Horse Hill Developments Ltd

Title: Surface Water Management Plan

Document Number: HHDL-EPR-HH-SWMP-013

Revision: 0

0	1st Issue	Prepared for Permit Variation	20/10/2020	ZG-SS	ZG-TF	TH
-	Draft	Permit Application Draft	20/10/2020	ZG-SS	ZG-TF	-
Rev.	**Status**	**Reason for Issue**	**Revision Date**	**Written by**	**Reviewed by**	**Approved by**
Revision History						

REVISION DESCRIPTION SHEET

Details to include revision number, a description of the revision indicating paragraphs and pages that have been revised, together with the date and approved signature.

Revision	Description	Date	Approved by
-	Drafted for Review	20/10/2020	-
0	Prepared for Permit Application Submission	20/10/2020	TH

Table of Contents

Page Left Blank Intentionally

1. INTRODUCTION

Horse Hill Developments LTD (HHDL) is a Limited Company that was formed to manage the exploration and production activities at the Horse Hill Well Site. HHDL is a consortium of natural resource companies and owns a 65% interest and operatorship of Petroleum Exploration and Development Licence (PEDL) 137 within which the Horse Hill Well Site is located.

HHDL is the holder of a number of Environmental Permits issued by the Environment Agency in accordance with the Environmental Permitting (England and Wales) Regulations 2016. The current permitted activities at the Horse Hill Well Site allow the undertaking of the following activities:

EPR/BB3300XG - A mining waste operation for the management of extractive waste from prospecting mineral resources, not involving a mining waste facility.

A mining waste operation for the management of non-hazardous extractive liquid waste and gas, from prospecting for mineral resources not including a waste facility resulting from well testing operation. No more than 10 tonnes of natural gas may be flared each day.

EPR/BB3691NN - The discharge of clean surface water off-site during periods of non-operational activity. Discharges to surface water may not take place during drilling, flow testing or well testing.

EPR/SP3339YS - The loading, unloading, handling or storage of, or physical, chemical or thermal treatment of crude oil with a capacity of no more than 500 tonnes.

EPR/AB3498DZ - SR 2014 No4 Permit for the Accumulation and Disposal of radioactive waste from the NORM Industrial Activity of the production of oil and gas.

As the development continues to progress, additional permitted activities have been identified as being necessary. As a result, HHDL have prepared an application to vary the environmental permits with the purpose of gaining permission to undertake the following activities:

- Construct up to four (4) new additional boreholes (HH-3/HH-4/HH-5/HH-6) in addition to the current two (2) boreholes (HH-1/HH-2) already constructed at the Horse Hill Well Site **(EPR/BB3300XG)**;
- Harness at least one (1) of the six (6) boreholes as a reinjection well for the purpose of providing production support **(EPR/BB3691NN)**;
- Undertake well treatments such as an acid wash and solvent treatments **(EPR/BB3300XG)**;
- Undertake a 90 day well test for each of the additional wells (HH-3/HH-4/HH-5/HH-6) before later being added to the portfolio of production wells at the site or being abandoned **(EPR/BB3300XG)**;
- Undertake an injectivity test within HH-2 (HH-2z) and any other wells as dictated by HHDL **(EPR/BB3691NN)**;
- Incinerate natural gas at a rate not exceeding 10 tonnes per day during production operations, until such a time that it can be demonstrated that the incineration of natural gas is no longer considered Best Available Technique through a cost benefit analysis **(EPR/BB3300XG)**;

HHDL will continue to undertake the following activities at the site in accordance with the current permissions presented within the permit:

- Store and handle crude oil up to a capacity of 500 tonnes within the existing infrastructure and within the current permitted boundary. Permit **EPR/SP3339YS** will not be the subject of a permit variation.

2. SCOPE

This Surface Water Management Plan (SWMP) is applicable to HHDL, its contractors and subcontractors and can be used in support of applications to the Environment Agency under the Environmental Permitting (England and Wales) Regulations 2016 (EPR2016), where there is a requirement to provide a SWMP.

3. DEFINITIONS

%	Percentage
AOD	Above Ordnance Datum
BS	British Standard
EPR2016	Environmental Permitting (England and Wales) Regulation 2016
FRA	Flood Risk Assessment
FT	Feet
g/m²	Grams per square metre
H_2S	Hydrogen Sulphide
HDPE	High Density Polyethylene
HH-1	Horse Hill 1 well
HH-2	Horse Hill 2 well
HH-3	Horse Hill 3 well
HH-4	Horse Hill 4 well
HH-5	Horse Hill 5 well
HH-6	Horse Hill 6 well
HHDL	Horse Hill Developments LTD
HRA	Hydrogeological Risk Assessment
L/S	Litres per Second
m	Metre
MD	Measured Depth
mm	Millimetre
m²	Metres squared
m³	Metres cubed
mg	Milligram
NORM	Naturally Occurring Radioactive Material
PEDL	Petroleum Exploration and Development License
QA	Quality Assurance
QC	Quality Control
SCC	Surrey County Council
SFRA	Reigate and Banstead Borough Council Strategic Flood Risk Assessment 2012
SuDS	Suitable Drainage System
SWMP	Surface Water Management Plan
TVDSS	True Vertical Depth Sub-Surface

4. LEGISLATION AND APPLICABILITY OF ENVIRONMENTAL PERMITS

The Horse Hill Well Site is the subject of a number of activities which, under current environmental legislation, requires an environmental permit. The Environment Agency regulate all permitted activities under the Environmental Permitting (England and Wales) Regulations 2016, as amended (EPR2016). Under EPR2016, Operators are required to submit environmental permit applications to the Environment Agency to seek approval to undertake such activities.

Onshore oil and gas developments have been the subject of the environmental permitting regulations since 1st October 2013, and as such a number of environmental permits have already been obtained. This SWMP aims to provide the Environment Agency, together with any other applicable regulators or authorities, such as Surrey County Council (SCC) on the proposed surface water management arrangements for the Horse Hill Wellsite.

4.1 Environmental Permitting (England and Wales) Regulations 2016.

4.1.1 Water Discharge Activity

Schedule 21 of EPR2016 relates to water discharge activities, including the discharge or entry to inland freshwaters, coastal waters or relevant territorial waters of any trade effluent. Environmental permit EPR/BB3691NN shall be varied to allow for the discharge of surface water during production and well testing activities from the well pad. During extended well testing and production operations the potential for hazardous substances at the site will be significantly lower than that of drilling and workover operations. Drilling operations and any well workovers during the lifetime of the development will require the surface water to be collected via a licenced haulier to an Environment Agency permitted waste facility with the interceptor isolated and closed off to prevent the discharge of water.

4.1.2 Groundwater Activity

Schedule 22 of EPR2016, relates to groundwater activities which require notification to the Environment Agency of the intention to discharge pollutants, together with the nature of these pollutants, into groundwater. The Environment Agency will then determine whether the groundwater activity requires an environmental permit and whether or not the activity can indeed be permitted.

The proposed operations will involve a groundwater activity, specifically the re-injection of produced water for the purpose of providing production support. As such, a permit under Schedule 22 of EPR2016 is anticipated by HHDL to be necessary and will be applied for.

4.2 Town and Country Planning Act 1990

The Horse Hill well site was originally granted planning permission in 2012 and constructed in 2014 consistent with an effective drainage strategy that was demonstrated to be SuDS (Sustainable Drainage Systems) compliant. On this basis the well site obtained the appropriate Environment Agency permit and was operational between 2014-2016. In 2017, planning permission was consented to retain the well site was for an additional period of 3 years. It is the intention of HHDL to retain the approved drainage strategy and associated maintenance regime for the ongoing well testing and production operations.

5. SITE LOCATION AND SETTING

The Horse Hill Well Site is shown in Figures 1. It is located in Surrey, approximately 3.5km north-west of Horley and approximately 3km north of Gatwick Airport.

The site is situated on the south side of Horse Hill, which is a north-east to south-west ridge of agricultural land.

The site address is:

Land off Horse Hill
Hookwood,
Horley,
Surrey
RH6 0RB

Nation Grid Reference: TQ 25297 43588

Figure 5.1: Horse Hill Wellsite (Image Sourced from Bing Maps 20/10/2020)

6. SURFACE WATER CONTAINMENT SYSTEM

The Horse Hill Well Site is designed, following standard industry practices, as a stable, level working platform to support a drilling rig and all associated equipment. The surface has been formed with a minimum of 300mm of granular material, compacted in accordance with the Specification for Highway Works on top of an appropriate geogrid for added strength.

The site is fully lined underneath the stone with a 1mm thick impermeable membrane made from Junifol High Density Polyethylene (HDPE) material, which is continuous through to a perimeter interceptor ditch. This impermeable membrane protects the surface water and groundwater from any site leakages, or potential spills. The membrane is further protected above and below using a 300g/m^2 non-woven geotextile. The use of crushed stone on top of an impermeable geomembrane layer is a standard and accepted method of site construction for onshore exploration well sites. The site was built by a competent contractor to industry standards, which included regular QA/QC checks on the site construction, as well as on the impermeable membrane, as outlined below.

All membranes delivered to site were accompanied by manufacturer's test data. The rolls of membrane were attached to a roll out frame, which in turn was attached to an excavator, the excavator tracked along unrolling the membrane, the membrane unrolled to the correct length, and once the correct length reached, the membrane was cut from the roll. The excavator then tracked adjacent to the panel of membrane laid and unrolled a further panel so that it overlapped the previous panel. This operation continued until the area was covered.

The membrane was placed with seam overlaps and prior to forming the joints, these overlaps were checked to ensure the weld area was clean, dry and free from imperfections. Welding (either hot wedge or extrusion welding) was carried out by certified welding technicians. When extrusion-welding methods were to be employed, the surface oxidation was removed from the membrane by sanding. Prior to commencing welding, a test weld was completed using off cuts of membrane and tested to destruction using field clamps in both the peel and shear modes. Failure must occur in the parent material and not enter the seam. The installation supervisor recorded all materials placed, roll numbers, panel numbers, seams welded and tested, and weather conditions.

All welds were tested as follows: site fusion welds were tested using air; twin fusion welds (hot wedge) were tested by sealing the ends of the air channel then inducing air pressure into the channel; extrusion welds were tested using spark testing methods. Welds which failed to conform to these non-destructive tests were repaired.

Vacuum testing employed purpose made equipment, which produced a vacuum over the tested area. A detergent / water solution was applied to the full test area prior to application of the test equipment, which will display any leaks by bubbling of the solution. Any leaks identified were subject to repair and retest.

The installation of membranes is sensitive to ambient temperature, moisture and high winds and no material installation or seam welding took place while adverse weather conditions exist. A concrete slab on site is formed around the well cellar. The cellar is sealed and the slab is set on top of the impermeable membrane layer, which is also sealed to the cellar so it is part of the overall larger impermeable site area. The surface water directed into the cellar can be disposed of off-site via a suction tanker to an authorised waste disposal facility.

The sealing of the cellar was tested by carrying out a 24-hour hydrotest: the cellar is filled with water and checks are made that this volume is retained over the 24-hour period. This was again verified on 10 October 2016. Both sets of results confirmed no leaks.

The approximate location of the impermeable membrane, covering all the internal well site area, is shown by the blue line in Appendix 1. This includes the interceptor ditch encircling the site and where the lining extends up, and on to, the bund beyond the ditch. At the entrance to the site the lining will be raised to the overall compound level (with the surface ramped up to this point on both sides to provide containment whilst allowing traffic to practically enter or leave the site). A cross sectional view across the well site showing the impermeable membrane and interceptor ditch is also shown in Appendix 1.

The interceptor ditch serves the purpose of collecting all surface drainage from the lined well site footprint. An earth bund has been constructed on the outside of the ditch. The ditch design is shown in a plan and in a cross-section in Appendix 1. It has a cross-sectional area of around 1.7m^2 and a length of approximately 290m, which gives a volume of around 500m^3 (500,000 litres) of fluid.

Rainfall onto the compound and bund area, as well as any potential contaminants such as diesel fuel and oil and chemicals used in operating the site, are directed into the interceptor ditch and then under gravity, via an outfall pipe and Class 1 SPEL oil bypass separator, into a 150mm pipe buried in a gravel swale beyond the lined bunded compound area, as shown in Appendix 1.

Isolation valves are installed both upstream and downstream of the separator (to allow full isolation of the site as well as isolation of the separator for maintenance works should they be required). The system is designed and operated to separate oil and water and fully conforms to both the Environment Agency PPG3 guidelines and European Standard BSEN-858-1-2 (less than 5mg of hydrocarbons/litre of water). The use of the separator has previous been approved by the Environment Agency and is in use when the site has no well operations being carried out. HHDL are seeking to change this to enable the discharge of collected surface during well testing and production operations also.

When any workover or drilling rig is on site, the separator isolation valves remain closed. After operations have been completed, the excess water is released to the environment, pending the testing of the ditch fluid and the results being sent to the Environment Agency as per the Water Discharge Permit, EPR/BB3691NN. Any oil contamination from the test equipment or site traffic will be retained in the separator and removed by road tanker off site at the end of the well work.

The separator is designed to address the risk of infrequent light contamination and small-scale spills and is sized as appropriate for the size of the site. It is not designed to manage a major spill of hazardous materials (considered extremely unlikely). In such circumstances, emergency procedures will define that the discharge valve on the separator remains closed and all contaminated water trucked off site for disposal at an approved facility. The construction design and method was previously approved by the Environment Agency following previous environmental permit applications for the site.

Within the centre of the site are two well cellars housing within them the two wells. The drilling of the original Horse Hill 1 (HH-1) well was drilled in 2014 to a depth of 2,717m (8,915ft) MD / 2,421m (7,942ft) TVDSS into the Triassic. The HH-1 well discovered oil within both the Portland Sandstones and the Kimmeridge Limestones. The well was re-entered in 2016 and a series of short tests confirmed the oil potential of the Portland Sandstone and the Kimmeridge Limestones at KL#4 and KL#3 levels. In 2018 the well was re-entered again for an Extended Well Test which was successful in flowing significant amounts of oil from all three target levels.

The HH-2 well was subsequently drilled 4th quarter of 2019 and was drilled to a depth of 708m (2,322ft) MD / 627m (2,056ft) TVDSS and terminated in the Portland Mudstone. From the HH-2 well a sidetrack well known as HH-2z was drilled, kicking off from a depth of 397m (1,301ft) MD / 324m (1,062ft) TVDSS and entered the Portland Mudstone 720m (2,362ft) MD / 620m (2,035ft) TVDSS and reached a total depth of 1,245m (4,086ft) MD / 589m (1,934ft) TVDSS. The HH-2 well (HH-2 and HH-2z) is currently shut-in.

The existing well site has been constructed to a standard capable of accommodating exploratory operations and any subsequent production activity. The well site comprises a stable and flat surface of crushed and compacted stone overlaying a high-density polyethylene (HDPE) impermeable membrane and protective geotextile layers allowing for tertiary containment and controlled drainage. Construction within the existing well site will comprise the installation of four (4) new concrete chambers to act as drilling cellars housing the new wells.

A surface conductor, which is a large diameter pipe, will be installed to provide a stable structural foundation for the subsequent drilling of each well. A conductor setting rig will be mobilised to Site with a mast of up to 15m in height to drill and set the conductor casing to a pre-determined depth, isolating the shallow water systems underlying the Site from deeper strata, a further form of tertiary containment.

7. SURFACE DRAINAGE MANAGEMENT IN PREPARATION FOR DISCHARGE

7.1 Drainage and Discharge Strategy

The surface water drainage strategy along with detailed plans showing the drainage layout, cross sections of the drainage elements, pipe sizes and invert and cover levels are provided in Appendix 1. The overall strategy presented is concomitant with the previously approved drainage strategy at the Site. This is justified based on the conclusions of the SuDS hierarchy assessment and that the Site area has not fundamentally changed since construction in 2014.

The aim of the drainage strategy is to attenuate and control rainfall-runoff from the existing well site compound platform area which covers an area of approximately 5,800m^2. The compound area is lined with a continuous impermeable membrane and 300GSM non-woven fleece layers over which porous granular sub base material is laid to a depth of 300mm. The gravel base has a porosity of approximately 20% which provides space for water in between the gravels. It is estimated that the gravel base provides approximately 350m^3 of storage.

The impermeable lining includes an open containment ditch encircling the Site which extends up, and on to, a containment bund beyond. At the well pad vehicular entrance, end sections of the ditch are connected via a pipe section. The well site is therefore a 'hydrologically contained area'. The containment drain is trapezoidal in shape and measures 0.75m at the base (set at 66mAOD) with a top width of 2.75m and 1:1 slopes. The drain has a cross-sectional area of 1.75m^2 and covers a length of 280m, which generates a maximum storage volume of approximately 500m^3.

Rainfall onto the compound and bund area drains to the containment ditch into a 150mm ID diameter plastic pipe set at an invert level of 66.1mAOD feeding into a Class 1 Oil Bypass Separator. Outfall from the separator is to a sealed 150mm ID diameter plastic pipe set within a gravel trench beyond the lined bunded compound. The trench is lined with a permeable Terram geotextile for stabilisation and reinforcement. The trench is rectangular in shape with a length of 60m along the western Site boundary followed by a length of 110m along the southern Site boundary.

The 150mm ID diameter plastic pipe at the southern Site boundary passes under a 4m wide farm access track and discharges under gravity to a field drainage dyke. The dyke is trapezoidal in shape and measures 0.75m at the base with a top width of 2.25m and 1:1 slopes. The pipe has an invert level at the dyke of 63.30mAOD. The dyke system ultimately drains to the Spencer's Gill watercourse some 600m to the south of the Site.

7.2 Flood Zone Setting

In terms of flood risk, the well site lies within a "Zone 1 Low Probability" area, having a less than 1 in 1,000 annual probability of river or sea flooding. The Proposed Development is classified as a 'Less Vulnerable' development with its activities focused on the production of oil and associated infrastructure and facilities. As defined in Planning Practice Guidance, 'Less Vulnerable' development is appropriate within Flood Zone 1.

The site is significantly inland and not at risk of flooding from the sea. Local watercourses are not tidally influenced.

The well site is wholly located within Flood Zone 1 and therefore considered to be at very low risk of flooding from fluvial sources. This is consistent with the Site's location in the headwaters of the catchment. The SFRA historical flood records identify no flooding at the Site. but show flooding in the town of Horley as a result of river flooding. This is a significant distance away from the Site.

Surface water flooding occurs when rainwater does not drain away or soak into the ground but lies on or flows over the ground surface. Areas that are most vulnerable to surface water flooding are low lying areas where surface water runoff can accumulate.

The updated Flood Map for Surface Water classifies the risk from surface water flooding using the following four categories:

- High – Greater than or equal to a 1 in 30 year (3.3%) chance in any given year;
- Medium – Between a 1 in 100 year (1%) and 1 in 30 year (3.3%) chance in any given year;

- Low – Between a 1 in 1,000 year (0.1%) and 1 in 100 year (1%) chance in any given year;
- Very Low – Less than a 1 in 1,000 year (0.1%) chance in any given year.

The proposed development will capture and manage surface water runoff at the well site with a discharge at the Greenfield runoff rate. No infiltration of surface water to the subsoils below will occur due to the use of a very low permeability of the HDPE membrane incorporated into the construction of the well site.

Based on the above, the overall risk from pluvial flooding to / from the Site is considered to be low/very low, provided that surface water is managed appropriately.

Groundwater flooding is the emergence of groundwater at the ground surface. Groundwater flooding occurs in response to a combination of already high groundwater levels (usually during mid or late winter) and intense or unusually lengthy storm events.

There is a very low risk of groundwater flooding at the Site because:

- The Site is within the headwaters of the catchment and is directly underlain by low permeability soils/rock with a low potential to transmit groundwater.
- The unnamed stream to the south/south west of the Site is fed by land drains and possibly springs close to Brittleware and Greenstead Hall Farms (625m and 900m southwest of the Site respectively). These drain away from the Site towards Spencer's Gill, a tributary of the River Mole.
- Surrey County Council Local Flood Risk Management Strategy (LFRMS) identifies no potential risk of groundwater flooding at the Site.
- The SFRA indicates no records of groundwater flooding affecting properties within the local area.
- The proposed development will use a very low permeability HDPE liner across the well site that provides a hydraulic break between the Site and any groundwater in the underlying soils/rock.

The Environment Agency's Risk of Reservoir Failure map shows that there is no residual risk of flooding to the site from a large, raised reservoir in the event of a structural failure or breach. The Reservoir Act 1974 defines a large reservoir as one that holds over 25,000m^3 of water.

There are no small reservoirs upstream or downstream of the Site. There are no canals upstream or downstream of the Site.

Based on the above, there is a no risk of flooding to / from the Site from artificial waterbodies.

There are no proposed connections from the Site to public sewers. There are no public sewers in close proximity to the Site and therefore no risk of flooding from public sewers.

Runoff generated over roads in the local area is managed by the respective road drainage systems and therefore the risk of flooding from roads to the Site is considered very low. Surface water shall be managed within the enclosed, bunded well site area as described in Section 3. Therefore, the risk of flooding from the Site to roads is considered very low.

The Site will be returned to pre-development condition with hardstanding areas dismantled and removed. The HDPE membrane will be removed, and the subsoil will be deep-tine cultivated in strips. There will be no change in runoff pathways or runoff volumes compared to pre-development levels.

A full Hydrogeological Risk Assessment and Flood Risk Assessment (P18-022 HHDL Horse Hill 2018 /RPT HRA/FRA Horse Hill Production) has previously been submitted to the Environment Agency.

7.3 Runoff Rates and Storage Requirements

The area draining to the containment ditch totals approximately 8,290m^2 and comprises the impermeable lined compound area, the containment ditch itself and the areas of bund with slopes falling towards the compound.

The approved drainage strategy by Hydrock adopted the WinDes ICP SuDS mean annual flood calculation methodology within the MicroDrainage software package to calculate the greenfield runoff rates for the Site. The MicroDrainage output is provided in Appendix 2. Envireau Water have since reviewed Greenfield Runoff Rates using HR Wallingford UKSuDS Greenfield Runoff Estimation Tool and deem them representative of the current conditions. The Greenfield Runoff Rates are summarised in Table 7.1.

