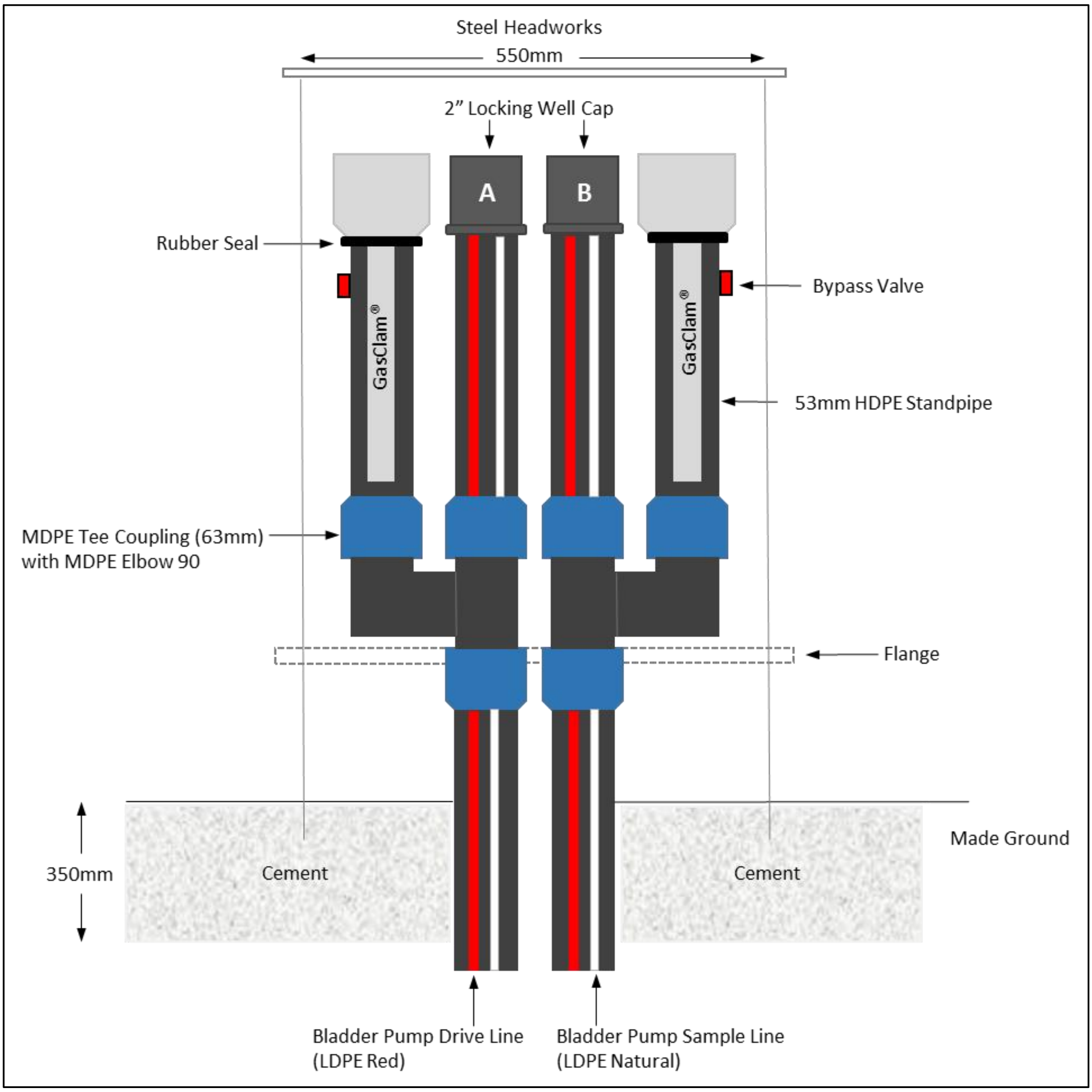
Borehole designation (Reference)	**BH01**		**BH02**		**BH03 (CMT)**	**BH04**	
	Shallow (A)	Deep (B)	Shallow (A)	Deep (B)	CMT-7	Shallow (A)	Deep (B)
Groundwater ingress (during construction)	5.5m 8.3m		6.0m 7.0m (rising to GL)		7.0m (rising to GL) 11.8m	16.5m	
Groundwater levels (on completion)	1.86m	1.86m	-0.48m	-0.48m	-0.15m - 0.21m	0.39m	0.47m

Table 13 Groundwater ingress and completion levels

BH02 Headworks design (not to scale)



BH01 and BH04 Headworks Design (not to scale)



9.10.3.6 Sampling determinants

The following tables provides details of the sampling determinants in correspondence to the ERA.