Greenfield Runoff Rates for Well Site Compound			
QBAR	**1 in 1 Year**	**1 in 30 Year**	**1 in 100 Year**
4.3 l/s	3.6 l/s	9.6 l/s	13.6 l/s

Table 7.1: Greenfield Runoff Rates

The outfall pipe from the internal open containment ditch will continue to discharge from the Site at a rate equal to or less than the QBAR (mean annual flow) greenfield rate of 4.3 l/s.

Hydrock used MicroDrainage to assess critical storm events for a 1 in 100 year design event (plus climate change allowance). A climate change allowance for increases in peak rainfall intensity of 5% was adopted. The critical storm duration was identified as 8 hours.

Envireau Water have reviewed the climate change allowance against the latest statutory allowances for flood risk and national SuDS guidance and deem them acceptable and in line with the current guidance. The drainage elements at the Site are shown to accommodate the 1 in 100 year storm event (plus 5% climate change allowance) whilst restricting all site runoff to a QBAR discharge rate of no greater than 4.3 l/s.

It is important to note that the MicroDrainage analysis has been undertaken conservatively as it does not take into account the storage available within the 300mm deep, porous gravel sub-base on top of the compound area.

7.3.1 Drainage Scheme Maintenance

A maintenance plan for the surface water drainage system at the Site shall be drawn up and carried out by the Site operators. The plan shall include regular inspection of all inlets, outlets, controls, inspection chambers and the oil separator. This shall include the removal of any obstructions and silt where necessary and checks on the physical structure of the drainage elements. Grass areas around the gravel trench shall be regularly strimmed to prevent the build-up of vegetation, silt and debris which could otherwise potentially cause blockages.

The maintenance plan shall also include provision for the inspection and maintenance of the field drainage dyke to the south of the Site. This shall include regular inspection and removal of obstructions and silt build-ups of the pipework at the farm access track and, when required, strimming of the channel vegetation to maintain adequate capacity and conveyance of flows.

7.3.2 Discharge and Sampling Operating Procedure

HHDL have previously submitted 'Operating Technique (HSE-HH1-PD-09)' to the Environment Agency as part of a Pre-Operational Measure. The Operating Technique explains the measures to be taken for the sampling, analysis, reporting and discharge of surface water from the wellsite and the parameters that are being monitored for.

For clarity HHDL is applying to vary the existing permit **EPR/BB3691NN** to permit the discharge of surface water during periods of well testing and production, in addition to non-operational periods. The procedures however shall remain the same and are considered by HHDL as still being applicable. For ease a copy of the procedure has been provided within Appendix 3.

8. SURFACE WATER MANAGEMENT IN PREPARATION FOR PRODUCTION SUPPORT

HHDL are proposing to harness collected surface water from containment bunds (bund water) by using it as re-injection water (together with produced water from the well) for the purpose of aiding in the production performance of the Horse Hill Wellsite.

8.1 Treatment of Bund Water and Produced Water

Water collected within containment bunds shall be sampled and analysed to establish its chemical properties and to identify which treatments may be needed to ensure it can be used as part of the reinjection water.

Both surface water and produced water require appropriate technological, chemical and bacteriological processing before re-injection can take place. It is necessary to remove all the components that adversely affect injection into the reservoir formation. Water, either surface water or produced water will require the removal of dissolved and dispersed organic components as well as suspended solids and adjustment of the compatibility with the receiving groundwater system, if needed. To remove components from produced water, biological, physical and chemical methods are available.

Surface water collected within the containment bunds shall be transferred to the produced water tank pending treatment prior to reinjection.

Such treatments may, if required, include the following:

- Fine filtration;
- Oxygen Scavenger
- Biocides;
- H_2S scavenger; and
- Corrosion Inhibitor.

8.1.1 Fine Filtration

Prior to injection of bund or produced water into the reservoir formation the water will be run through both coarse and fine filtrations. The filters shall clean the water and remove any impurities, such as solids (e.g. sand and silt, scales etc). Typical filtration is to 2 micrometres, but really depends on reservoir requirements. The filters are so fine so as not to block the pores of the reservoir which can reduced injection performance. The filters will be maintained and regularly cleaned as part of the site process and maintenance.

8.1.2 Oxygen Scavenger

Oxygen often needs to be removed from the water because it promotes corrosion and growth of certain bacteria. Bacterial growth in the reservoir can produce toxic hydrogen sulphide, a source of serious production problems, and block the pores in the rock. In order to treat this an oxygen scavenging agent can added to the bund/produced water prior to injection. Dosage amounts are subject to laboratory tests and product technology.

8.1.3 Biocide Treatment

Both surface and produced water contain biological constituents (primarily bacteria) that can contaminate the water-treatment or injection systems. Because bacteria have the ability to multiply rapidly into colonies, they can cause plugging of surface and downhole equipment and injection-well formations, promote corrosion of surface piping and downhole tubulars, and generate H_2S that can cause pitting corrosion. Therefore, it is essential to develop means to control bacteria growth in surface-water-treatment and injection systems. Biocides can be added to the process prior to injection to reduce and/or eliminate damaging bacteria. Testing of waters will be required to determine any necessary and correct biocide solution.

8.1.4 H_2S Scavenger

Whilst currently not an issue in the Horse Hill reservoir, should hydrogen sulphide production become a problem, then H2S scavenger can be injected with the injection fluids to prevent H2S related corrosion and issues which can reduce safety risks and improve asset integrity management.

8.1.5 Corrosion Inhibitors

Corrosion is defined as the destruction of metal by either chemical or electrochemical reaction in the given environment. Because piping and processing equipment are normally made of metals that are in contact with produced water, chemical or electrochemical reactions can occur. The likelihood and rate of corrosion is dependent upon various factors including water pH, metallurgy, dissolved oxygen, dissolved salts, and acid gases in water, temperature, pressure, and fluid velocity. Corrosion inhibitors can be added to the injection fluids to slow or prevent corrosion occurring. Testing of waters will be required to determine any necessary and correct inhibitor solution.

8.2 Integrity Testing of Reinjection Well(s)

Prior to the undertaking of the groundwater activity each reinjection well shall be the subject of a test to confirm its integrity. Well construction, operation and maintenance shall be conducted in accordance with HHDL Well Planning Design and Operating Standards. The standards are applied to each well during initial construction and throughout its lifecycle, including integrity management. The results of the integrity test shall be made available to the Health and Safety Executive and, if requested, the Environment Agency.

8.3 Injectivity Testing

Produced water will be separated, filtrated and chemical dosed (if necessary subject to lab tests) so ensure it is suitable for reservoir reinjection. The water will then be injected down the well at low initial rates until downhole (surface back pressure) is observed on the well pressure gauges. As the Portland reservoir is low pressure then it is possible that back pressure may be minimal or not observed at all. The injection rate will be stepped up in increments to obtain the maximum achievable injection rate whilst maintaining the downhole/surface pressures 10% below formation fracture pressure and well below any wellhead and casing design pressures.

This will provide the maximum allowable surface/downhole injection pressures and the maximum achievable injection rate. It should be noted that these pressures/rates are likely to be much greater than rates/pressures needed to actually sustain water injection into the HH field.

8.4 Risk Assessment

Envireau Water produced a HRA and FRA in November 2018 that concluded that there would be very low risks associated with produced water reinjection. This was on the basis that injection pressures would be controlled to ensure they do not exceed the fracture gradient of the injection formation (the Portland Group) that would cause geomechanical impacts including indirect discharge to groundwater bearing formations. It was acknowledged that a detailed assessment of the reinjection activity would need to be carried out to support the environmental permit process.

The HRA and FRA has been updated following consultation with the Environment Agency. It was agreed that a standalone document considering produced water reinjection would be prepared and appended to the updated HRA and FRA. The document, provided in Appendix 4 therefore considers:

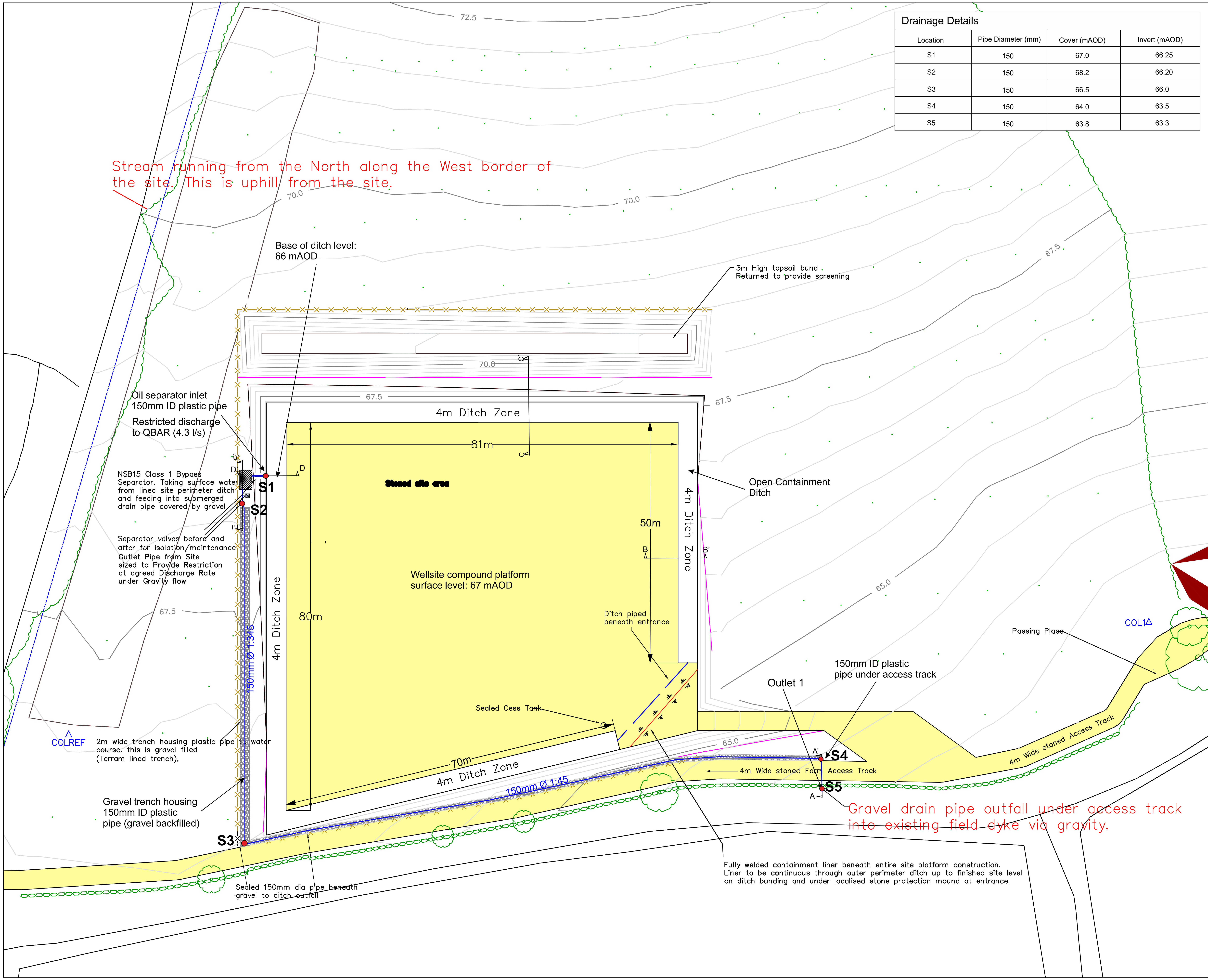
- A concept for the reinjection of produced water, in the context of the established regulatory framework;
- Details of the geological structure and the geomechanical properties of the formation into which reinjection will take place;
- Details of the production well and how well integrity is achieved, maintained and monitored;
- Details of how the reinjection activity will be carried out and monitored;

- An assessment of the risk that the reinjection activity poses to groundwater resources and the subsequent requirements for groundwater monitoring.

The additional information presented in this report confirms the 'very unlikely' likelihood assigned to the risk of produced water impacting groundwater bearing formations above the Portland Groups in the HRA and FRA. The 'very low' residual risk associated with produced water reinjection at the site is therefore valid.

APPENDIX 1 - SITE PLANS

Page Left Blank Intentionally



Stream running from the North along the West border of the site. This is uphill from the site.
72.5
70.0
67.5
65.0
Base of ditch level: 66 mAOD
3m High topsoil bund
Returned to provide screening
Oil separator inlet 150mm ID plastic pipe
Restricted discharge to QBAR (4.3 l/s)
NSB15 Class 1 Bypass Separator. Taking surface water from lined site perimeter ditch and feeding into submerged drain pipe covered by gravel
Separator valves before and after for isolation/maintenance
Outlet Pipe from Site sized to Provide Restriction at agreed Discharge Rate under Gravity flow
S1
S2
S3
S4
S5
4m Ditch Zone
81m
50m
80m
70m
Stoned site area
Open Containment Ditch
Wellsite compound platform surface level: 67 mAOD
Ditch piped beneath entrance
Sealed Cess Tank
150mm Ø 1:345
150mm Ø 1:45
2m wide trench housing plastic pipe in water course. this is gravel filled (Terram lined trench).
Gravel trench housing 150mm ID plastic pipe (gravel backfilled)
Sealed 150mm dia pipe beneath gravel to ditch outfall
COLREF
COL1
Passing Place
Outlet 1
150mm ID plastic pipe under access track
4m Wide stoned Farm Access Track
4m Wide stoned Access Track
Gravel drain pipe outfall under access track into existing field dyke via gravity.
Fully welded containment liner beneath entire site platform construction. Liner to be continuous through outer perimeter ditch up to finished site level on ditch bunding and under localised stone protection mound at entrance.

Drainage Details

Location	Pipe Diameter (mm)	Cover (mAOD)	Invert (mAOD)
S1	150	67.0	66.25
S2	150	68.2	66.20
S3	150	66.5	66.0
S4	150	64.0	63.5
S5	150	63.8	63.3

KEY:

NOTES:

REVISION HISTORY

REV	DATE	BY	DETAILS	APR
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	NOV17	JF	ORIGINAL FOR ISSUE	JF

ZETLAND GROUP
FROM CONCEPTION TO COMPLETION
ZETLAND GROUP LIMITED
23A MILTON STREET, SALTBURN BY THE SEA, TS12 1DJ
T: +44(0)1287 625650 E: info@zetlandgroup.com W: www.zetlandgroup.com
Registered in England No. 05964499. Registered office: 23A Milton Street, Saltburn by the Sea, TS12 1DJ

SITE: HORSE HILL WELLSITE, SURREY

PROJECT:

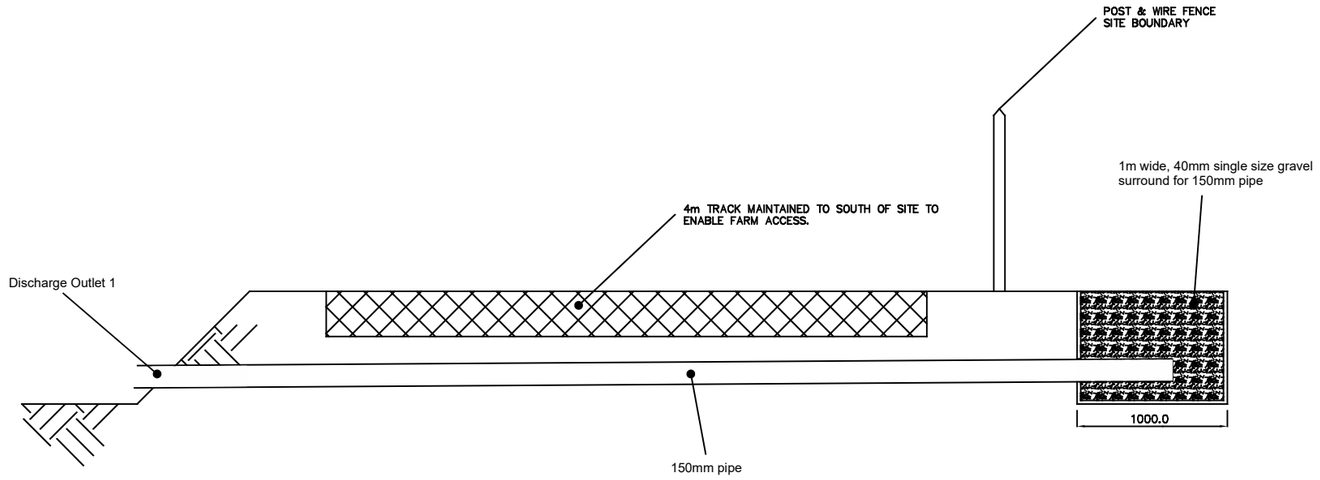
TITLE: AS-BUILT SITE DESIGN & SCHEMATIC LAYOUT

CLIENT: HORSE HILL DEVELOPMENTS

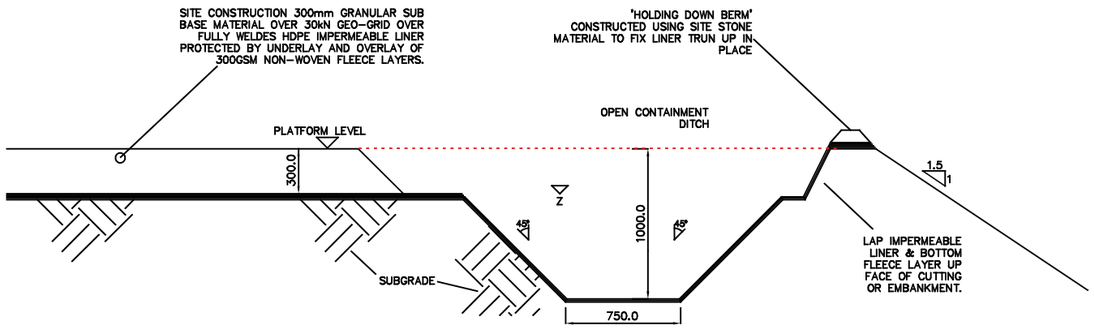
Scale: 1:500
Size: A2
Sheet: 1 of 2

DWG. No: ZG-HHD-HH-PA-01

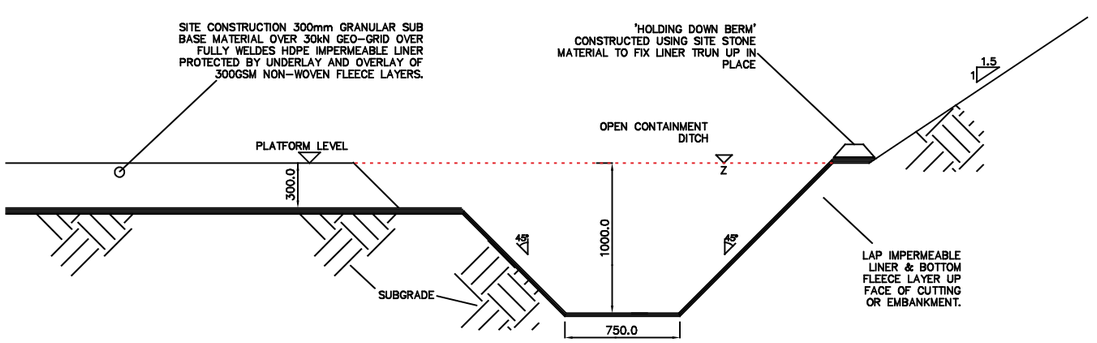
SECTION A–A' SOUTHERN BOUNDARY
1:40



SECTION B–B' EASTERN BOUNDARY
1:40



SECTION C–C' NORTHERN BOUNDARY
1:40



KEY:

NOTES:

FOR LOCATION OF CROSS-SECTIONS, REFER TO DRAWING NO. ZG-HHD-HH-PA-01

REVISION HISTORY				
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	NOV17	JF	ORIGINAL FOR ISSUE	JF
REV	DATE	BY	DETAILS	APR

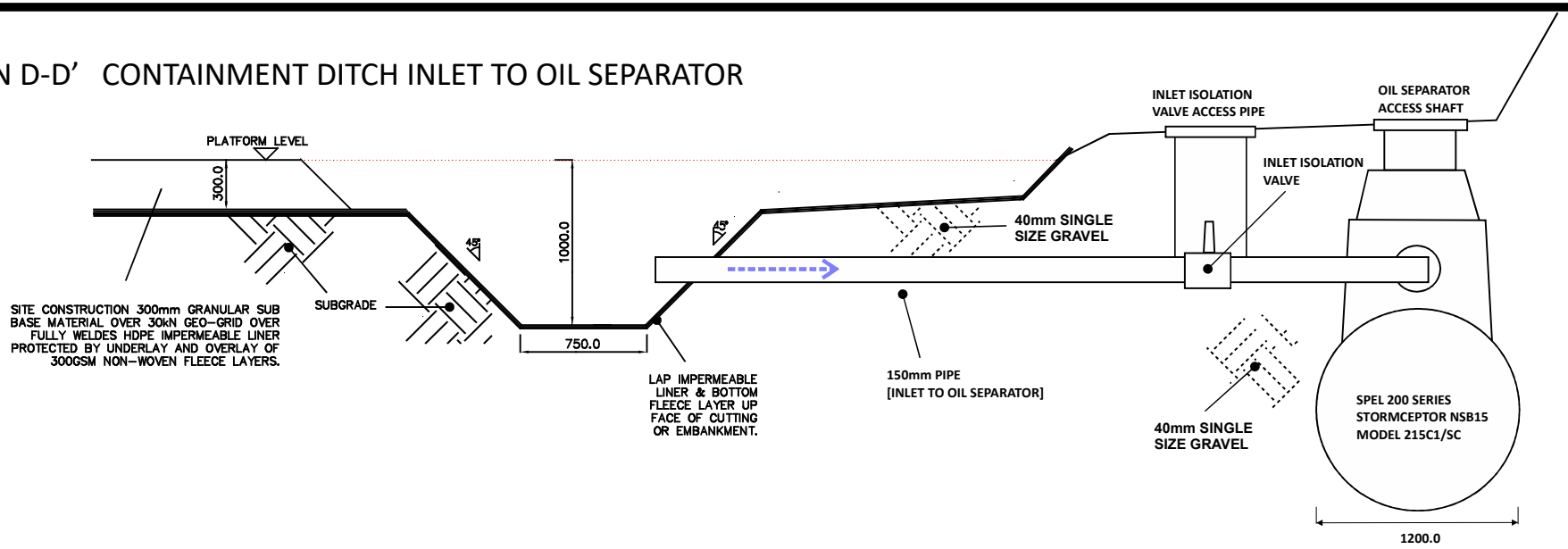
ZETLAND GROUP
FROM CONCEPTION TO COMPLETION
ZETLAND GROUP LIMITED
23A MILTON STREET, SALTBURN BY THE SEA, TS12 1DJ
T: +44(0)1287 625600 E: info@zetlandgroup.com W: www.zetlandgroup.com
Registered in England No. 05904456. Registered office: 23A Milton Street, Saltburn by the Sea, TS12 1DJ

SITE:	HORSE HILL WELLSITE, SURREY
PROJECT:	
TITLE:	AS-BUILT SITE DESIGN CONTAINMENT DITCH DETAIL SECTIONS
CLIENT:	HORSE HILL DEVELOPMENTS

Scale:	1:40	DWG. No: ZG-HHD-HH-PA-02
Size:	A3	
Sheet:	2 of 2	

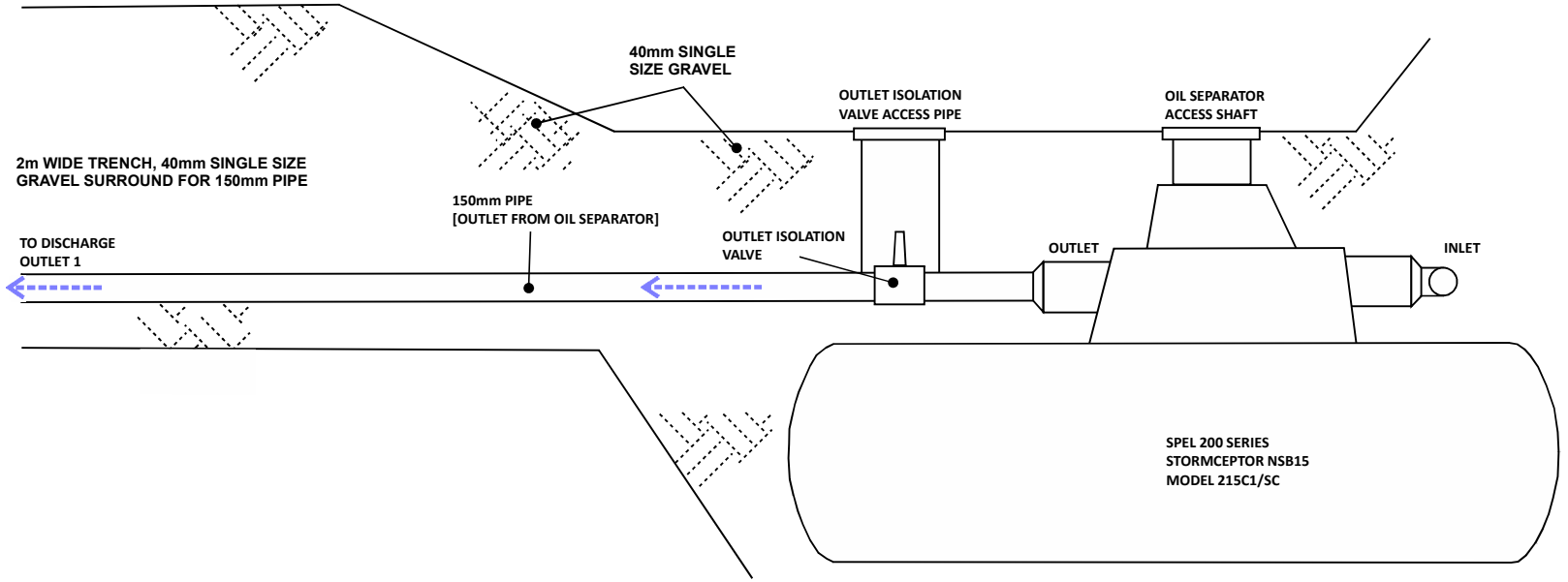
SECTION D-D' CONTAINMENT DITCH INLET TO OIL SEPARATOR

1:40



SECTION E-E' OIL SEPARATOR OUTLET TO DISCHARGE OUTLET

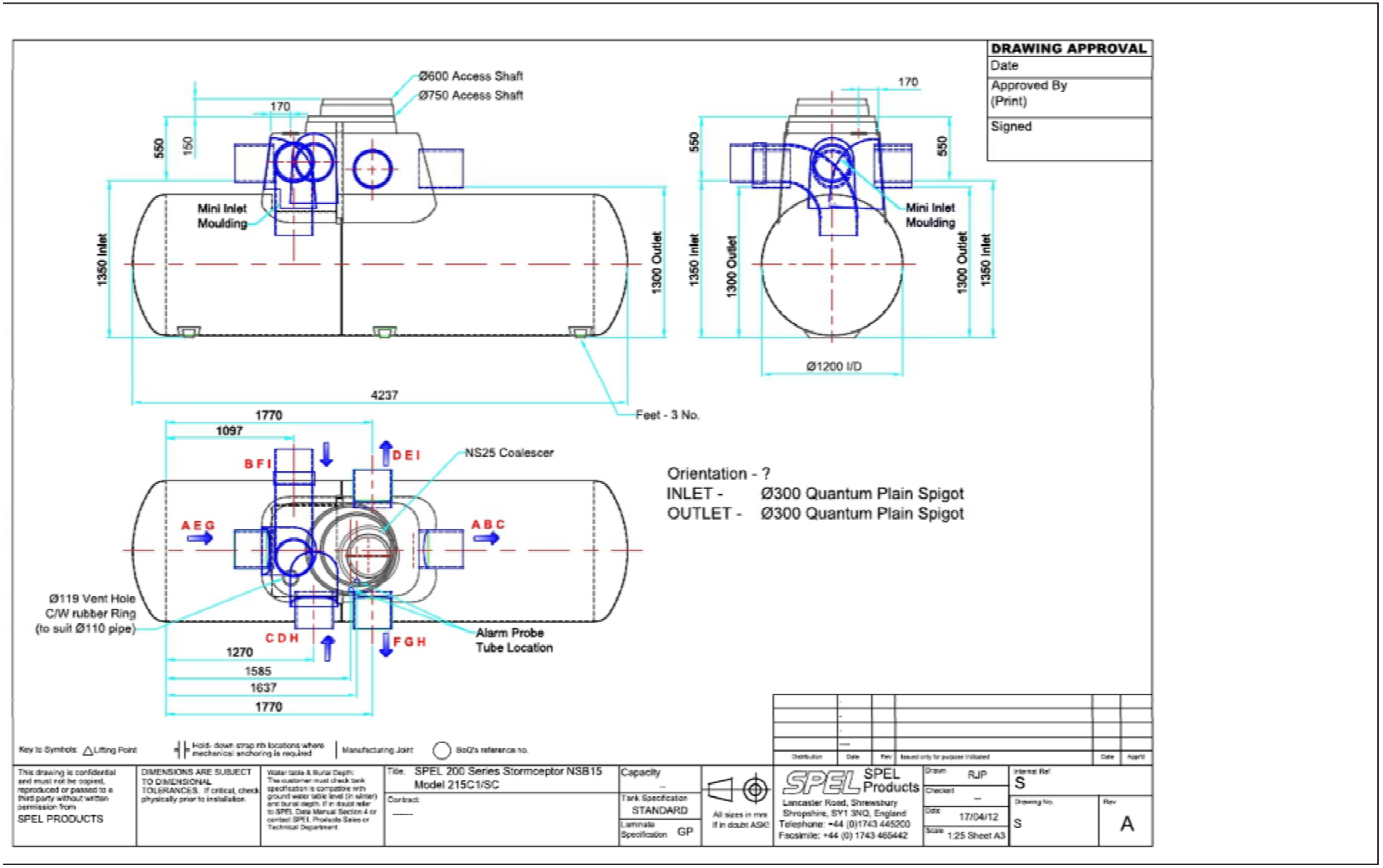
1:40



envireau WATER

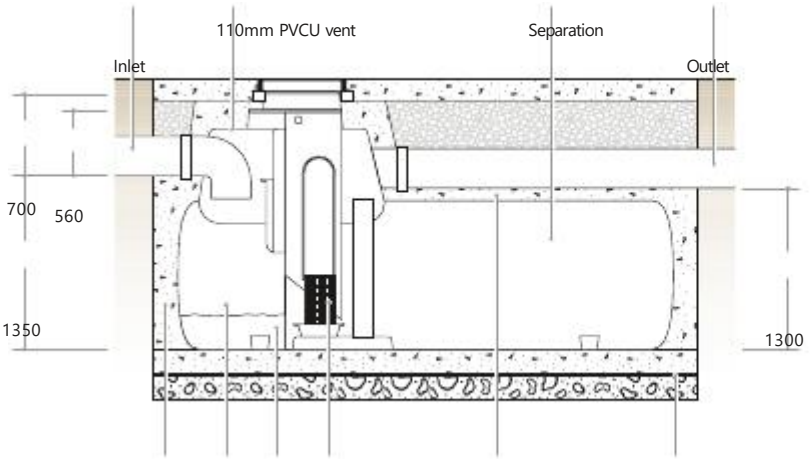
Ref: P:\UKOG Horse Hill (2165)\40 - Reporting\Appendices Date: 13/02/2018	**Horse Hill Well Site**
Appendix A	Sections D-D' and E-E'

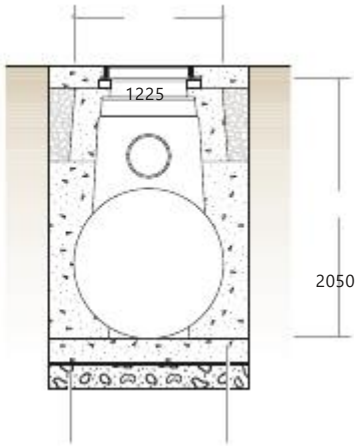
ppendix D: Separator information



SPEL Stormceptor® by-pass separators

200 series, class 1 with silt capacity





150mm minimum thickness concrete surround | Primary Silt chamber | Coalescer

150mm minimum thickness concrete over the top.* | Polythene membrane

150mm hardcore (where base of excavation is of unstable ground) | 150mm concrete base

* Fabric reinforcement may be necessary where vehicle loading has to be taken into account or where high extension access shafts are to be fitted

SPEL automatic alarm/monitoring system

Requirement of the Environment Agency's Pollution Prevention Guidelines PPG3

The SPEL automatic alarm/monitoring system provides continuous monitoring of the separator contents by sensing when the

light liquid within the separator has filled to a predetermined level (with design safety margins), and provides a simple audio-visual warning to alert the operator that the separator needs to be emptied.

Maintenance

The SPEL 200 series Stormceptor class 1 by-pass separators have good access to both the primary chamber and the light liquid separation chamber for periodic emptying of retained light liquids and silt which is essential to maintain the units optimum performance.

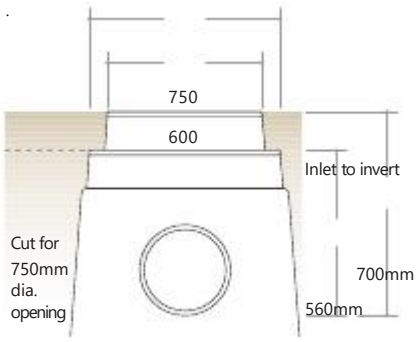
Periods between emptying will have to be determined depending on site conditions but normally at least twice a year.

For detailed instructions see section 9.

Procedure in brief

1. Lift handle and coalescer unit out of the tank and place ahead of the separator.
2. Remove foam insert and wash with normal water pressure, ensuring the dirty water runs into the separator.
3. Empty light liquids and silt alternating between both chambers to avoid excessive pressure one side of the partition.
4. Re-insert the foam insert into the stainless steel coalescer unit and re-insert the coalescer unit into the separator.

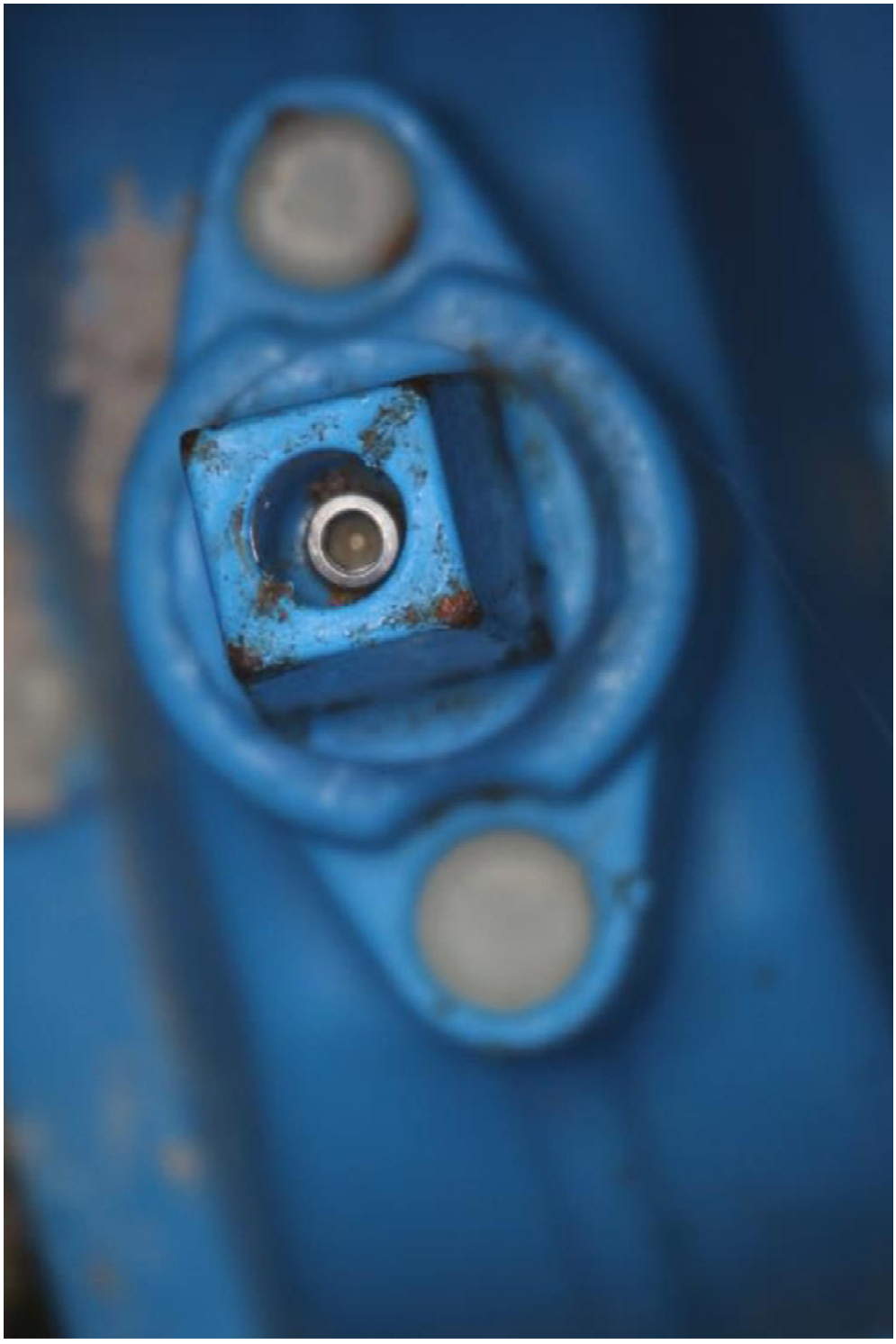
Catchment area m²	SPEL ref	Nominal size NSB	Oil storage litres NSBx15	Silt storage litres NSBx100	Overall length (mm)	Max pipe (mm)
2222	204C1SC	4	60	400	1860	300
3333	206C1SC	6	90	600	2110	300
4444	208C1SC	8	120	800	2260	300
5556	210C1SC	10	150	1000	2920	300
8333	215C1SC	15	225	1500	4227	300



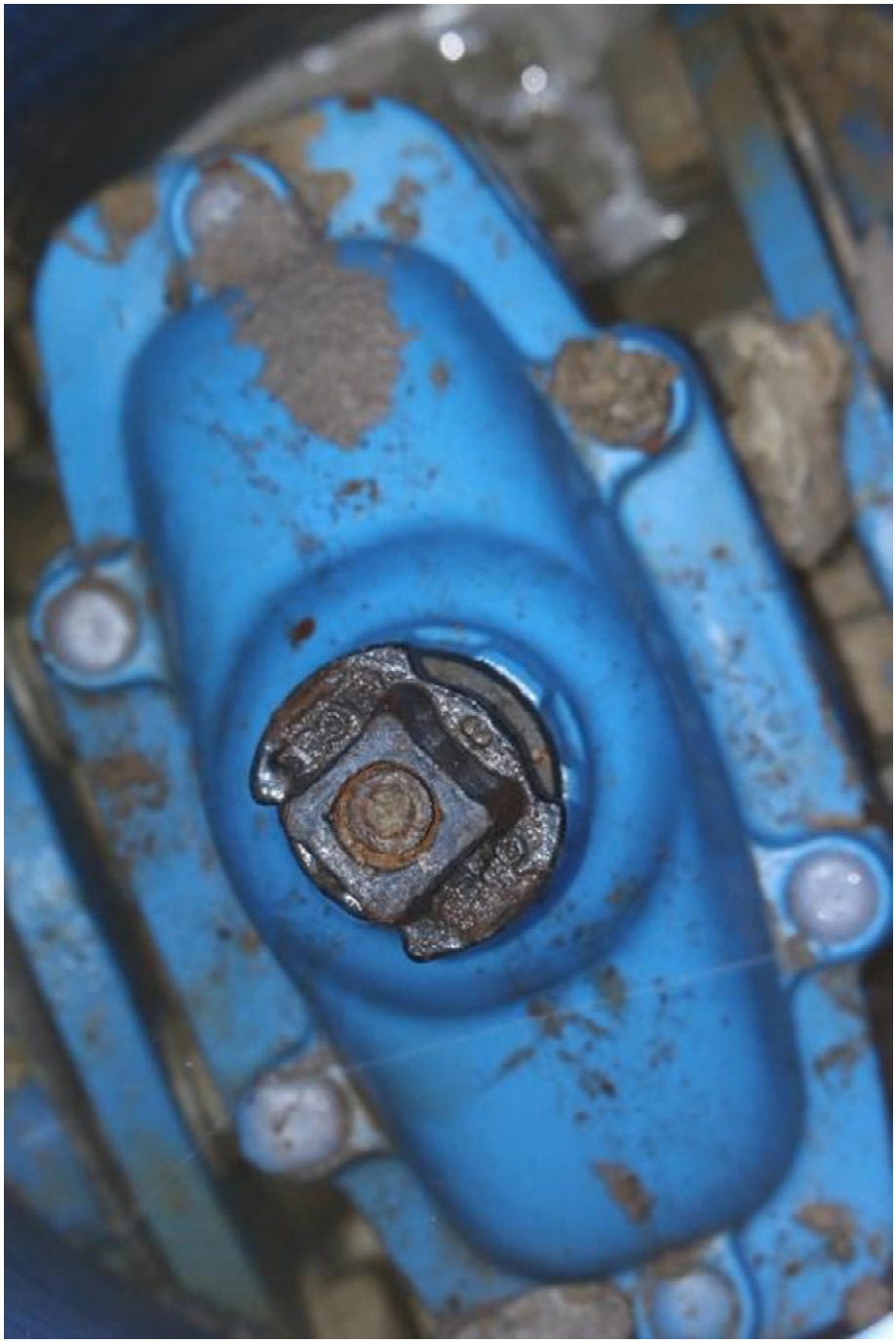
Dual access shaft openings

For access to desludge primary chamber, cut to 750mm dia. access shaft opening. Where a silt trap is incorporated upstream or silt build up will not occur 600mm diameter access shaft may be adequat

Picture 8 closed valve with handles removed going into Separator



Picture 9 Closed valve with handle removed coming out of Separator



APPENDIX 2 - MICRODRAINAGE

Page Left Blank Intentionally

ICP SUDS Mean Annual Flood

Input

Return Period (years)	1	Soil	0.450
Area (ha)	0.829	Urban	0.000
SAAR (mm)	800	Region Number	Region 6

Results **l/s**

QBAR Rural	4.3
QBAR Urban	4.3
Q1 year	3.6
Q1 year	3.6
Q30 years	9.6
Q100 years	13.6

Hydrock Consultants Ltd		Page 1
Over Court Barns Over Lane Bristol BS32 4DF	Horse Hill for Magellen Petroleum Ltd	
Date July 2013 File Storage.srcx	Designed by RJH Checked by	
Micro Drainage	Source Control 2013.1.1	

Summary of Results for 100 year Return Period (+5%)