Table 14: Dissolved groundwater determinants

Determinant	Justification for analysis
Methane	Key target gas
Carbon dioxide	Tracer gas for methane and potential constituent of on-site and off-site source gas
Oxygen	Potential constituent of on-site and off-site source gases
Nitrogen	Potential constituent of on-site and off-site source gases
Ethane	Higher chain hydrocarbons – identifier for thermogenic provenance
Propane	Higher chain hydrocarbons – identifier for thermogenic provenance
Butane	Higher chain hydrocarbons – identifier for thermogenic provenance

Table 15: Indicative groundwater quality determinants

Determinant	Justification for analysis
$\delta^{13}C\text{-}CH_4$	Dissolved methane provenance
$\delta^{13}C\text{-}CO_2$	Dissolved carbon dioxide provenance
Carbon dioxide	Natural soils / potential as indicator of methane gas
Heavy metals (dissolved)	Indicative of formation water ingress into aquifers
Strontium (dissolved)	Indicative of formation water ingress into aquifers
Earth metals (dissolved)	Indicative of formation water ingress into aquifers
Dissolved methane	Key target gas
Dissolved ethane	Higher chain hydrocarbon – indicator of thermogenic gas
Dissolved propane	Higher chain hydrocarbon – indicator of thermogenic gas
Dissolved butane	Higher chain hydrocarbon – indicator of thermogenic gas
Ammoniacal nitrogen, nitrite and nitrate	Indicative of groundwater quality
Bromide and chloride	Indicative of formation water ingress into aquifers
Biological oxygen demand (BOD)	Indicative of groundwater quality

Determinant	Justification for analysis
and Chemical oxygen demand (COD)	
pH	Indicator of change in geochemistry – ingress of stimulation fluids or formation waters
Salinity	Indicative of formation water ingress into aquifers above
Total dissolved solids	Indicative of formation water ingress into aquifers above
Total Petroleum Hydrocarbons – Criteria Working Group split	Indictor of fuels and oils used on site
Total suspended solids	Measure turbidity of groundwater

9.10.4 Pre-operational monitoring

At least three samples of groundwater from each monitoring borehole have been undertaken and carried out monthly over a minimum period of three months prior to the commencement of the drilling of the injection wells in accordance with the pre-operational permit measure PO8.

9.10.5 Operational monitoring

Routine ground-gas and groundwater samples will be taken from the monitoring well weekly during drilling and then extending to monthly once the upper sections of Sherwood sandstone is cased off. During hydraulic fracturing groundwater monitoring will be conducted weekly and extended to monthly during initial well testing. Monitoring of groundwater will be extended to every three months during the extended well testing phase subject to results of previous groundwater monitoring data. The options will be discussed with the Environment Agency at the time of extended well testing.

9.10.6 Abandonment monitoring

Routine ground-gas and groundwater samples will be taken from the monitoring well on a monthly basis during the abandonment phase. The frequency of monitoring will be conducted in line with the prevailing regulatory conditions at the time.

9.10.7 Restoration monitoring

Routine ground-gas and groundwater samples will be taken in line with prevailing requirements, site history and Site Condition Report. The frequency of monitoring will be conducted in line with the prevailing regulatory conditions at the time.

For clarity, the deployment of gas glams takes continuous groundwater data including electrical conductivity, temperature and groundwater level. In addition, headspace methane and carbon dioxide concentrations are continually monitored.

Groundwater quality samples will be extracted using a bladder pump system which requires a site visit by an environmental monitoring contractor.

In the event that electrical conductivity identifies variations from previous monitoring results, the monitoring frequency of water quality samples will be increased to weekly or daily depending on the scenario in consultation with the Environment Agency to ascertain data using the bladder pump system and sending results off to a UKAS accredited laboratory.

As per Cuadrilla's Environmental Monitoring Procedure, the results of the sampling shall be sent off site to a UKAS accredited laboratory for analysis. The results shall be benchmarked against baseline results. In the unlikely event of significant change to groundwater quality levels above baseline, there will be immediate investigation into the reliability of the data as a first protocol e.g. checking calibration dates, tampering of samples, and deviation from laboratory procedures.

If a trend of continued and significant variation to baseline data is identified, the operations shall be immediately suspended to investigate and address those causes if they are linked to the operations on site. All work and assessment of groundwater shall be conducted by an independent consultancy. The results shall be documented in a monthly report and published on Cuadrilla website.

9.11 Surface water

A site review has identified a number of surface water sampling locations. Figure 4 illustrates the sampling points for surface water monitoring.

A comprehensive baseline of surface water monitoring data has been established by both Cuadrilla and an independent consultant.

Real time monitoring shall be supported by laboratory analysis (at the prevailing frequency detailed in the permit) as a substantial body of representative monitoring data has been collated demonstrating no significant changes between baseline conditions and results gathered during active operations (including drilling, hydraulic fracturing and flow testing). A summary of the evidence justifying this measure is included in HSE-Permit-INS-PNR-014 Summary of environmental monitoring at Preston New Road (January 2019).

Cuadrilla shall notify the Environment Agency of changes to the frequency of sampling. In the event that the hand held monitoring equipment or laboratory analysis identifies any significant changes to water quality from the baseline, additional samples shall be sent for further laboratory testing. This will be followed up by a period of more frequent sampling in agreement with the Environment Agency.

The sampling locations have been identified to provide a representative assessment of water quality before the stream (tributary of Carr Bridge Brook) flows from the south past the site and continues north easterly.