Half Drain Time : 784 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	9.558	0.558	0.0	4.3	4.3	147.4	O K
30 min Summer	9.656	0.656	0.0	4.3	4.3	196.5	O K
60 min Summer	9.747	0.747	0.0	4.3	4.3	247.1	Flood Risk
120 min Summer	9.825	0.825	0.0	4.3	4.3	294.1	Flood Risk
180 min Summer	9.860	0.860	0.0	4.3	4.3	315.9	Flood Risk
240 min Summer	9.877	0.877	0.0	4.3	4.3	326.9	Flood Risk
360 min Summer	9.892	0.892	0.0	4.3	4.3	337.3	Flood Risk
480 min Summer	9.893	0.893	0.0	4.3	4.3	337.8	Flood Risk
600 min Summer	9.886	0.886	0.0	4.3	4.3	332.9	Flood Risk
720 min Summer	9.875	0.875	0.0	4.3	4.3	325.9	Flood Risk
960 min Summer	9.856	0.856	0.0	4.3	4.3	313.8	Flood Risk
1440 min Summer	9.824	0.824	0.0	4.3	4.3	293.6	Flood Risk
2160 min Summer	9.778	0.778	0.0	4.3	4.3	265.1	Flood Risk
2880 min Summer	9.730	0.730	0.0	4.3	4.3	237.1	Flood Risk
4320 min Summer	9.632	0.632	0.0	4.3	4.3	183.9	O K
5760 min Summer	9.535	0.535	0.0	4.3	4.3	136.6	O K
7200 min Summer	9.444	0.444	0.0	4.3	4.3	97.2	O K
8640 min Summer	9.361	0.361	0.0	4.3	4.3	65.7	O K
10080 min Summer	9.288	0.288	0.0	4.3	4.3	41.1	O K
15 min Winter	9.596	0.596	0.0	4.3	4.3	165.8	O K
30 min Winter	9.702	0.702	0.0	4.3	4.3	221.4	Flood Risk
60 min Winter	9.801	0.801	0.0	4.3	4.3	279.0	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	98.888	0.0	153.5	26
30 min Summer	66.424	0.0	206.2	41
60 min Summer	42.535	0.0	264.1	70
120 min Summer	26.253	0.0	326.1	128
180 min Summer	19.480	0.0	362.9	188
240 min Summer	15.658	0.0	388.9	246
360 min Summer	11.524	0.0	429.4	364
480 min Summer	9.256	0.0	459.8	482
600 min Summer	7.802	0.0	484.5	600
720 min Summer	6.781	0.0	505.4	658
960 min Summer	5.431	0.0	539.6	770
1440 min Summer	3.963	0.0	590.7	1026
2160 min Summer	2.886	0.0	645.2	1432
2880 min Summer	2.301	0.0	685.9	1844
4320 min Summer	1.670	0.0	746.5	2636
5760 min Summer	1.328	0.0	791.6	3392
7200 min Summer	1.113	0.0	829.1	4104
8640 min Summer	0.963	0.0	861.4	4760
10080 min Summer	0.853	0.0	889.7	5448
15 min Winter	98.888	0.0	171.9	26
30 min Winter	66.424	0.0	231.0	40
60 min Winter	42.535	0.0	295.8	68

Summary of Results for 100 year Return Period (+5%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	9.887	0.887	0.0	4.3	4.3	334.1	Flood Risk
180 min Winter	9.927	0.927	0.0	4.3	4.3	360.8	Flood Risk
240 min Winter	9.948	0.948	0.0	4.3	4.3	375.5	Flood Risk
360 min Winter	9.971	0.971	0.0	4.3	4.3	391.7	Flood Risk
480 min Winter	9.978	0.978	0.0	4.3	4.3	396.8	Flood Risk
600 min Winter	9.977	0.977	0.0	4.3	4.3	395.7	Flood Risk
720 min Winter	9.970	0.970	0.0	4.3	4.3	390.8	Flood Risk
960 min Winter	9.946	0.946	0.0	4.3	4.3	374.2	Flood Risk
1440 min Winter	9.904	0.904	0.0	4.3	4.3	345.3	Flood Risk
2160 min Winter	9.840	0.840	0.0	4.3	4.3	303.4	Flood Risk
2880 min Winter	9.770	0.770	0.0	4.3	4.3	260.1	Flood Risk
4320 min Winter	9.621	0.621	0.0	4.3	4.3	178.1	O K
5760 min Winter	9.470	0.470	0.0	4.3	4.3	107.9	O K
7200 min Winter	9.325	0.325	0.0	4.3	4.3	53.3	O K
8640 min Winter	9.188	0.188	0.0	4.3	4.3	16.3	O K
10080 min Winter	9.097	0.097	0.0	4.2	4.2	4.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
120 min Winter	26.253	0.0	365.2	126
180 min Winter	19.480	0.0	406.5	184
240 min Winter	15.658	0.0	435.6	242
360 min Winter	11.524	0.0	480.9	358
480 min Winter	9.256	0.0	515.0	472
600 min Winter	7.802	0.0	542.6	584
720 min Winter	6.781	0.0	566.0	692
960 min Winter	5.431	0.0	604.3	896
1440 min Winter	3.963	0.0	661.5	1110
2160 min Winter	2.886	0.0	722.6	1564
2880 min Winter	2.301	0.0	768.3	1996
4320 min Winter	1.670	0.0	836.0	2816
5760 min Winter	1.328	0.0	886.6	3568
7200 min Winter	1.113	0.0	928.6	4184
8640 min Winter	0.963	0.0	964.7	4752
10080 min Winter	0.853	0.0	996.4	5128

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.350	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+5

Time Area Diagram

Total Area (ha) 0.828

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.276	4	8	0.276	8	12	0.276

Model Details

Storage is Online Cover Level (m) 10.000

Swale Structure

Infiltration Coefficient Base (m/hr)	0.00000	Length (m)	290.0
Infiltration Coefficient Side (m/hr)	0.00000	Side Slope (1:X)	1.0
Safety Factor	1.0	Slope (1:X)	1000.0
Porosity	1.00	Cap Volume Depth (m)	0.000
Invert Level (m)	9.000	Cap Infiltration Depth (m)	0.000
Base Width (m)	0.8		

Depth/Flow Relationship Outflow Control

Invert Level (m) 9.000

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	4.3000	0.900	4.3000	1.700	4.3000	2.500	4.3000
0.200	4.3000	1.000	4.3000	1.800	4.3000	2.600	4.3000
0.300	4.3000	1.100	4.3000	1.900	4.3000	2.700	4.3000
0.400	4.3000	1.200	4.3000	2.000	4.3000	2.800	4.3000
0.500	4.3000	1.300	4.3000	2.100	4.3000	2.900	4.3000
0.600	4.3000	1.400	4.3000	2.200	4.3000	3.000	4.3000
0.700	4.3000	1.500	4.3000	2.300	4.3000		
0.800	4.3000	1.600	4.3000	2.400	4.3000		

APPENDIX 3 - OPERATING TECHNIQUE DOCUMENT HSE-HH1-PD-09

Page Left Blank Intentionally

HORSE HILL
DEVELOPMENTS

Horse Hill Development Ltd (HHDL)

Operating Technique Document

Doc No.: HSE-HH1-PD-09

Document Control Page

Operator:	Horse Hill Developments Ltd
Well:	Horse Hill-1 Exploration Well
Report Title:	Operating Technique Document
Date:	18 May 2015
Document Ref:	HSE-HH1-PD-09

Revision Record:

DATE	REV NO	DESCRIPTION	PREPARED	CHECKED	APPROVED
03/11/2014	A01	Final for Issue	FD	JD	DHO

Table of Contents

1 Introduction

Horse Hill Developments Ltd (hereinafter referred to as "HHDL") has prepared an Environmental Permit application for a Water Discharge Activity at the Horse Hill -1 well site, Horse Hill, Hookwood, Horley, Surrey (Application Ref: EPR/BB3691NN/A001).

The application relates to the discharge of rainfall from the well site following completion of the drilling programme in early November 2014, when the rig and all associated drilling related equipment have left the site (See pictures, site now empty). The discharge will be through a SPEL Class 1 Bypass Separator, model 215 C1/SC and into a field dyke via a buried pipe.

This Operating Technique document has been prepared to outline the measures HHDL will put in place to mitigate against the potential risk of residual contaminants being present in the discharge from the well site once the rig has left the site. It should be read in conjunction with the following documentation which has been submitted to the EA in support of the Environmental Permit Application:

- Application Forms (Part A, B2, B6 & F2);
- Non-Technical Summary for Water Discharge Permit Application (document number HSE-HH1-PD-08);
- "Site Plans" (document number HSE-HH1-PD-07);
- "Environmental Risk Assessment" (document number HSE-HH1-PD-09);
- "HHDL HSE Management System Framework Document" (document number HSE-HH1-OP-01);
- "Continuation Sheet" (document number HSE-HH1-PD-010);
- "Horse Hill-1 Environmental Method Statement" (document number HSE-HH1-PD-02);
- "Site Condition Report and Management and Monitoring Plan" (document number HSE-HH1-PD-03);
- "Addendum to Mining Waste Application" (document number HSE-HH1-PD-06).

2 Horse Hill Well Site

The well site for the Horse Hill-1 well is designed, following standard industry practices, as a stable working platform to support the rig and all associated equipment. It is underlain by an impermeable membrane made from JUNIFOL PEHD 1,0 G/G and surrounded by an interceptor ditch with an earth bund on the outside of the ditch.

Rainfall onto the compound and bund area, as well as any potential contaminants such as fuel and oils used in operating the drilling machinery, is directed into the interceptor ditch. The ditch, which is located in the lined compound, has a trapezium X-sectional area of around 1.7 m^2 and a length of approximately 290 m which gives a volume of around 500 m^3 (equivalent to around 500,000 litres) of fluid (refer to Figure 2.1).

A pipe is buried underneath the well site following the swale route, as previously shown , which is connected upstream to a Class 1 Bypass Separator and downstream to a field dyke discharge point (located at National Grid Reference TQ 25306 435489). The Class 1 Bypass Separator model 215 C1/SC is designed and operated to effectively separate oil and water and fully conforms to both the Environment Agency's latest PPG3 guidelines and European standard BSEN-858-1-2. See appendix D.

It achieves a final discharge to surface water drain of less than 5 mg hydrocarbon per litre of water as per suppliers information.

It was installed as new by Fox as part of the construction of the well site. The unit was sized by the supplier using their tables, examples can be seen in Appendix D

An isolation valve is installed on the outfall from the bunded compound area both upstream and downstream of the Class 1 Bypass Separator (this allows full isolation of the site as well as isolation of the separator for maintenance works if required). See pictures.

During site construction and prior to the drilling rig's arrival on site, the isolation valve on the Class 1 Bypass Separator was left open so that rainfall across the site drained to the perimeter ditches, through the Class 1 Separator and into the field dyke via the buried pipe. Once the rig arrived on site, the isolation valves were closed, handles removed and the water in the perimeter ditches was used to make up the drilling fluid or, if not required for this purpose, was tankered off site for disposal at a permitted disposal facility. This has continued to be the situation since the rig has left.

The site at present is completely empty of all equipment. The site has been monitored on a weekly basis to ensure water build up is removed by tanker for off site disposal. There has also been regular water testing as originally discussed.

3 Ditch Water Composition

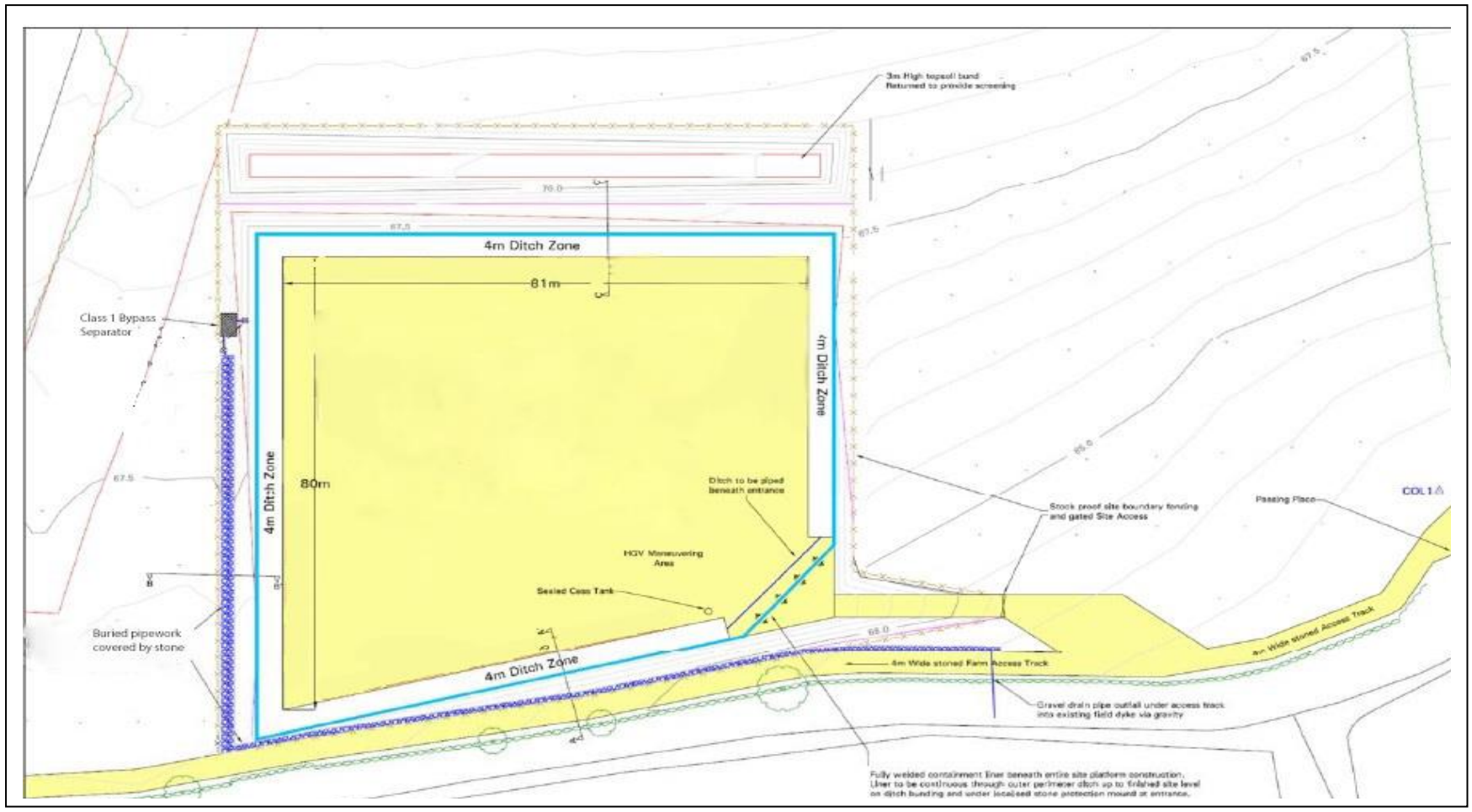
During the rig attendance on site, HHDL took samples of the water within the perimeter ditches on a weekly basis. Example of the sampling data for the ditch water is provided in Appendix A which demonstrates a Total Petroleum Hydrocarbon (TPH) (C10-C40) level of < 35 µg/l. This is consistent with the continuing effectiveness of the anti-pollution measures described in the Non-Technical Summary (document HSE-HH1-PD-08 Rev A1); in other words the water in the ditch has a composition similar to rainwater as the rainwater picks up minimal / no hydrocarbon contamination during its infiltration into the ditch because there is no contamination on site. The level of hydrocarbon contamination is so low that the presence of the Class 1 Bypass Separator is immaterial (i.e. the Separator performance of less than 5 mg/l will have a negligible impact on the quality of water discharged from the site once the isolation valve is opened).

HHDL continued to take samples of the ditch water on a regular basis after the departure of the rig, which occurred in November 2014. Any fluid that remains within the perimeter ditches will be tankered off site for disposal at a permitted disposal facility.
From this point onwards there will be no active sources of pollution as:

- The well will have been suspended resulting in the isolation of the well from the environment through multiple barriers;
- The rig and all associated drilling related equipment is no longer on site;
- The additional secondary containment and bunding provided around the rig mud tanks and the additional mud and cuttings tanks on the well site will be removed at the same time as the rig is removed;
- Any fluid in the interceptor ditch will have been tankered off site.

Consequently, it is very unlikely that there will be any pollution sources (e.g. dried oil spills) remaining on site. As such, the only fluid source when the rig has left the site is rainfall. It is this rainfall which HHDL proposes to discharge from the site in accordance with the procedure outlined in Section 4.

Figure 2.1: Well Site Layout



Note: following discussions with the Environment Agency, a pipe has been buried underneath the site, which is connected upstream to the Class 1 Bypass Separator and downstream to the field dyke discharge point. This design change was discussed with, and agreed by, the Flood & Water Services Team of the Surrey Highways Asset Planning Group.

4 Discharge and Sampling Operating Procedure.

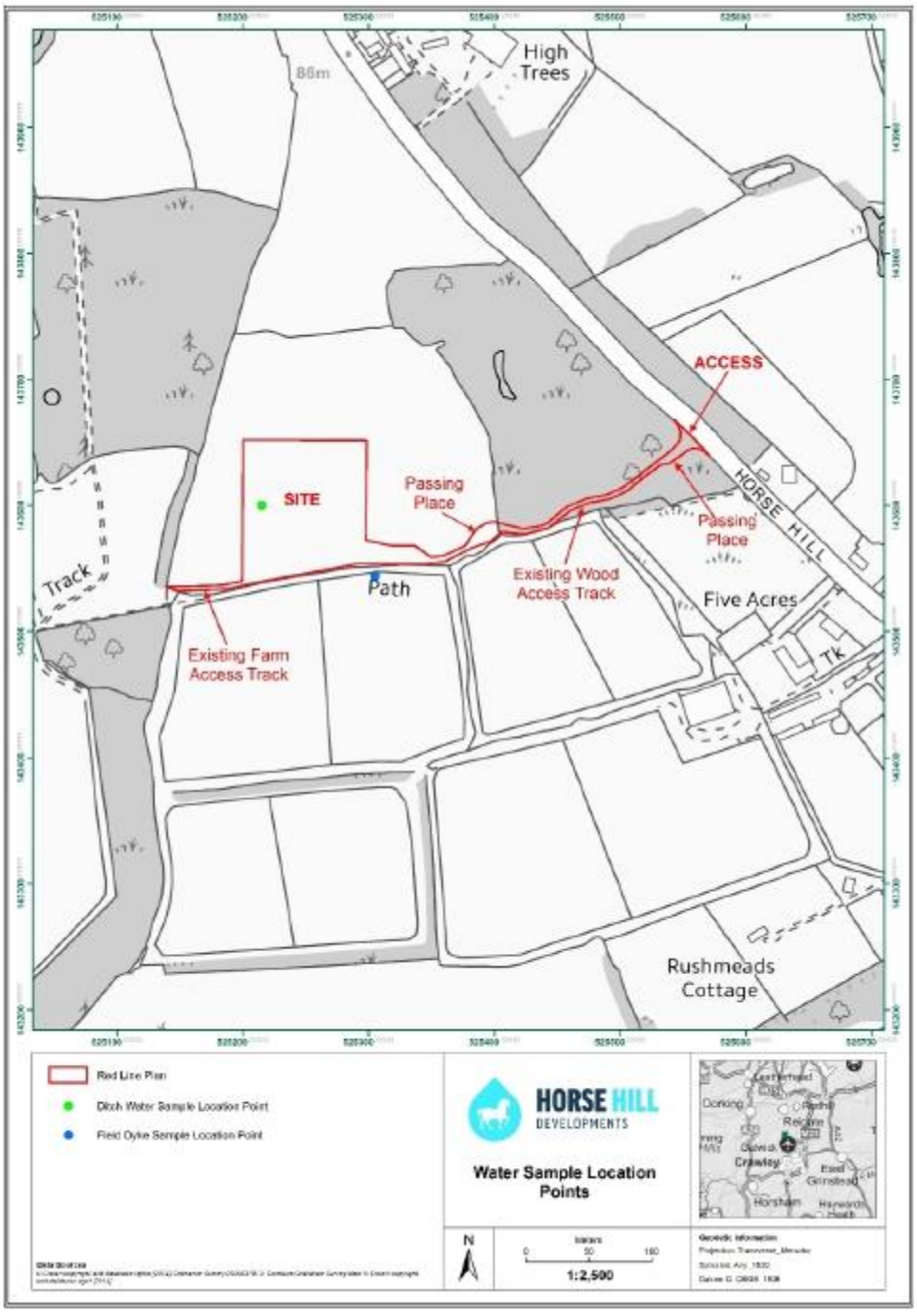
Once the rig has been removed from the well site and any fluid remaining within the perimeter ditches has been tankered off site for disposal, HHDL will implement the following procedure to ensure that discharge from the ditch does not cause any pollution: :

1. One week after the rig left the well site and any fluid remaining within the perimeter ditches has been tankered off site for disposal, a visual inspection of the ditches will be made to ensure there are no visible signs of contamination. HHDL will take a photographic record of the well site (including the perimeter ditches) and forward this to the Environment Agency to prove that the drilling operations have ceased and key potentially polluting sources associated with the drilling activity have been removed. (see pictures attached.

2. Water samples will then be taken from the following location, as illustrated on Figure 4.1. Note: the only source of water once any fluid remaining within the perimeter ditches has been tankered off site for disposal is rainwater
    - **Sample point –perimeter ditch prior to input valve to Separator (TQ 25215 43600)**
      The purpose of sampling the water prior to it being discharged is to demonstrate that any rainfall discharged from the site will not be contaminated. A sample will be taken from the water collected within the site

.

Figure 4.1: Water Sample Location Points



3. Due to low levels of contaminants anticipated, any collected samples will be sent to a UKAS accredited laboratory for detailed analysis. The parameters, monitoring standard method, monitoring frequency and EQSs are listed below. Where a monitoring standard or method has not been specified, HHDL will ensure that the analysis method chosen has a Limit of Detection less than the EQS (or equivalent) specified in the table below.

Parameter	Monitoring frequency	Monitoring standard or method	EQS (or equivalent)
pH	(a) Once prior to first discharge following any activity at the well site and/or following storage of potentially polluting liquids on site. (b) Monthly thereafter	BS ISO 10523	Not less than pH 6 and not greater than pH 9.
Ammoniacal Nitrogen (expressed as N)		BS EN ISO 11732	0.5mg/l
ATU-BOD as O_2		BS EN 1899-1	1mg/l
COD as O_2		BS 6068-2.34	10mg/l
Total Arsenic as As		BS EN ISO 11969:	50ug/l
Total Cadmium as Cd		BS EN ISO 5961	0.9ug/l
Chloride		SCA blue book 51 ISBN 0117516260	250mg/l
Chromium VI		BS 6068-2.47 ISO 11083	3.4ug/l
Total Copper as Cu		BS 6068-2.29 ISO 8288	10ug/l
Total Iron as Fe		BS EN ISO 15586:	1000ug/l
Total Lead as Pb		BS 6068-2.29 ISO 8288	7.2ug/l
Manganese		Monitoring standard or method chosen must ensure that Limit of Detection is less than EQS (or equivalent).	300ug/l
Total Mercury as Hg		BS EN 1483	0.07ug/l
Total Nickel as Ni		BS 6068-2.29 ISO 8288	20ug/l
Total Zinc as Zn		BS 6068-2.29 ISO 8288	75ug/l
Benzene		Monitoring standard or method chosen must ensure that Limit of Detection is less than EQS (or equivalent).	50ug/l
Toluene		Monitoring standard or method chosen must ensure that Limit of Detection is less than EQS (or equivalent).	380ug/l (95 percentile)
Xylene		Monitoring standard or method chosen must ensure that Limit of Detection is less than EQS (or equivalent).	30ug/l

Once the sample has been analysed, the results will be compared against the EQS (or equivalent) for each parameter as shown in the table above. If any of the sample results are greater than EQS (or equivalent), the water within the perimeter ditch (and site) will be considered to be contaminated and will be tankered away. The process documented above in 2-3 would be repeated. Only upon receipt of an analysis report from the laboratory which shows that all results did not exceed EQS (or equivalent), would the water be considered uncontaminated. At that stage, HHDL would forward the report, along with ALL other previous sampling reports, to the Environment Agency for inspection and request that written approval is provided to allow the discharge from the well site to commence.

The sampling regime follows the following procedure. Samples are taken on the day and sent directly to the Lab for analysis, the lab usually turns the results around within 2 weeks, as the example report shows below the tests commenced the day after samples were taken. A report will normally be sent the day of completion of tests, dependent on the test being carried out. HH will respond to the results on the day of receipt and react accordingly to the findings as mentioned in point 6 below.

4. Once written approval has been received from the Environment Agency, HHDL will open the valves to Class 1 Bypass Separator in order to commence discharging the water from the well site. The maximum daily volume of effluent to be discharged from the site will be 26 m^3 and the maximum rate of discharge will be 0.3 litres per second. It is assumed this discharge will occur around 1-2 weeks after the initial water samples were taken. In the interim period, when the valves are closed, if torrential rain threatens to overflow the perimeter ditches, HHDL will tanker the water within the ditches off site for disposal at a permitted disposal facility.

5. On commencement of the discharge, a water sample will be taken from the effluent sampling point at field dyke sample location point (TQ 25306 43549) and sent to the laboratory for analysis. The parameters and LOD of the techniques that will be used to analyse the sample will be the same as those listed above. The analysis report will be sent to the Environment Agency for their records. A visual inspection will also be made of the field dyke to confirm that the discharge is not having an adverse visible effect. The output will be inspected on a regular basis to ensure that the quality of the water has not deteriorated in any way. This will be carried out everytime a sample is taken, or more often if there has been a long rainy period.

6. The valves to the Class 1 Bypass Separator will then remain open until such point any activity re-commences on the well site which would result in a potential pollution source when the valves will be shut. (e.g. testing of the well).
   Once the valve is open, a monthly testing regime will be carried out at the effluent sampling point (field dyke smple location point), depending on the water flow.
   Should there not be any flow from the site at the effluent sample point, a response will be made to The Environment Agency advising that there was no discharge and a sample could not be taken
   Results will be sent in on a quarterly basis unless samples show the returns to be outside of the given parameters.
   If any of the concentrations are greater than the EQS, then the discharge would be considered to be contaminated. In this event the input and output valves to the separator would be shut as soon as reasonably practicable and any fluid within the perimeter ditches would be tankered off site for disposal.
   HHDL to notify the Environment Agency of any breach of EQS as soon as reasonably practicable and no later than 7 days after HHDL receives the analysis report. HHDL to also notify the Environment Agency of the period that the valve was left open after the sample was taken.
   Once an EQS has been breached and the valves are closed, the process documented above in Point 2-3 would be repeated i.e. sample taken of the water in the perimeter ditch.
   Upon receipt of an analysis report from the laboratory, showing that the results indicate that the water is uncontaminated, HHDL will forward the report, along with ALL other previous sampling reports to the Environment Agency for inspection and request that written approval is provided to allow the discharge from the well site to commence. Points 4-6 will then be repeated also.

7. The Separator will be monitored on a regaular bases and will be maintained as per the manufactures instruction – at least twice a year.
   Should contaminants be found in the chambers of the seperator, the vavles will be shut and the separator emptied by suction tanker and cleaned . The waste water will be taken to a licensed waste site.

5 Control of Records

HHDL will ensure that the water sample laboratory analysis reports, visual inspection records and records of the inspection and maintenance of the Class 1 Bypass Separator are held by the company and made available for inspection by Environment Agency staff on request. HHDL will keep these records for a minimum of 6 years.

Appendix A: Ditch Water Sample Analysis Report

Unit A2
Windmill Road
Ponswood Industrial Estate

St Leonards on Sea
East Sussex
TN38 9BY
Telephone: (01424) 718618
Facsimile: (01424) 729911
info@elab-uk.co.uk

UKAS TESTING
2683

THE ENVIRONMENTAL LABORATORY LTD

Analytical Report Number:	14-01504
Issue:	1
Date of Issue:	08/12/2014
Contact:	
Customer Details:	Angus Energy Weald Basin No3 Ltd Suite 1A, 38 Princes House Jermyn Street London
Quotation No:	Q14-00078
Order No:	Not Supplied
Customer Reference:	Not Supplied
Date Received:	25/11/2014
Date Approved:	08/12/2014
Details:	Horse hill

Approved by:

Any comments, opinions or interpretations expressed herein are outside the scope of UKAS accreditation (Accreditation Number 2683

Sample Summary

Report No.: 14-01504

Elab No.	Client's Ref.	Date Sampled	Date Scheduled	Description	Deviations
10105	1	25/11/2014	26/11/2014		

1

2683

Results Summary

Report No.: 14-01504

ELAB Reference	10105
Customer Reference	
Sample ID	
Sample Type	WATER
Sample Location	1
Sample Depth (m)	
Sampling Date	25/11/2014

Determinand	Codes	Units	LOD	
Inorganics				
Ammoniacal Nitrogen as N	N	mg/l	0.1	1.2
BTEX				
Benzene	N	ug/l	1	< 1.00
Toluene	N	ug/l	1	< 1.00
Ethylbenzene	N	ug/l	1	< 1.00
Xylenes	N	ug/l	1	< 1.00
MTBE	N	ug/l	1	< 1.00
Total Petroleum Hydrocarbons				
Total TPH (C10-C40)	N	ug/l	35	< 35

2683

1

Results Summary

Report No.: 14-01504

ELAB Reference	10105
Customer Reference	
Sample ID	
Sample Type	WATER
Sample Location	1
Sample Depth (m)	
Sampling Date	25/11/2014

Determinand	Codes	Units	LOD	
SVOC				
Diethanolamine	N	ug/l	1	< 1.00

2683

Method Summary

Report No.: 14-01504

Parameter	Analysis Undertaken On	Date Tested	Method Number	Technique
Water				
BTEX in waters		01/12/2014		GC-MS
Ammonia in waters		28/11/2014	151	Colorimetry
SVOC in waters		28/11/2014	167	GC-MS
Total Petroleum Hydrocarbons in waters		28/11/2014	178	GC-FID

ELAB

UKAS TESTING 2683

Report Information

Report No.: 14-01386

Key

U	hold UKAS accreditation
M	hold MCERTS and UKAS accreditation
N	do not currently hold UKAS accreditation
^	MCERTS accreditation not applicable for sample matrix
S	Subcontracted to approved laboratory UKAS Accredited for the test
SM	Subcontracted to approved laboratory MCERTS/UKAS Accredited for the test
I/S	Insufficient Sample
U/S	Unsuitable sample
n/t	Not tested
<	means "less than"
>	means "greater than"

Comments or interpretations are beyond the scope of UKAS accreditation
The results relate only to the items tested
Uncertainty of measurement for the determinands tested are available upon request

Deviation Codes

a	No date of sampling supplied
b	No time of sampling supplied (Waters Only)
c	Sample not received in appropriate containers
d	Sample not received in cooled condition
e	The container has been incorrectly filled
f	Sample age exceeds stability time (sampling to receipt)
g	Sample age exceeds stability time (sampling to analysis)

Where a sample has a deviation code, the applicable test result may be invalid.

Sample Retention and Disposal

All soil samples will be retained for a period of one month
All water samples will be retained for 7 days following the date of the test report
Charges may apply to extended sample storage

Appendix B: Photographs

Picture 1 Field Dyke Drainage Site, October 2014

Picture 2 Field dyke drainage March 2015

Picture 3 and 4 Site at present time

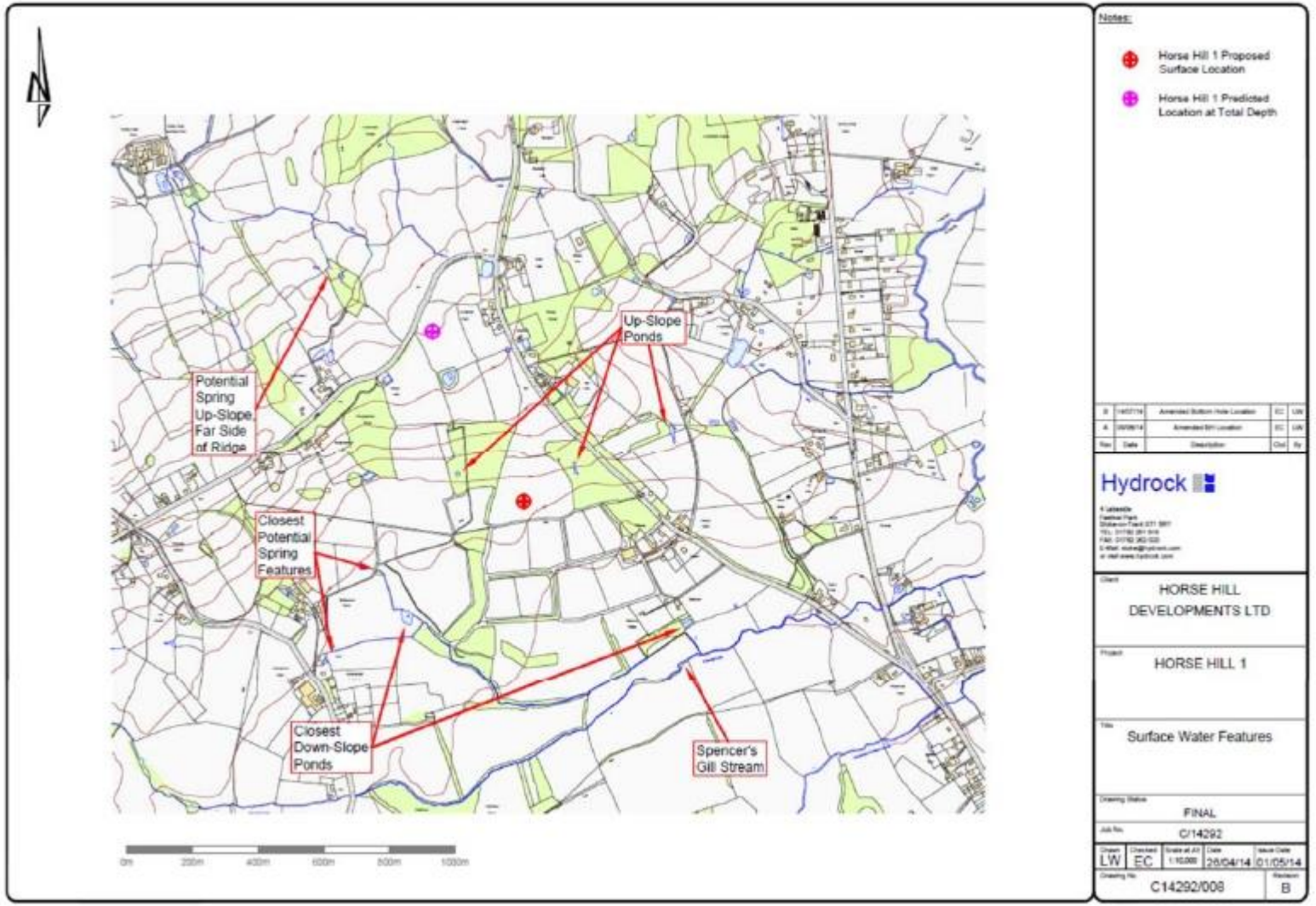
Picture 5 Stone covered pipe across roadway

Picture 6 and 7 Stone covered pipe from separator to dyke

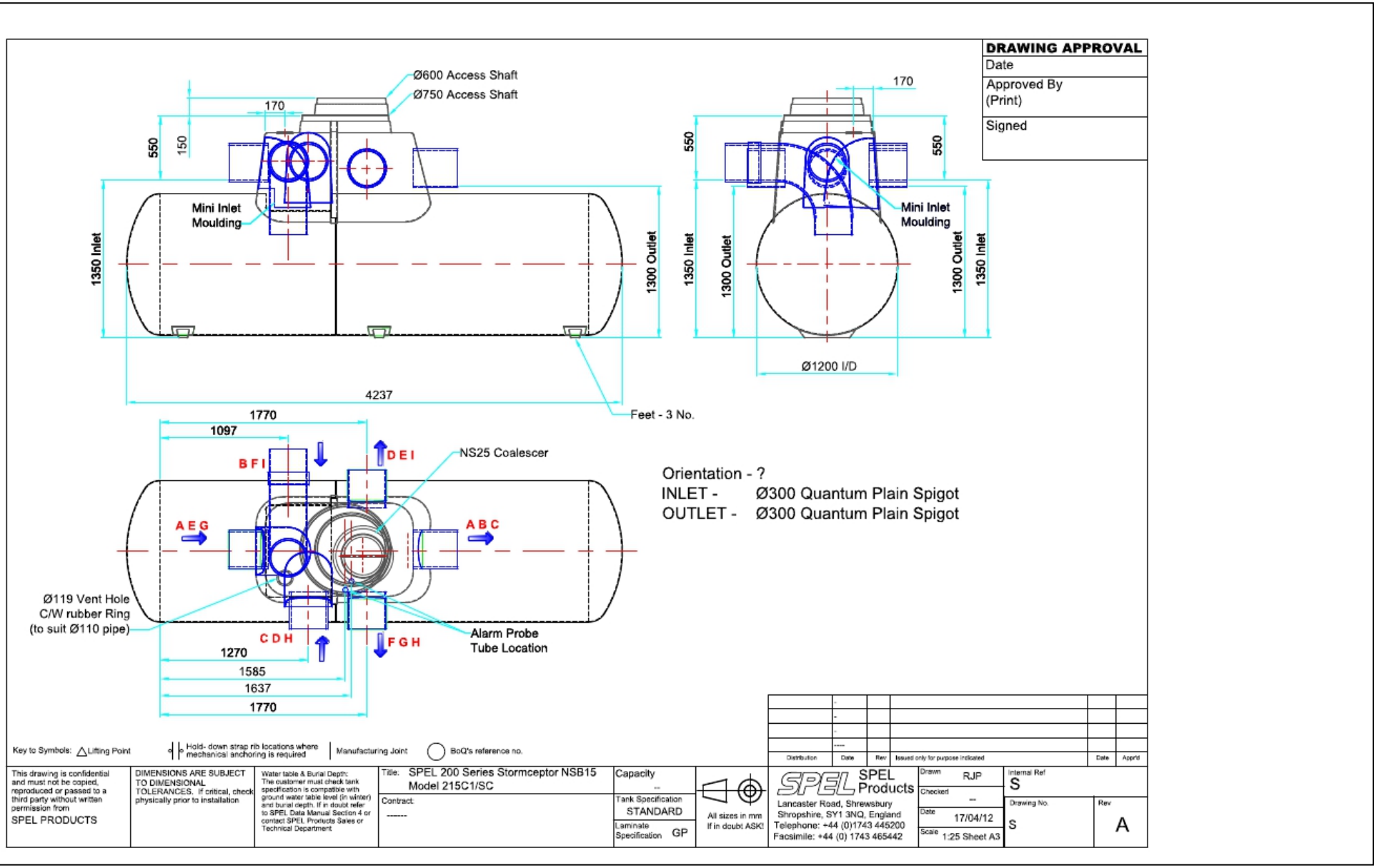
Picture 8 closed valve with handles removed going into Separator

Picture 9 Closed valve with handle removed coming out of Separator

Appendix C: Surface Water Features Map

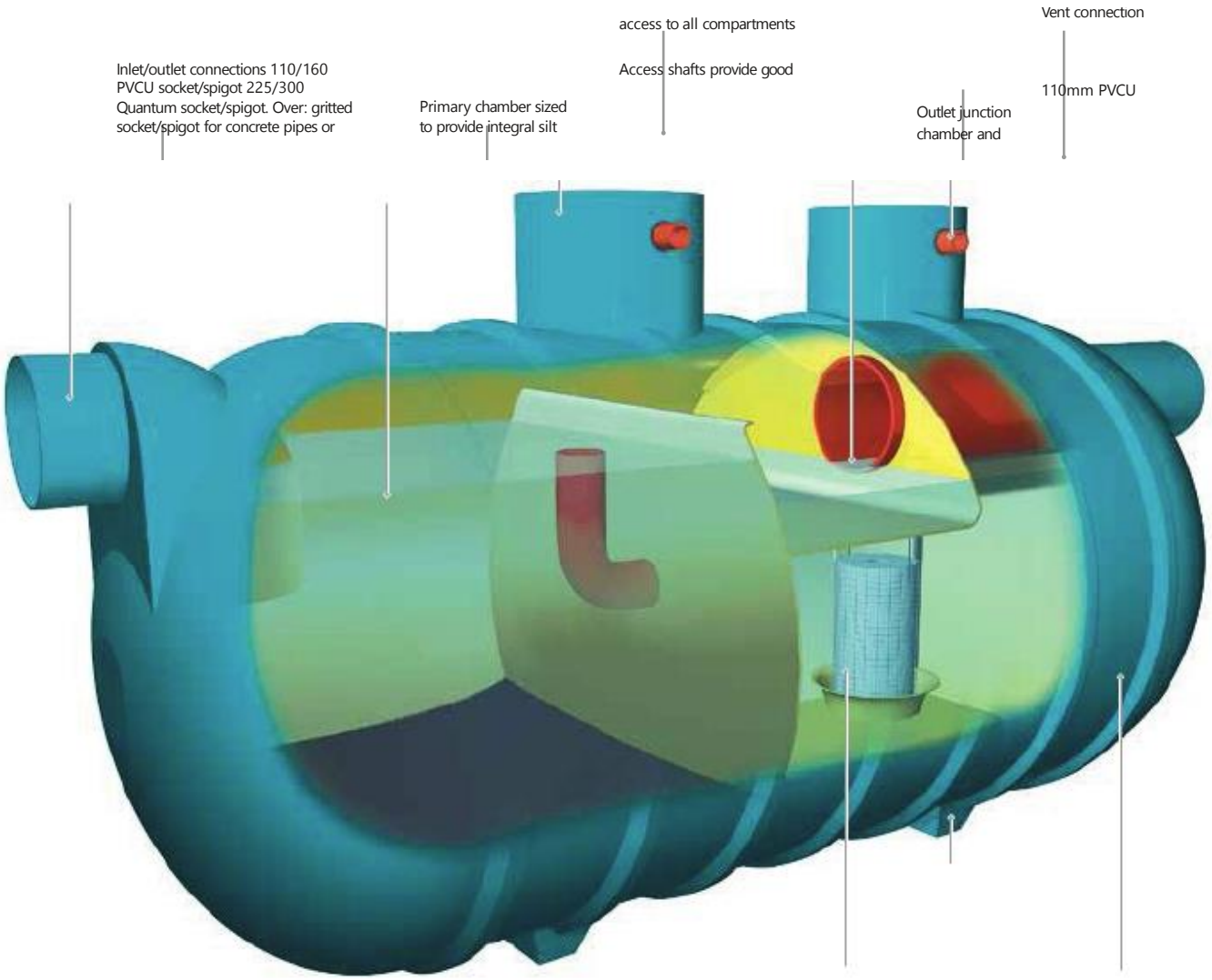


Appendix D: Separator information



SPEL Stormceptor® Class 1 by-pass separator

Compliant to the European Standard BS EN 858-1, the Environment Agency's Pollution Prevention Guidelines PPG3 and the Construction Products Regulations.



The SPEL Stormceptor is a well proven high quality factory-made unit specially designed and fabricated to provide a very effective means of separating oil and other light liquids from stormwater drainage systems.

The SPEL Stormceptor was the first Environment Agency listed class 1 by-pass separator to BS EN 858-1:2002.

The SPEL Stormceptor has been used effectively throughout the UK and abroad since 1985. All sizes and types of development have been catered for, including industrial development sites, hypermarkets and airports. Areas of up to 30 hectares can be covered with a single unit.

The 'heart' of the SPEL Stormceptor is the unique long life, low maintenance coalescer unit which 'polishes' the final effluent AFTER 90% hydrocarbons of silt have been separated out.

Selecting size of SPEL Stormceptor

The nominal size (NSB) is obtained by this formula: NSB = 0.0018A(m^2) where A is the catchment area.

	NSB	Model	Class 1 or 2 C1 or C2	Silt Cap. SC	Orientation inlet/outlet	Inlet/outlet diameter
Example 1	20	320	C1	SC	D	600/600
Example 2	50	4100	C2	–	A	900/900

Example 1

SPEL Stormceptor class 1 by-pass separator NSB 20 model 320C1/SC/D 600/600 (with silt capacity).

Example 2

SPEL Stormceptor class 2 by-pass separator NSB 100 model 4100C2/A 900/900 (without silt capacity).

How to select and specify

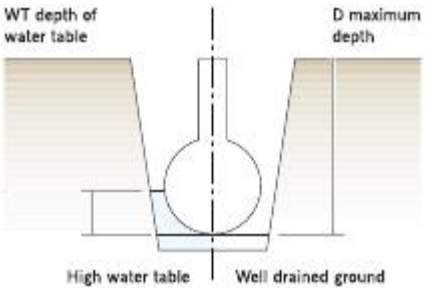
1. In accordance with the EA Pollution Prevention Guidelines PPG3:
   - Determine the type of separator – full retention or by-pass.
   - Determine the class of separator – class 1 or 2.
   - Specify whether silt capacity is required integrally or separately upstream of the separator.
2. Against the catchment area within which your requirements fall, the SPEL Separator nominal size can be ascertained.
3. Inlet/outlet pipe connection orientation A-I (see options below).
4. Inlet/outlet diameter in mm.
5. SPEL Separators are available in four specifications to suit invert depths and ground water conditions. Standard, Heavy, Extra Heavy and Special, see tables alongside.
6. Optional extras available see 5.6 and 5.7.
   - SPEL coalescer unit guide rail system.
   - SPEL coalescer unit lifting/locating/ locking system.
   - SPEL Econoskim® light liquid skimming and separate containment system.
   - SPEL mechanical anchoring system. See 4.11/4.12.
7. SPEL automatic alarm/monitoring system. See 5.7.