A minimum of 6 samples have been taken before drilling to establish a baseline and further sampling will continue at frequencies determined in the EMMP during operations and after operations have been completed.

Sampling shall be undertaken during baseline and operations in accordance with UKOOG guidelines. Samples shall be sent off site to an accredited UKAS laboratory for assessment. Table 16 expresses the determinants which shall be analysed against EQS standards and the baseline data during operations.

Table 16: Indicative Surface Water Determinants

Determinants
Water samples
Acrylamide
Arsenic
Aluminium
Antimony
Beryllium
Barium
Boron
Bromide
Calcium
Cadmium
Chloride
Chromium
Copper
Cobalt
Iron
Lithium
Lead
Magnesium
Mercury
Nickel
Potassium
Vanadium
Silver
Selenium
Strontium
Sodium
Zinc
pH
TDS
Total alkalinity as $CaCO_3$
Ammoniacal nitrogen as N
Nitrate
Nitrite
COD
GRO (BTEX)
DRO

As per Cuadrilla's EMMP, the results shall be benchmarked against the EQS standards and baseline results. In the unlikely event of water quality levels significantly different to baseline conditions, there will be immediate investigation into the reliability of the data as a first protocol e.g. checking calibration dates, tampering of samples, and deviation from laboratory procedures.

If sampling reveals a trend of continued significant variation to baseline data and EQS, operations shall be suspended to investigate and address those causes if they are linked to the operations on site. The results shall be documented in a monthly report and published on the Cuadrilla website.

9.12 Dust

Movement of tankers on a gravel pad and access and egress roads has a minor impact of creating dust to the local environment. A speed restriction of 5-10mph shall apply to movement of vehicles along the access and egress track.

A programme of onsite directional and depositional dust monitoring shall be deployed for the duration of the baseline assessment and during the operational period of drilling and hydraulic fracturing only. The results of the dust monitoring shall be documented within the environmental monitoring report and published on the Cuadrilla website.

9.13 Soils

Prior to site construction soil samples were taken by an independent consultancy to form the baseline of soil quality. Further sampling shall be conducted at the site restoration stage to compare the results to the baseline and inform a review of the Site Condition Report.

9.14 Complaints

If any complaints are received from stakeholders, including neighbours, they will be recorded, investigated and responded to without delay in accordance with the Cuadrilla's existing complaints handling procedures. Complaints will additionally be reported to the Environment Agency, with whom actions to avoid a recurrence will be discussed and agreed.

The results of all monitoring will be used to update the Site Condition Report (HSE-Permit-INS-PNR-003) for the permitted operation, to inform changes to the WMP and Cuadrilla Environmental Operating Standards, and will be shared with the Environment Agency. The monitoring details shall be used to inform the site closure plan.

10.0 Proposed plan for closure

If a decision is taken to close the site, the wells shall be plugged and abandoned (decommissioned) in accordance with established procedures and the following regulatory provisions:

- the Borehole Sites and Operations Regulations 1995;
- the land-based requirements of the Offshore Installations and Wells (Design & Construction etc) Regulations 1996;
- Petroleum Exploration and Development Licence (PEDL) 165.

In addition, the guidance set out by UKOOG entitled ‘UK Onshore Shale Gas Well Guidance’ will also be observed.

Plugging and abandoning requires isolating different zones of the wellbore (e.g. at surface, hydrocarbon and permeable) by permanent barriers. The permanent barriers, for example cement plugs, are designed to ensure complete isolation of the wellbore. During the isolation the cement plug will be tagged, touching the top of the cement plug with a drill pipe, to verify its position and confirm the cement has set. The sealing capability of the plug / barrier is verified further by a pressure test, for example the magnitude of which should be a minimum of 500 psi above the injection pressure below the barrier but not exceed the casing strength. Once the wellbore has been plugged and abandoned no further maintenance is required. However to verify barrier construction, monitoring of the well pressure will be conducted in agreement with the regulator at the time of abandonment. This process will follow the Oil & Gas UK and UK Onshore Operators Group guidelines, and is reviewed by an independent well examiner and the HSE.

Closure of the above ground mining waste facility will take place when the process is no longer required and equipment is demobilised from site including returned waste cuttings and muds. Further detail will be developed in the site closure plan.

When the site is closed, a closure plan will be developed that covers all the required measures detailed in the relevant Environment Agency guidance prevailing at that time. Additional guidance for: mining waste operations" as part of any application to surrender the environmental permit. This will cross-reference the updated Site Condition Report and take into account any changes in site conditions. The closure plan will include a commitment to post well abandonment monitoring in line with the historical operation of the site and in accordance with regulatory/ industry guidance at the time of plugging and abandonment of the well.

11.0 Appendix A: Drilling fluid additives disclosure

12.0 Appendix B: Natural mineral contaminants

13.0 Appendix C: BAT appraisal

14.0 Appendix D: Drilling muds waste analysis

15.0 Appendix E: Air quality analysis

16.0 Appendix F: Chemical additives

17.0 References

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