Specification

Standard, heavy, extra heavy or special specification available dependent upon tank burial depth and water table level in winter. The tables below refer to tanks with a concrete surround. For extra heavy and special specification range and pea gravel surround refer to section 4 or contact technical sales.

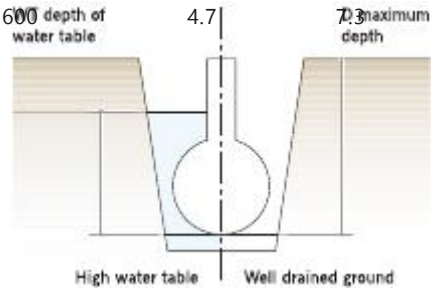
Standard tanks

Series	WT(m)	D(m)
100/200	1.0	4.0
300	0.9	4.0
400	1.3	5.0
500	1.9	5.7
600	2.4	6.2



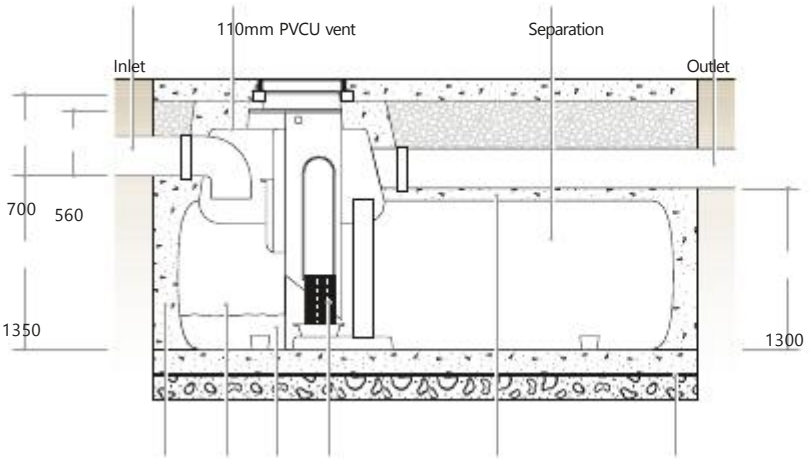
Heavy tanks

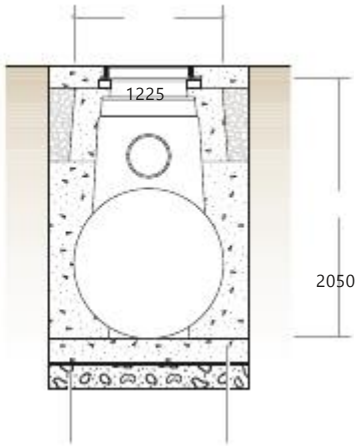
Series	WT(m)	D(m)
100/200	2.0	6.0
300	2.8	5.6
400	3.5	6.0
500	4.5	7.25
600	4.7	7.3



SPEL Stormceptor® by-pass separators

200 series, class 1 with silt capacity





150mm minimum thickness concrete surround | Primary Silt chamber | Coalescer | 150mm minimum thickness concrete over the top.* | Polythene membrane | 150mm hardcore (where base of excavation is of unstable ground) | 150mm concrete base

* Fabric reinforcement may be necessary where vehicle loading has to be taken into account or where high extension access shafts are to be fitted

SPEL automatic alarm/monitoring system

Requirement of the Environment Agency's Pollution Prevention Guidelines PPG3

The SPEL automatic alarm/monitoring system provides continuous monitoring of the separator contents by sensing when the

light liquid within the separator has filled to a predetermined level (with design safety margins), and provides a simple audio-visual warning to alert the operator that the separator needs to be emptied.

Maintenance

The SPEL 200 series Stormceptor class 1 by-pass separators have good access to both the primary chamber and the light liquid separation chamber for periodic emptying of retained light liquids and silt which is essential to maintain the units optimum performance.

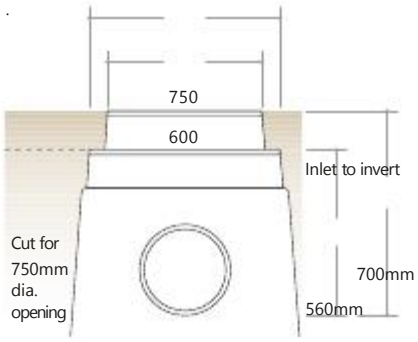
Periods between emptying will have to be determined depending on site conditions but normally at least twice a year.

For detailed instructions see section 9.

Procedure in brief

1. Lift handle and coalescer unit out of the tank and place ahead of the separator.
2. Remove foam insert and wash with normal water pressure, ensuring the dirty water runs into the separator.
3. Empty light liquids and silt alternating between both chambers to avoid excessive pressure one side of the partition.
4. Re-insert the foam insert into the stainless steel coalescer unit and re-insert the coalescer unit into the separator.

Catchment area m²	SPEL ref	Nominal size NSB	Oil storage litres NSBx15	Silt storage litres NSBx100	Overall length (mm)	Max pipe (mm)
2222	204C1SC	4	60	400	1860	300
3333	206C1SC	6	90	600	2110	300
4444	208C1SC	8	120	800	2260	300
5556	210C1SC	10	150	1000	2920	300
8333	215C1SC	15	225	1500	4227	300



Dual access shaft openings

For access to desludge primary chamber, cut to 750mm dia. access shaft opening. Where a silt trap is incorporated upstream or silt build up will not occur 600mm diameter access shaft may be adequat

APPENDIX 4 - HYDROGEOLOGICAL AND FLOOD RISK ASSESSMENT

Page Left Blank Intentionally

HYDROGEOLOGICAL AND FLOOD RISK ASSESSMENT

HORSE HILL WELL SITE, SURREY.

For

Horse Hill Developments Ltd
Suite 3B Princes House
38 Jermyn Street
London
SW1Y 6DN

By

Envireau Water
Aske Stables
Aske
Richmond
North Yorkshire
DL10 5HG

Tel: 01748 889 268
E mail: info@envireauwater.co.uk
Web: www.envireauwater.co.uk

Ref: P20-040 HHDL Horse Hill Permit \ RPT HRA FRA HHDL
February 2021

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

Revision	Details	Completed by	Date	Checked by	Date
REV01	Draft for Internal Review	SC	09/11/18	PH	09/11/18
REV02	Draft for Internal Review	SC	21/11/18	PH	23/11/18
REV03	Draft for Client Issue	PH	25/11/18	JD	26/11/18
REV04	Client Issue	PJ	27/11/18	PH	28/11/18
REV05	Reissue-MPA/EA Comments	PJ	19/07/19	PH	25/07/19
REV06	Update following Sch.5 notice	SC	25/02/21	PH	26/02/21

HYDROGEOLOGICAL AND FLOOD RISK ASSESSMENT

HORSE HILL WELL SITE, SURREY

Non-Technical Summary

Envireau Water has been commissioned by Horse Hill Developments Limited ("HHDL") to prepare a Hydrogeological Risk Assessment (HRA) and Flood Risk Assessment (FRA) for a Proposed Development at their Horse Hill well site on land near Horley, Surrey ("the Site"). The Site is located in Petroleum Exploration and Development Licence (PEDL) 137. The report provides an update to work originally carried out in 2018/19 and is intended to support an environmental permit application.

The Proposed Development comprises modifications to an existing well site compound to accommodate up to 6 (six) oil production/reinjection wells and the production of oil.

The design philosophy for the Site follows the principles for the containment of potential contaminants set out in CIRIA guidance C736 – Containment Systems for the Prevention of Pollution. The Site incorporates a very low permeability high density poly-ethylene (HDPE) membrane forming a hydraulic barrier and protecting surface water and groundwater systems. A quality assurance procedure has verified the integrity of the Site. This membrane will be retained in the Proposed Development.

Surface water collecting in the drainage system at the Site will be attenuated and clean water will be discharged to a local watercourse at a rate not exceeding the greenfield runoff rate. The well site drainage system is designed to accommodate rainfall volumes generated by a 1:100 year (+ climate change) event. Water collecting in bunded process areas will be treated and reinjected together with produced water for production support. Any water that is not suitable for discharge (e.g. surface runoff collected during drilling and workover activities) will be contained and tankered away from the Site to an Environment Agency permitted waste facility.

A hydrogeological conceptual model has been developed based on a detailed review of background information including the Site setting, local hydrology (surface water systems), geology and hydrogeology. The conceptual model provides an understanding of the potential hydraulic pathways between the well site and various water features (receptors), which is fundamental to the risk assessment process. In this case, there are five hydrogeological units, namely:

- The Superficial Deposits /weathered bedrock (Unit 1): Unit 1 has low-moderate permeability and limited storage. These strata have the potential to support a shallow groundwater system with a resource value for drinking water and other supplies.
- The Weald Clay Formation (Unit 2). Overall, Unit 2 is very poorly permeable (very low hydraulic conductivity), has limited storage, and is considered Unproductive strata. However, thin productive layers within the formation have the potential to support a shallow groundwater system with a resource value for drinking water and other supplies. Due to the thick units of argillaceous strata, vertical hydraulic conductivity within the formation is very low; this unit therefore provides a hydraulic break between shallow groundwater and deeper groundwater in Unit 3 and Unit 4.
- The Tunbridge Wells Sand, Wadhurst Clay and Ashdown Formations (Unit 3). Unit 3 has moderate hydraulic conductivity and storage. Water within these formations is likely to have resource value, although water quality may be poor due to the distance from outcrop and limited throughflow. Permeability and water quality are likely to decrease with depth.

North Office, Aske Stables, Aske,
Richmond, North Yorkshire, DL10 5HG
t 01748 889268
e info@envireauwater.co.uk
w www.envireauwater.co.uk

Envireau Ltd. Registered in England and Wales No. 6647619
Registered office: Cedars Farm Barn, Market Street, Draycott, Derbyshire, DE72 3NB

- The Purbeck Group (Unit 4). Unit 4 has limited hydraulic conductivity and limited storage. The predominantly argillaceous sequence through the Purbeck Group (particularly the top of the formation) and the anhydrite at the base of the formation provides a hydraulic break between groundwater in Unit 3 and hydrocarbon bearing formations in Unit 5.
- The Jurassic Strata (Unit 5). Unit 5 has low-moderate hydraulic conductivity and limited storage. Formations from the Portland Group downwards contain hydrocarbons and formation water with no resource value. Poorly permeable clay and mudstone horizons separate the hydrocarbon bearing strata.

There is no movement of water between the different hydrogeological units and the principal recharge mechanism for water to each unit is where the formations outcrop at surface. It is unlikely that faulting will provide a direct pathway for transmission of fluids between the deep, Jurassic water bearing units and shallow groundwater systems, as evidenced by a review of local seismic data and faulting carried out by HHDL and through differences in water quality between units.

Using the conceptual model, a hydrogeological risk assessment (HRA) has been carried out taking account of with the Environment Agency's technical guidance which examines the risk to a wide range of receptors. The risk assessment has been carried out using the Source-Pathway-Receptor (S-P-R) approach with reference to Environment Agency technical guidance. The risks associated with the construction and restoration of sites and the construction, testing and decommissioning of oil and gas wells is well understood. There is good understanding of the geology, hydrology and hydrogeology at the Site. Mitigation measures for the oil and gas industry are clearly defined, tested and known to work. Furthermore, a detailed assessment of produced water reinjection demonstrates that the water reinjection is the best environmental option (BEO) at this location. Therefore, a semi-quantitative (Tier 1/2) assessment is appropriate to assess the risks associated with the Proposed Development.

The risk assessment takes account of best practice construction techniques incorporated within the design philosophy for the existing well site; and takes account of the fact that an environmental permit will be required from the Environment Agency prior to the commencement of operational activities at the Site. The risk assessment takes account of receptor sensitivity, the magnitude of impact, the potential significance of effect and the likelihood that a hazard may occur; and shows that with the embedded and additional mitigation measures in place, the residual risk for all the identified hazards reduces to either 'very low' or 'none'.

The mitigation measures with respect to produced water reinjection take account of Environment Agency guidance to ensure no induced seismicity or excessive overpressure could arise that would cause geomechanical impacts or transmission between hydraulic units to occur.

Overall, the Proposed Development has a very low risk profile. This is a reflection of the high level of embedded mitigation within the design and construction of the existing well site compound and the existing and proposed wells, combined with additional mitigation that will be provided through the implementation of robust environmental management systems. The effectiveness of the mitigation measures will be demonstrated through an appropriate scheme of monitoring that will be agreed with the Environment Agency and incorporated within an environmental permit.

From a flood risk perspective, the well site is located in Flood Zone 1 (very low probability of flooding). A flood risk assessment (FRA) has been carried out taking account of with the National Planning Policy Framework (NPPF) and the accompanying online resource, National Planning Practice Guidance (NPPG): Flood Risk and Coastal Change 2014. The FRA demonstrates that the Site is at a low risk of flooding and the Proposed Development will not have a detrimental impact on drainage and flooding elsewhere providing that surface water is managed appropriately.

Envireau Water
26/02/2021

HYDROGEOLOGICAL AND FLOOD RISK ASSESSMENT

HORSE HILL WELL SITE, SURREY.

1 INTRODUCTION

Envireau Water has been commissioned by Horse Hill Developments Limited ("HHDL") to prepare a Hydrogeological Risk Assessment (HRA) and Flood Risk Assessment (FRA) for a Proposed Development at their Horse Hill well site on land near Horley, Surrey, ("the Site"). The Site is located in Petroleum Exploration and Development Licence (PEDL) 137.

The Proposed Development comprises:

> *"The retention of an existing well site and vehicular access onto Horse Hill to accommodate the drilling of four additional boreholes (adding to the two existing wells on site), including potential reinjection well and subsequent reinjection; site construction works on the existing site to facilitate process and storage areas to accommodate up to 500 tonnes of crude oil, an enclosed ground flare, an oil heater, separators, above ground pipe and cable tracks, water monitoring boreholes and ancillary development enabling the production of hydrocarbons inclusive of well maintenance workovers and sidetrack drilling followed by decommissioning and site restoration."*

This is a conventional onshore oil development and does not involve hydraulic fracturing ('fracking').

1.1 Hydrocarbons in the Weald Basin

Hydrocarbons in the Weald Basin were first discovered in the 19th Century and subsequent exploration activities, particularly from the 1930s onwards, resulted in commercial oil and gas production in the region. In 2014 the area had 13 producing oil and gas sites [Ref.1].

The principal source rocks in the region are organic rich Jurassic shales of the Lias Group, Corallian Group and Kimmeridge Clay Formation. Hydrocarbons have been discovered or produced from reservoir rocks in Jurassic and Cretaceous strata including: the Lias Group, Great Oolite Group, Corallian Group, Kimmeridge Clay Formation, Portland Group, Purbeck Group and Wealden Group; one discovery was also made in Devonian strata.

1.2 Planning & Permitting History

The existing Horse Hill well site was constructed as an exploratory well site in 2014; a single exploratory hydrocarbon well (HH-1) targeting Jurassic strata was drilled, tested and appraised for hydrocarbons between 2014 and 2016.

In 2017, planning permission was granted to extend testing for up to 3 years, this included the drilling and testing of a sidetrack well (HH-1z) targeting limestones within the Kimmeridge Clay Formation and the construction and testing of an additional appraisal well and sidetrack (HH-2 and HH-2z) targeting the Portland Group/Kimmeridge Clay Formation. HH-2 and HH-2z were constructed in late 2019; HH-1z is yet to be drilled. The existing wells are currently suspended pending production/reinjection.

An HRA and FRA was prepared by Envireau Water for the Site in November 2018 [Ref.2] and a planning application was submitted to SCC in December 2018 for the following development:

"Retention and extension of an existing well site, hh1 and hh2 wells, and vehicular access to allow: the drilling of four new hydrocarbon wells and one water reinjection well; the construction of a process and storage area and tanker loading facility; new boundary fencing; well maintenance workovers and sidetrack drilling; and ancillary development enabling the production of hydrocarbons from six wells, for a period of 25 years."

The Environment Agency was consulted as part of the planning process and provided comments to SCC on 08/02/2019 [Ref.3]. In addition, a number of comments and points of clarification were also received from SCC's geological/geotechnical consultants [Ref. 4, 5] which were addressed separately by Zetland Group [Ref. 6, 7]. An updated HRA and FRA was then produced by Envireau Water in July 2019 [Ref. 8] taking account of the consultation responses, with particular reference to Produced Water Reinjection and groundwater monitoring. Planning permission was granted in September 2019 (RE18/02667/CON).

Environmental permits for the Site have been issued and varied a number of times since the operations began. HHDL currently hold four (4) permits for the Site. These permits relate to: a mining waste operation; the discharge of clean surface water; handling and storage of crude oil; and, the accumulation and disposal of Naturally Occurring Radioactive Materials ('NORM') from the production of oil.

An application was made to vary the existing permits to accommodate the new development in late 2019. The Environment Agency requested further information under an EPR Schedule 5 Notice [Ref. 9] in 2020. Following this, HHDL has revised the Proposed Development and it no longer includes the construction of an extension to the well site or a dedicated standalone produced water reinjection well.

1.3 Purpose of This Report

This report updates the technical work originally previously in 2018/19 and takes into account changes made to the Proposed Development by HHDL and comments made by the Environment Agency under an EPR Schedule 5 Notice [Ref. 9]. It is intended that this document will be used to support the environmental permitting process.

The HRA is based on a hydrogeological conceptual model and has been conducted with reference to the methodology and framework for groundwater risk assessment set out by DEFRA in Green Leaves III (GL III) [Ref.10],

and the Environment Agency's approach to groundwater protection [Ref.11] and associated technical guidance [Ref.12, 13]. The Groundwater Monitoring Plan presented in Appendix G is based on the findings of the HRA.

The produced water reinjection concept presented in Appendix C takes account of the mitigation and management approaches discussed in the Environment Agency Science Report SC150027 'Reinjection of fluids to deep geological formations' [Ref.14], to minimise or remove the conditions that could give rise to geomechanical impacts, and the risks of impacts to groundwater receptors.

The FRA has been written and submitted with reference to the National Planning Policy Framework (NPPF) 2018 [Ref. 15] and the accompanying online resource, National Planning Practice Guidance (NPPG) 25: Flood Risk and Coastal Change 2014 [Ref. 16].

2 PROPOSED DEVELOPMENT

2.1 Site Layout

The Site comprises an existing well site and access track. The existing well site comprises an enclosed compound housing the necessary plant and equipment to drill, test and decommission two (2) (previously consented) exploratory hydrocarbon wells and contain and dispose of produced fluids and waste materials. An access track enters the well site from the main road to the east. The layout of the existing Site is shown on a scale plan in Appendix A and further detail is provided in the Site Condition Report (SCR) [Ref. 17].

The existing well site incorporates a surface water containment and drainage system with a very low permeability high density poly-ethylene (HDPE) liner, granular working platform and containment/drainage ditches. The HDPE liner forms a tertiary containment system to ensure surface water at the Site can be contained and appropriately managed, and that groundwater is protected. The Site was designed and constructed taking account of the principles for the containment of potential contaminants set out in CIRIA guidance C736 – Containment Systems for the Prevention of Pollution [Ref. 18].

A surface water drainage system is in place at the Site; this was designed in accordance with conditions to the exploration consent issued 16th January 2012 by SCC (planning permission RE10/2089). The same design was retained as part of a further exploration consent issued 1st November 2017 (planning permission RE16/02556/CON) and was verified by a qualified drainage engineer in 2018 [Ref. 19]. Clean surface water from the Site is discharged to a field drainage system via an oil interceptor and ultimately drains into a local watercourse (Spencer's Gill). The existing Site will be retained and modified for the proposed well construction and production operations.

2.2 Development Phases

The phases of the Proposed Development are summarised in Table 1 below and are discussed in the following subsections.

Table 1 Summary of Development Phases

Phase of Development	Development Description
Phase 1 - Existing Well Site Modifications	• Construction of four (4) new concrete drilling cellars to accommodate hydrocarbon production wells and produced water reinjection wells.
Phase 2 - Well Management and Drilling	• Conversion of existing HH-1 well for hydrocarbon production and existing HH-2/2z for produced water reinjection. • Drilling of up to four (4) wells to accommodate hydrocarbon production and produced water reinjection.
Phase 3 - Production and Well Management	• Oil production for a period of 20 years with periodic well interventions and maintenance workovers.
Phase 4 - Plugging, Abandonment and Decommissioning	• Removal of all surface production equipment followed by the plugging and abandonment of all wells.
Phase 5 - Site Restoration and Aftercare	• Removal and disposal of all construction materials, surface bunding and stone surfacing followed by the regrading of soils and subsequent aftercare monitoring.

2.2.1 Phase 1- Existing Well Site Modifications.

The works presented below will be carried out during this phase:

- Four (4) concrete drilling cellars will be constructed to house four (4) new wells. These will be tied into the HDPE liner system already in place at the site.
- Hard standing will be installed to support drilling equipment, pipe tracks and other ancillary equipment.
- Installation of conductor casing for the four (4) new wells to a depth of approximately 18m bgl into the Weald Clay Formation using a specialist water well drilling rig.
- The surface water management and drainage system will be retained and will be tied into the new drilling cellars.

2.2.2 Phase 2- Well Management and Drilling

Existing well HH-1 will be converted for oil production and HH-2/2z will be converted for produced water reinjection. The proposed produced water reinjection is described in detail in Appendix C.

Four (4) new wells will be constructed for oil production/produced water reinjection.

The following works will be completed during this phase:

- Mobilisation of plant, materials and equipment including: drilling rigs and ancillary equipment, diesel generators, mud pumps, steel casings and tubing.
- Transfer and storage of fuels and drilling chemicals on-site.
- Conversion of HH-1/1z to a production condition and HH-2/2z for a produced water reinjection (existing wells). This will involve workover operations whereby dilute acid is introduced into the wells to remove carbonate scale and re-establish formation permeability. This is a very similar process to that used in the water well industry. Production tubing will be inspected and removed/replaced where necessary.
- Drilling of four (4) new wells (HH-3 - HH-6). These holes will be drilled as pilot holes and side-tracked into the production formations as required. The exact construction of the wells is not yet defined but each new well will follow the same design principles. HH-3 may be used either for oil production or production support (by produced water reinjection into the Portland Formation) as required.

2.2.3 Phase 3- Production and Well Management

The production of hydrocarbons and associated operations will be carried out over a period of up to 20 years. The following works will be carried out during this phase:

Production

- Installation of production equipment including surface mounted pumps (one (1) per well), three (3) oil storage tanks with a combined capacity of no greater than 500 tonnes.
- The extraction of oil using either linear rod pumps, electrical submersible pumps, progressive cavity pumps or jet pumps. Natural gas and formation water will be produced (as by-products) as part of this process.
- Separation of oil, gas and formation water using a bath heater followed by a 3-phase separator.
- The transfer of oil in above-ground pipework to on-site storage tanks.
- The transfer of formation water in above-ground pipework to on-site storage tanks.

- Flaring of natural gas.
- Reinjection of produced water to the Portland Group as required for production support.
- The export of oil to an off-site refinery by road oil tanker.

Well Management

- Each well will be subject to a workover before production can begin. This will involve cleaning the well and pumping nitrogen or brine into the well to displace any residual drilling fluid to the surface.
- Maintenance workovers will be performed periodically on each producing well at an approximate frequency of once every 4 years (5 workovers are anticipated in the 20-year operational life of a single well).
- Maintenance workovers may involve the replacement of pumps and production tubing and rehabilitation of the well/formation. Cleaning workovers may involve acid washing, where a dilute acid is circulated in the well (in a limited quantity) to remove carbonate scale and re-establish formation permeability where it has been reduced during production. This is a very similar process to that used in the water well industry. Hot oiling may also be employed whereby a small quantity of produced oil is circulated in the well to dissolve/unblock any restrictions to flow within production tubing, e.g. from the build-up of natural waxes.
- Cleaning workovers (acid washing as detailed above) may also be used in the produced water reinjection well(s) as required.

2.2.4 Phase 4- Plugging, Abandonment and Decommissioning

This phase will comprise the plugging of the wells and their decommissioning in accordance with current UK Oil and Gas Guidelines after completion of the works. The works will involve/include:

- A final workover operation to clean the wells and prepare them for abandonment. Typically, the workover would be expected to use hydrochloric acid, an iron precipitate inhibitor and corrosion inhibitor.
- The installation of cement plugs to seal the well. Rubber cement retainers will be used to prevent movement of the plugs during setting.
- Cutting off the drilling cellar 1.5m below the expected finished ground surface and installation by welding of a steel plate across the well casing to close the opening.
- The cleaning and removal of all surface plant, machinery and equipment from the Site.

2.2.5 Phase 5- Site Restoration and Aftercare

This phase will return the Site to its pre-development state by the removal of all surface structures and materials, including the HDPE liner.

- All concrete structures including bunding, hardstanding etc. will be cleaned and removed from the Site for recycling. The well cellars will be deconstructed with the lowest pre-cast concrete ring of the well cellar left in place. The cellars will then be capped and backfilled with previously excavated surface soils.
- The compacted stone granular working platform will be excavated and removed from Site to a permitted waste facility.
- The HDPE liner and geotextile membranes will be removed from the Site.
- The subsoil beneath the liner will be inspected, levelled and cultivated. Any contaminated soils will be excavated and removed from the Site to a permitted waste facility.

- Top soil stored in bunds will be replaced to its pre-development condition. The soil will be improved if it has degraded during storage and will be compressed, ploughed and cultivated.

2.3 Granular Working Platform and Tertiary Containment System

The existing well site is constructed of a 300mm granular sub-base material over a 30kN geo-grid forming a granular working platform; this overlies a 1mm thick Junifol very low permeability HDPE liner. The liner itself is underlain and overlain by protective layers of geotextile material composed of 300g/m^2 non-woven fleece. This system prevents infiltration of contaminants or contaminated water into the underlying soil and rock. The as-built construction of the HDPE liner system and granular working platform at the Site are presented in the Site Condition Report (SCR) [Ref. 17] for the Site.

This working surface/liner system will be retained and the additional wells will be drilled from within its footprint via new drilling cellars (described in Sub-section 2.4). A quality assurance process will demonstrate the integrity of the tertiary containment system at the Site.

2.4 Drilling Cellars

For the existing wells on the Site (HH-1, HH-2/2z), the well head equipment is contained within drilling cellars (a specially constructed concrete chamber) at each well. The drilling cellars are a minimum of 2.75m in depth and constructed from pre-cast concrete rings set upon a reinforced base and concrete jacket surround. The cellars are tied into the working platform and sealed to the HDPE liner system as detailed in the Site Condition Report (SCR) [Ref. 17]. These structures contain drilling muds recovered at surface during drilling operations and safely contain the well head equipment during construction and operation of the wells.

For each of the new wells (HH-3-HH-6) a new drilling cellar will be constructed. The cellar will be tied into the HDPE liner system. The installation procedure for new drilling cellars is:

- Excavation of the surface stone aggregate, geotextile membrane and the HDPE liner. The geotextile and HDPE liner will be cut at a specific length to provide enough material to allow them to be joined to the well cellar.
- The subsoil will be excavated to circa 3m bgl.
- A short section of steel casing will be installed approximately 1m below the bottom of the excavation before a concrete chamber is constructed to form the cellar.
- A 400mm thick reinforced concrete base will be set into the bottom of the excavation around the steel casing.
- A Precast Cast Concrete (PCC) ring will then be set into the concrete base with an overlap of the concrete above the base of the PCC ring. Additional PCC rings will then be added to line the well cellar to surface. Each PCC ring will be sealed together using Tockstrip concrete joint sealant. All lifting points will be plugged and sealed.
- The PCC rings are then encased in a 200mm thick concrete jacket surround. The HDPE liner and geotextile membrane will then be folded upward along the external wall of the well cellar and banded to the cellar to ensure liner integrity.

Integrity tests will be carried out after the installation of new drilling cellars to verify that they are sealed and able to contain fluids, details of these tests are described in the Site Condition Report (SCR) [Ref. 17].

2.5 Ratholes & Mouseholes

A "rathole" and "mousehole" may be used at each new well on the Site depending on the final choice of drilling rig. These structures comprise shallow sealed boreholes (typically <10m bgl) which act as storage spaces for sections of drill string during drilling operations. If required, they would be constructed either within the concrete jacket surround of the drilling cellar or within the drilling cellar itself and tied into the HDPE liner system. The holes would be lined with closed bottom steel casing to seal them off from the surrounding soil and rock and grouted into place.

Where ratholes/mouseholes are installed within drilling cellars, integrity tests will be carried out after installation to verify that the drilling cellars remain sealed and able to contain fluids, details of these tests are described in the Site Condition Report (SCR) [Ref.17].

2.6 Bunded Containment Areas

Bunded storage forms part of the secondary containment system for potential contaminants to the surface and shallow groundwater system at the Site in accordance with CIRIA guidance C736 – Containment Systems for the Prevention of Pollution [Ref. 18].

Bunded containment areas will be constructed of concrete in accordance with the same CIRIA guidelines. Where two or more tanks are installed within the same bund, the capacity of the bund is the greater of:

1. 110 per cent of the capacity of the largest tank within the bund, or,
2. 25 per cent of the total capacity of all of the tanks within the bund, except where tanks are hydraulically linked in which case they should be treated as if they were a single tank.

The bunded storage areas will contain storage tanks for:

- extracted hydrocarbons;
- produced water for reinjection;
- plant and equipment fuel; and
- liquid chemicals for use in production operations: corrosion inhibitors, surfactant, hydrochloric acid, potassium chloride, ammonium chloride, ethylene glycol monobutyle ether (EGMBE), soda ash.

The bunds have been designed as sealed containment structures and incorporate a blind sump (a low space with no outfall which collects the water). Rainfall collected in the sump will be removed via pumping using hoses.

2.7 Hard Standings

A number of hard standings will be constructed from concrete in operational areas of the Site. The depth of the concrete will be a maximum of 300mm and will be constructed to prevent impact on the underlying HDPE liner. Surface stone from the granular working platform will be made flush with the edge of the concrete hard standings.

2.8 Management of Foul Water

Foul water and sewage produced during the construction, operation and decommissioning of the Site will be collected and contained in sealed wastewater storage tanks on-site and then transported off-site to a permitted

waste facility. There will be no connections for wastewater or sewage from the welfare facilities to the Site drainage system.

2.9 Management of Extractive Waste

Drilling and production operations will produce extractive waste including drilling muds, rock cuttings, excess cement and spent dilute acid/other well treatment fluids. These materials will be contained before transfer to an off-site permitted waste facility in accordance with an environmental permit.

2.10 Management of Produced Gas and Fluids

It is expected that the wells will produce oil with the potential for associated volumes of produced gas and produced water.

During production, oil comingled with natural gas and formation water will be pumped to the surface using either linear rod pumps, electrical submersible pumps, progressive cavity pumps or jet pumps. Oil, gas and produced (formation) water will be transmitted across the Site in enclosed above-ground pipework and separated using a three-phase separator. Oil and produced water will be stored within storage tanks located within the produced fluid bund. Oil would then be collected by road tanker and sent off-site and produced water would be reinjected into the production formation via the reinjection well(s). Surface water collecting in the produced fluid bund will be collected, treated and reinjected with the produced water for production support.

Natural gas will be managed in accordance with Best Available Techniques (BAT) under the conditions of an environmental permit.

2.11 Well Construction and Operation

2.11.1 Standards

It is a requirement for all new wells to be constructed and operated in accordance with the Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 [Ref. 20] and the Borehole Sites and Operations Regulations (BSORS), 1995 [Ref. 21]. These regulations require a well to be designed, constructed, suspended and abandoned in such a way as to prevent unplanned escape of fluids at any time during operation and after abandonment.

Well records will be inspected by an independent well examiner to assess the well design, construction and maintenance and ensure that good industry practice is followed throughout their life-cycle and decommissioning.

The existing wells (HH-1 and HH-2/2z) have been constructed in accordance with the above regulations. The same regulations will apply to the four (4) new wells that are now proposed.

2.11.2 Design Concept for New Wells

The new wells will be constructed to target productive horizons within the Jurassic Portland Group and Kimmeridge Clay Formation. Cemented steel casings will be used to prevent groundwater movement between geological formations and stop potentially polluting formation water or hydrocarbons in the deeper formations migrating

upwards to shallower groundwater systems. Once the wells are constructed, blow out prevention equipment will control the migration of fluids and gases to the surface during construction and operation of the well.

The design for the wells can be summarised as follows:

Portland Group Wells

One (1) new well (HH-3) will be drilled to target the Portland Group sandstones for oil production. The well will be constructed with the following features:

- A main well drilled near vertically to approximately 750m bgl into the Kimmeridge Clay Formation. This will include two (2) sets of cemented steel casing: a conductor casing at 340mm diameter set into the Weald Clay Formation at 18m bgl; and, a casing at 245mm diameter set into mudstones of the Purbeck Group at 550m bgl. Water based mud will be used for drilling to depths of 550m bgl, oil-based muds may be used below this depth.
- A sidetrack well (HH-3z) will be drilled from within the main well at circa 395 – 430m bgl. The main well will be plugged back with cement barriers to seal it off and facilitate the drilling of the sidetrack. The sidetrack will pass through the Purbeck Group to arrive near horizontally in the Portland Group sandstones (the production formation). The sidetrack will include a cemented steel casing at 178mm set into the Portland Group. The hole will be extended near horizontally along the Portland Group Sandstones and a slotted production liner will be installed.

The cemented well casings will protect the shallow groundwater system, seal out and protect the Wealden Group strata and prevent migration of fluids from deeper formations along the wellbore. Before the drilling of the sidetrack the main well will be plugged with cement barriers to seal off the lower section and prevent migration of fluids along the wellbore.

Existing well HH2/2z which targets the Portland Formation will be converted to a produced water reinjection well. The well comprises a main well (HH-2) and sidetrack well (HH-2z). The main well has been plugged back with cement barriers to seal off the lower section and prevent the migration of fluids along the wellbore. The well is currently suspended pending conversion. The sidetrack well is cased with cemented steel casing into the Portland Group. This ensures that the shallow groundwater system and Wealden Group strata are protected/isolated from the operations and from migration of fluids from deeper formations along the wellbore. The design concept and operational controls for produced water reinjection are considered in detail in Appendix C.

The proposed HH-3 well may be converted for use as a produced water reinjection well in the future if required. The well would reinject produced water and treated surface water from the bunded process areas to the Portland Formation for production support. Such a conversion would follow the principals outlined in Appendix C and would be subject to a pre-operational permit condition agreed with the Environment Agency.

Kimmeridge Clay Formation Wells

Three (3) additional production wells, HH-4, HH-5 and HH-6 may be constructed in future to target the Kimmeridge Clay Formation. The design for the wells has not yet been finalised and will be confirmed in detail as part of the WR11 process.

The wells will be constructed with the following outline features:

- A main well drilled to approximately 950m bgl in the Kimmeridge Clay Formation
- A cemented steel conductor casing at 508mm diameter set to 18m bgl within the Weald Clay Formation
- A second cemented steel casing string at 340mm diameter set to a depth of approximately 550m bgl into mudstones Portland Group.
- A third cemented steel casing string at 245mm diameter (exact depths to be confirmed) set into mudstones of the Portland Group.
- A sidetrack drilled out at between 390 - 430m bgl to land near horizontally within the Kimmeridge Clay Formation, this will then be cased into the Kimmeridge at 245mm diameter and cemented.

The cemented well casings will protect the shallow groundwater system, seal out and protect the Wealden Group strata and prevent migration of fluids from deeper formations along the wellbore. Before the drilling of the sidetrack the main well will be plugged with cement barriers to seal off the lower section and prevent migration of fluids along the wellbore.

2.11.3 Drilling Fluids

Drilling fluids (or "muds") are used in the drilling of wells to cool and lubricate the drill bit and bring drill cuttings to the surface. The specification of the drilling fluids is designed to minimise fluid loss or fluid gain to/from the rock formations, whilst allowing the drilling to progress.

It is proposed to use water-based muds (WBM) for the installation of conductor casings and construction of the wells from surface to a minimum depth of 400m bgl. Below this depth, low-toxicity oil-based muds (LTOBM) may be used to facilitate 'geo-steering' and advance the drilling through deep formations to the target co-ordinates.

2.11.4 Workover Operations

A workover is an intervention in a well typically required when tubing is installed or when rehabilitation is required because the production casing and/or natural fractures in the rock have become blocked with scale or other fine particles which impair hydrocarbon flow. Workovers are expected to be required approximately every 4 years in each well (i.e. a total of 5 workovers are envisaged in a 20 year lifetime of a single well). Both 'acid washing' and 'hot oiling' workovers will be carried out in the production/reinjection wells and these workover operations will be subject to approval from the Environment Agency as part of the environmental permitting process.

An acid washing workover operation "cleans" the well with a dilute hydrochloric or acetic acid wash; a mixture of surfactant, corrosion inhibitor and brine is used to aid the process. The acid reacts readily with carbonate minerals and dissolves fine particles; the reaction neutralises the acid and produces carbon dioxide, water and calcium chloride which flow back to the surface with the produced hydrocarbons. The proposed workovers including details of the chemicals and volumes to be used are described in full in the Waste Management Plan for the Site [Ref. 22]

None of the chemicals used will be hazardous as defined by UKTAG [Ref. 23] and the use of all chemicals during the drilling, testing and operation of the wells will be subject to an environmental permit. The technique (minus the use of surfactants and EGMBE) is similar to that used following drilling of boreholes for public and private water supplies, commercial water wells and geothermal wells in carbonate rocks to remove fine particles and enhance or reinstate natural permeability (flow).

Hot oiling is a technique used to dissolve or remove blockages that impede flow from a hydrocarbon well; commonly caused by the build-up of natural paraffin waxes in the production tubing of a well. This type of workover uses a small quantity of produced oil which is heated at surface and re-circulated in the well. No waste is generated in the process and the re-circulated oil is diverted back to the oil storage tanks at surface and forms part of the final oil product for export.

2.12 Well Abandonment

All wells will be abandoned in accordance with current UK Oil and Gas guidelines [Ref.24] to prevent the release of fluids. Cement plugs will isolate all distinct permeable zones from each other and from the land surface. The well abandonment will be reviewed by an independent well examiner to verify this process.

2.13 Produced Water Reinjection

It is proposed to reinject produced water into the Portland Group in accordance with an environmental permit. The produced water may be reinjected together with surface water collected from bunded process areas at the Site. The purpose of the reinjection is to provide production support. The surface water will be treated before reinjection.

The produced water reinjection concept is described in detail in Appendix C.

2.14 Environmental Permitting

HHDL currently holds four (4) environmental permits for the Site:

EPR/BB3300XG - A mining waste operation for the management of extractive waste from prospecting mineral resources, not involving a mining waste facility.

A mining waste operation for the management of non-hazardous extractive liquid waste and gas, from prospecting for mineral resources not including a waste facility resulting from well testing operation. No more than 10 tonnes of natural gas may be flared each day.

EPR/BB3691NN - The discharge of clean surface water off-site during periods of non-operational activity. Discharges to surface water may not take place during drilling, flow testing or well testing.

EPR/SP3339YS - The loading, unloading, handling or storage of, or physical, chemical or thermal treatment of crude oil with a capacity of no more than 500 tonnes.

EPR/AB3498DZ - SR 2014 No4 Permit for the Accumulation and Disposal of radioactive waste from the NORM Industrial Activity of the production of oil and gas.

HHDL are seeking to vary the existing permits to accommodate the Proposed Development activities. Details of the proposed changes are described in the Waste Management Plan for the Site [Ref. 22] and are addressed in this report where relevant to the HRA. Specifically, proposed changes to the discharge of surface water run-off (EPR/BB3691NN) are discussed in Section 3.

3 SURFACE WATER MANAGEMENT

3.1 Surface Water Drainage Scheme

The existing Site surface water drainage scheme will be retained. The function of the drainage scheme is to attenuate and control rainfall-runoff. The scheme was validated by a qualified drainage engineer in 2018 [Ref. 19] and is able to contain a 1 in 100 year storm event with a 10% climate change allowance, without discharging.

In outline the scheme can be summarised as follows:

- The existing well site compound area is lined with a continuous very low permeability HDPE membrane and 300g/m^2 non-woven fleece layers over which porous granular sub base material is laid to a depth of 300mm.
- The lining includes an open containment ditch encircling the Site which extends up and on to a containment bund beyond. An interceptor ditch serves the purpose of collecting all surface drainage from the lined well site footprint.

Further construction detail on the existing drainage system at the Site is provided in the Site Condition Report (SCR) [Ref. 17].

3.2 Discharge of Surface Water

The proposed discharge of clean surface water run-off during the different operational phases of the development is summarised below:

Inactive Periods

HHDL currently hold an Environmental Permit (EPR/BB3691NN) allowing the discharge of water during non-operational ('inactive') periods. The water is discharged from the Site's interceptor ditch to a tributary of a nearby watercourse (Spencer's Gill) via a submerged pipe. The water passes through a Class 1 SPEL Oil bypass separator before being discharged.

Oil Production

The potential to generate surface water contamination during oil production is low because sealed pipework and tanks provide primary and secondary containment for produced oil and fluids. HHDL will therefore seek to vary the environmental permit to allow discharge of water from the Site's interceptor ditch during oil production.

Drilling Operations and Well Workovers

There is an increased (although still low) potential to generate surface water contamination during drilling and workover operations. Therefore, during these activities, the Site will operate as a 'hydrologically contained system' with no discharge of water to the environment. All surface water will be collected in the interceptor ditch and then removed from the Site to an Environment Agency permitted waste facility. No alterations are to be made to the drainage on the existing access track, with surface water draining from the track via existing drainage routes as is currently the case.

4 SITE SETTING

4.1 Location and Topography

The Site is located 2km west of the town of Horley and 1.2km east of the Hamlet of Norwood Hill at NGR TQ 2527 4359. The hills of the North Downs are located approximately 8km to the north and London Gatwick Airport is located 2.2km to the southeast of the Site. The Proposed Development covers a total area of approximately 2.08 Ha (the existing well site footprint).

The Site is part of the low-lying clay vale of the Low Weald and sits at an elevation of approximately 65m Above Ordnance Datum (AOD) on the south side of a small limestone ridge. The ridge reaches 90m AOD north of the Site and a high point of 97m AOD 1km to the west at Norwood Hill. The terrain at the Site slopes gently down to the south/southeast towards Spencer's Gill, an eastward flowing tributary stream of the River Mole, which lies at an elevation of approximately 56m AOD.

The Site location is shown on Figure 1 and Figure 2.

4.2 Current and Historical Land Use

Historic Ordnance Survey maps from 1874, 1897, 1944 and 1991 [Ref. 25] show that the Site was previously undeveloped farmland. There are no potentially polluting activities associated with past land uses that would designate the Site as contaminated land and a contaminated land risk assessment has not been carried out as part of this assessment.

5 HYDROLOGY

The hydrological features relevant to the Site are summarised below and presented on Figure 2.

5.1 Setting and Watercourses

The local hydrological base is the River Mole which lies approximately 1.2km east of the Site at an elevation of approximately 54m AOD and flows northwards towards the River Thames. A small unnamed stream is located approximately 570m downslope from the Site to the southeast at an elevation of approximately 55m AOD. This stream is fed by land drains and possibly springs (marked as "issues") close to Brittleware and Greenstead Hall Farms (625m and 900m southwest of the Site respectively). The stream joins Spencer's Gill some 650m southeast of the Site and drains eastward joining the River Mole approximately 1.4km to the east.

Several other streams are located within 2km of the Site: to the south, beyond Spencer's Gill, Hookwood Common Brook flows towards the River Mole; and to the northwest, beyond the crest of the ridge, a number of land drains and streams issue and flow to the north and northwest into Deanoak Brook.

In terms of flood risk, the Site lies within a "Zone 1 Low Probability" area, having a less than 1 in 1,000 annual probability of river or sea flooding. The potential impact of the proposed development on flood risk is considered in Section 10.4.

5.2 Natural and Artificial Waterbodies

A small pond is located in woodland immediately to the east of the Site. Several ponds are mapped along the course of the unnamed stream to the south of the Site: one (1) pond is located 600m southwest of the Site at approximately 60m AOD close to Brittleware farm; two (2) small ponds are located in woodland near Rushmeads cottage at 535m and 540m southwest of the Site and are fed by the unnamed stream just before it joins Spencer's Gill, these are at elevations of approximately 50m AOD.

Numerous small ponds are located upslope of the Site to the northeast, north and northwest within a 3km radius. The closest of these ponds are located in the areas of High Trees, Wrays Wood, Horsehill Farm and Rowgardens Wood and are at a higher elevation than the Site. The ponds appear natural in character based on OS mapping data and are likely to be fed predominately by surface run-off.

5.3 Soils

Cranfield University's SoilScapes database [Ref. 26] describes the soils at the Site as slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils with impeded drainage and moderate natural fertility.

5.4 Catchment Characterisation

The hydrological catchment at the Site has been characterised using the Flood Estimation Handbook Web Service [Ref. 27] and is summarised in Table 2.

The Base Flow Index (BFI) is a low value and shows that the groundwater contribution to stream/river discharge is small. Concomitantly, the Standard Percentage Runoff (SPR) is high, reflecting the low overall permeability of the clay soils within the catchment and low rates of infiltration into the soils. This is consistent with the soil classification in Section 5.3.

Table 2 Hydrological Catchment Descriptors

Catchment Descriptors	Abbreviation	Catchment Values
Catchment Area	AREA	0.98km^2
Mean Catchment Altitude	ALTBAR	70m
Base Flow Index (BFI) associated with each HOST soil class	BFIHOST	0.2320
Standard Percentage Runoff (SPR) associated with each HOST soil class	SPRHOST	50.85%
Proportion of time that catchment soils are defined as 'wet' (soil moisture deficit of less than 6mm)	PROPWET	0.360
Standard Average Annual Rainfall (SAAR) (1961 – 1990)	SAAR	755mm
Extent of urban and suburban land within catchment	URBEXT$_{2000}$	0.000

6 GEOLOGY

The geological setting has been characterised with reference to published BGS geological maps [Ref 28, 29, 30] and associated geological memoirs [Ref. 31, 32], borehole records from the online BGS Geoindex [Ref. 33] and the UK Onshore Geophysical Library (UKOGL) [Ref. 34] as well as a geological report published by DECC [Ref. 1] and geological information provided by HHDL [Ref. 35, Ref. 36] . The geological setting of the Site is shown on Figure 3.

6.1 Regional Geology

The Site is located within the 'Low Weald': an area of low-lying terrain defined broadly by the outcrop of the Lower Cretaceous Weald Clay Formation which is encircled by a ridge of more resistant Lower Greensand Group rocks. The Site is within the northern part of the Weald Basin, a Permian to Cretaceous extensional sedimentary basin containing organic rich and hydrocarbon bearing rocks. The basin has been folded into an east-west trending anticlinal fold known as the Weald Anticline. The oldest rocks outcropping in the region, of the Cretaceous Purbeck Group, occur in the denuded core of the anticline in the eastern part of the Weald.

6.1.1 Superficial Deposits

Superficial deposits are not widespread in the Low Weald and consist primarily of alluvium and river terrace deposits closely associated with present and past watercourses; isolated patches of periglacial head are also found sporadically throughout the region.

6.1.2 Bedrock Geology

Cretaceous rocks outcrop at surface throughout the Weald; these are underlain by a thick succession of Jurassic and older strata. The Jurassic strata are concealed except at a few small outcrops in the Heathfield area where the Limestones of the Purbeck Group (Late Jurassic/ Early Cretaceous) are present. In the north of the Reigate district the Cretaceous Chalk Group is unconformably overlain by Palaeogene strata.

The regional stratigraphy is summarised in Table 3 below. The wells at the Site will target hydrocarbon bearing formations within the Jurassic sequence and therefore no information is presented with respect to the older strata below the Jurassic sequence.

6.1.3 Structural Geology

The region is dominated structurally by the Weald Anticline, a regional fold structure formed during the Alpine orogeny of the late Oligocene to middle Miocene epochs. The fold trends roughly west-east through the region and plunges gently to the west. Numerous subsidiary and parallel anticlinal and synclinal folds also affect the region. Generally, strata dip gently away from the anticlinal axis. Fault trends within the basin are generally east-west.

Table 3 Regional Geological Sequence

Age	Group	Formation	Description
Quaternary-recent	Fluvial Deposits	Alluvium	Silty clay- can contain layers of sand, silt, peat, clay and basal gravel.
	River Terrace Deposits		Sandy gravel- local lenses of silt, clay or peat.
	Residual Deposits Group	Clay with Flints Formation	Clay, silt sand and gravel with flint nodules and pebbles.
	Mass Movement Deposits	Head	Polymict of gravel/sand/clay with rock fragments (composition dependent on location), poorly sorted and stratified.
Eocene	Bracklesham Group	Bagshot Formation	Sand silt and clay overlying micaceous locally clayey sand with sparse seams of gravel.
	Thames Group	London Clay Formation	Silt and clay.
Palaeocene	Lambeth Group	Reading Formation	Clay and silt with sand beds.
	Montrose Group	Thanet Formation	Sand, clayey and glauconitic in part.
Cretaceous	White Chalk Subgroup	Newhaven Chalk Formation; Seaford Chalk Formation; Lewes Nodular Chalk Formation	Smooth chalks with numerous marl seams and flint bands; firm chalks with flints and marls; Nodular chalks interbedded with softer chalks.
		Newpit Chalk Formation; Holywell Nodular Chalk.	Blocky chalk with numerous marls; nodular chalks with thin marls and shell debris in part.
	Grey Chalk Subgroup	West Melbury Chalk and Zig Zag Chalk Formations	Marly chalk and hard grey limestone; blocky chalk with rhythmic alternations of marl and marly chalks in the lower part.
	Selborne Group	Upper Greensand Formation	Sand and sandstone, fine-grained, silt, glauconitic, shelly.
		Gault Formation	Pale to dark grey or blue-grey clay or mudstone, glauconitic in part, with a sandy base.
	Lower Greensand Group	Folkestone Formation	Medium and coarse grained well sorted cross bedded sands and sandstones.
	Lower Greensand Group	Sandgate Formation	Fine sands, silts and silty clays, commonly glauconitic.
		Hythe Formation	Sand, sandstone and silts; locally pebbly.
		Atherfield Clay Formation	Sandy mudstone.
	Wealden Group	Weald Clay Formation	Clay and silty mudstone with subsidiary beds of sandstone, limestone and ironstone. Individual lenticular units of sandstone and limestone are mapped within the Weald Clay.
		Tunbridge Wells Sand, Wadhurst Clay and Ashdown Formations.	Fine sand and clay.
	Purbeck Group	Durlston and Lulworth Formations.	Interbedded mudstones, limestones and evaporites.
Jurassic	Portland Group	Portland Sandstone Formation	Siltstones, sandstones, silty mudstones, dolomite.
	Kimmeridge Clay Formation		Mudstones (calcareous or kerogen rich or silty or sandy) thin siltstone and cementstone beds, locally sands and silts.
	Corallian Group		Interdigitating limestones, marls, sandstones, sands.

Age	Group	Formation	Description
	Oxford Clay Formation		Silicate mudstone, slightly silty with sporadic beds of argillaceous limestone nodules.
	Kellaways Formation		Mudstone, grey, commonly silty or sandy with beds of generally calcareous siltstone and sandstone.
	Great Oolite Group		Variety of mudstone-dominated and ooidal, bioclastic and fine-grained limestone formations.
	Inferior Oolite Group		Varied succession of ooidal, peloidal, sandy, ferruginous and shelly limestones, with subordinate sandstone, lime-mudstone and mudstone beds.
	Lias Group		Mudstone and silty mudstone; thin tabular or nodular beds of argillaceous limestone; siltstone and sandstone beds; ironstone beds.

6.2 Site Specific Geology

The geological setting of the Site is presented on Figure 3 and is described in detail below.

6.2.1 Superficial Deposits

The BGS 1:50,000 and 1:10,000 scale mapping data for the area shows that there are no superficial deposits present at the Site. Residual soils and weathered bedrock is however expected to a depth of up to 5m bgl.

The closest superficial deposits on BGS GeoIndex online mapping are alluvium (silt and clay with gravel) deposits of limited extent associated with Spencer's Gill approximately 0.65km to the southeast. BGS 1:10,000 mapping also shows head deposits (a variable mixture of clay, sand and gravel) along the valley approximately 0.35km south and 1km east of the Site. River terrace deposits of coarse gravel with cobbles and sand are present approximately 1.75 km to the east of the Site in the Horley area.

6.2.2 Bedrock Geology

The bedrock at the Site is Cretaceous Weald Clay Formation which comprises a sequence of mudstones with thin sandstones, limestones and ironstones. The Weald Clay Formation is underlain by the Tunbridge Wells Sand, Wadhurst Clay and Ashdown Formations which together make up the Wealden Group. Beneath the Wealden Group, the upper part of the Purbeck Group completes the Cretaceous sequence; this is underlain by a large thickness of Jurassic and older strata. The expected geology at the Site is summarised in Table 4. The depths and thicknesses presented in Table 4 are based on those stated in extracts of the geological completion report for the HH -1 well (drilled in 2014) which was provided to Envireau Water by HHDL in October 2018 [Ref. 35].

Several published geological maps are relevant to the Site. The Site is located on the 1:50,000 scale map sheet 286 (Reigate) and 1:10,000 scale map sheet TQ24SE; and close to the boundary of the 1:50,000 scale map sheet 302 (Horsham). Some differences in the thickness of strata are noted between the published geological data and HH-1. This is considered to be a reflection of the different ages and scales of the published material and the continuing re-interpretation of the stratigraphic sequence made possible through new data acquisition, e.g. at HH-1.

Table 4 Expected Geological Sequence at the Site

Age	Group/Formation		Description	Approx. Thickness (m)	Approx. Depth to base of unit (m TVD bgl)
Cretaceous	Wealden Group	Weald Clay Formation	Dark grey thinly-bedded mudstones (shales) with subordinate siltstones, fine- to medium-grained sandstones and ironstones and limestones.	150	150
		Tunbridge Wells Sand Formation	Interbedded mudstones siltstones, sands and sandstone. Includes ~25m thick Grinstead Clay Member- a mudstone.	90	240
		Wadhurst Clay Formation	Thinly-bedded mudstones with subordinate beds of siltstone, fine-grained sandstone, shelly limestone, clay ironstone and rare pebble beds.	55	295
		Ashdown Formation	Siltstones and silty fine-grained sandstones with subordinate amounts of finely-bedded mudstone and mudstone units commonly divided by thin pebble beds.	100	395
	Purbeck Group	Durlston and Lulworth Formations	Interbedded mudstones, limestones and evaporites. The lower ~20m is anhydrite overlain by limestone.	225	620
Jurassic	Portland Group		Upper part predominantly limestone; lower part predominantly argillaceous, dolomitic sandstones/sands with some mudstones/shale.	130	755
	Kimmeridge Clay Formation		Mudstones; thin siltstone and limestone beds; locally sands and silts.	460	1360
	Corallian Group		Succession of limestones, sandstones, siltstones and mudstones.	150	1540
	Oxford Clay Formation		Silicate-mudstone with sporadic beds of argillaceous limestone nodules.	120	1670
	Kellaways Formation;		Mudstone, grey, commonly silty or sandy with beds of generally calcareous siltstone and sandstone.	15	1685
	Great Oolite Group		Variety of mudstone-dominated and ooidal, bioclastic and fine-grained limestone formations.	85	1770
	Inferior Oolite Group		Varied succession of ooidal, peloidal, sandy, ferruginous and shelly limestones, with subordinate sandstone, lime-mudstone and mudstone beds.	175	1945
	Lias Group	Bridport Sand Formation; Beacon Limestone Formation	Micaceous silt and fine sand locally with calcite cemented sandstone beds and lenses; limestone, ferruginous-ooidal in lower part, nodular in upper part, conglomeratic in parts.	105	2050
		Dyrham Formation	Silty and sandy mudstone with interbeds of silt or very fine sand.	110	2160

Age	Group/Formation		Description	Approx. Thickness (m)	Approx. Depth to base of unit (m TVD bgl)
		Charmouth Mudstone Formation; Blue Lias Formation	Laminated shales and mudstones, locally concretionary and tabular limestone beds; Thinly interbedded limestone and calcareous mudstone or siltstone.	310	2470

Cretaceous Strata

The Weald Clay Formation is at surface beneath the Site and throughout the surrounding area. The formation comprises primarily mudstone however, minor beds of sandstone and limestone are mapped by the BGS north of the Site; one such limestone forms the high ground at Norwood Hill. As the dip of the bedding is to the northwest (see Section 0), these mapped sandstone and limestone units are stratigraphically above the bedrock at the Site and will not be encountered in the construction of the new wells. BGS GeoIndex online mapping shows two discrete beds of clay-ironstone within the Weald Clay at 1.5km south and 4.2km southeast of the Site, these units are laterally impersistent, however it is assumed that they may be present beneath the Site. Other thin sandstone, limestone and ironstone beds may be present in the lower part of the Weald clay Formation as shown on the adjacent BGS 1:50,000 geological map for the Horsham district [Ref. 29].

The Hastings Beds Subgroup (of the Wealden Group) outcrops approximately 5.1km southeast of the Site and comprises two thick units of sandstone: the Tunbridge Wells Sand and Ashdown Formations separated by mudstones of the Grinstead and Wadhurst Clay Formations.

The Purbeck Group comprises mudstones, limestones and evaporites of the Durlston and Lulworth Formations including the "Purbeck Anhydrite" at its base. It should be noted that the lower part of the Purbeck Group is classified as Jurassic in age.

Jurassic Strata

The Jurassic strata beneath the Site contain hydrocarbons and are the focus of the planned production operations. Previous testing and appraisal operations at the Site proved oil in the Portland Group and Kimmeridge Clay Formation.

Regionally the Portland Group rocks comprise siltstones, sandstones, limestones, and dolomites. The upper part is formed of the "Portland Limestone" (Portland Stone Formation); this is poorly defined as a unit in the Weald but may be represented by calcareous and glauconitic sands. The lower part of the Portland Group is referred to as the Portland Sand Formation, a mixed succession of carbonate and siliciclastic lithologies. However, at depth in the Weald this formation is generally more argillaceous than in other areas [Ref. 31] and can be difficult to distinguish from the underlying Kimmeridge Clay Formation. The geological completion report for HH-1 shows the Portland Group rocks to comprise an upper and lower sandstone unit separated by an argillaceous unit [Ref. 36].

6.2.3 Structural Geology & Faulting

The bedrock strata are expected to dip approximately 1-2° to the northwest. There are no mapped faults at the Site shown on the 1:50,000 BGS mapping data; however, BGS 1:10,000 mapping [Ref. 30] shows several small faults in the Weald Clay Formation in the vicinity of the Site. The closest of these are two northwest-southeast trending faults mapped approximately 1.1 - 1.4km northwest of the Site, one of which is down throwing to the northeast. There is an east-west trending fault offsetting ironstone bands in the Weald Clay mapped approximately 1.3km south of the Site (throw direction not recorded).

HHDL has provided interpreted seismic sections for the Horse Hill oil prospect. A series of plan view maps and seismic cross sections are included in Appendix F. The maps show the positions of the existing and proposed wells with respect to known faults. The sections show the well trajectories for the existing and proposed wells with stratigraphic boundaries and known faults displayed. The exact trajectory for proposed wells HH-4 – HH-6 is not yet known, therefore a wedge shape has been included on the map (Figure 5 of Appendix F) to denote the area in which the proposed wells may be drilled. The interpreted sections show that none of the local faults penetrate to the surface and most terminate below the Wealden Group or at/close to the base of the Wadhurst Clay Formation. The sections also show that the existing and proposed wells do not cross any faults which could act as a pathway between the production/reinjection formations and groundwater in the Ashdown Formation and Tunbridge Wells Sand Formation, nor the shallow groundwater system in the weathered top of the Weald Clay Formation.

A fault is interpreted close to the HH-2 well as shown on Figure 5 in Appendix F. This fault terminates at the Lulworth Limestone (Purbeck Group) and is therefore not a pathway between the formation/reinjection formations and groundwater in the overlying strata.

7 HYDROGEOLOGY

7.1 Terminology

The terms "Groundwater", "Aquifer" and "Groundwater Body" are defined by the Water Framework Directive (WFD) [Ref. 37] and Groundwater Daughter Directive (GWDD) [Ref. 38], as follows:

- Groundwater: all water which is below the surface of the ground in the saturated zone and in direct contact with the ground or subsoil.
- Aquifer: a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.
- Groundwater Body: a distinct volume of groundwater within an aquifer or aquifers.

These definitions do not however differentiate between (relatively shallow) aquifers that contain relatively fresh, recently recharged groundwater with a 'resource value' for drinking water and other uses, and deeper systems containing low quality groundwater (formation water or produced water) with 'no resource value'.

The UK Technical Advisory Group (UKTAG) provides guidance to agencies responsible for implementing the WFD in the UK. The UKTAG Guidance Paper on Defining & Reporting on Groundwater Bodies [Ref. 39] defines a depth of 400m as the default maximum depth at which a groundwater body loses its value as a resource that can be either exploited for human activities and/or support surface flows and ecosystems and/or have a connection with surface water receptors.

7.2 Groundwater Systems

The presence of groundwater systems has been assessed using information from the Environment Agency publications – the physical properties of major aquifers in England and Wales [Ref. 40] and the physical properties of minor aquifers in England and Wales [Ref. 41], combined with the terminology described in Section 7.1.

The hydrogeological sequence at the Site is summarised in Table 5 below.

Table 5 Hydrogeological Sequence

Group/ Formation	EA Aquifer Designation	Description/Comments
Superficial Deposits	Secondary A	The Superficial deposits comprise river terrace deposits, alluvium and head; these are generally a mixture of sand and gravel with lenses of silt, clay or peat locally. These deposits are not present at the Site; however, alluvium and head deposits are found at lower elevations to the south along Spencer's Gill; and alluvium and river terrace deposits are found to the east and southeast in the Horley area. Groundwater is likely to be present in sand and gravel horizons or at the formation base where it meets the Weald Clay Formation and may be able to support small local water supplies. Groundwater flow is likely to be in a southerly direction, following the topography of the land surface.

Group/ Formation	EA Aquifer Designation	Description/Comments
Weald Clay Formation	Unproductive / Secondary A	The mudstones within the Weald Clay Formation are classed as Unproductive strata with the sandstone and limestone bands classed as Secondary A aquifers. The Weald Clay Formation is predominantly argillaceous and can be considered largely as Unproductive strata; separating shallow groundwater from deeper, water bearing formations. Shallow groundwater may be present in the weathered top of the formation. Laterally discontinuous lenticular sandstone, limestone and ironstone beds are present within the Weald Clay. These units are separated by argillaceous strata and recharge is from direct infiltration at surface. Permeable layers within the Weald Clay are considered as potentially useful water supplies locally. Historic borehole records in the Horley area show that the Weald Clay has been targeted as an aquifer locally. Although some wells were recorded as dry or very poorly yielding, others penetrated water bearing strata and recorded artesian conditions and considerable yields. Groundwater flow directions within the Weald Clay are expected to follow the structural dip of the bedrock which is to the northwest at the Site. Locally, the shallow groundwater system will drain southwards towards local watercourses.
Tunbridge Wells Sand Formation	Secondary A	The Tunbridge Wells Sand Formation and the Ashdown Formation are classed as Secondary A aquifers at a regional scale and are hydraulically separated by the Unproductive, poorly permeable Wadhurst Clay Formation. The Weald Clay Formation acts as a confining layer above these formations and therefore the primary recharge mechanism is direct infiltration at the outcrop areas, approximately 5km to the southeast. The Site lies down dip from the areas of outcrop. These formations (particularly the Ashdown Formation) yield good supplies in the Horsham area and could potentially provide useful water supplies in the area of the Site, although they are not targeted locally. Groundwater flow in the Tunbridge Wells Sand Formation and the Ashdown Formation is expected to follow the structural dip of the bedrock which is to the northwest at the Site. For the Ashdown Formation, values of transmissivity range from 1 to 1662 m^2/d, with a geometric mean of 86.3 m^2/d. Specific capacities range from 1.9 to 545 $m^3/d/m$, with a geometric mean of 40.7 $m^3/d/m$. The storage coefficient values for the aquifer range from 1.3 x 10^{-5} to 8.5 x 10^{-2}. Values of transmissivity for the Tunbridge Wells Sand Formation are lower than for the Ashdown Formation, ranging from 6.1 to only 39.5 m^2/d, with a geometric mean of 1 $9m^2/d$. The range of specific capacity values are similar to that of the Ashdown Formation (2.9 to 511.1 $m^3/d/m$) but with a lower geometric mean of 19.2 $m^3/d/m$. Storage coefficient values have a fairly narrow range: 4.8 x 10^{-4} to 7.7 x 10^{-2}.
Wadhurst Clay Formation	Unproductive	
Ashdown Formation	Secondary A	
Purbeck Group	Secondary A; Unproductive Strata	The Purbeck Group passes conformably up into the Ashdown Formation and comprises the Durlston Formation (Cretaceous in age) overlying the Lulworth Formation (Jurassic in age). The Purbeck Group comprises mudstones and limestones and is classed as a Secondary A aquifer on a regional scale. However, the limestones contain water of limited importance for supply as their outcrop is very limited. The Purbeck Group at the Site is concealed beneath approximately 400 m of overlying formations. Furthermore, the HH-1 completion report demonstrates that the top ~70 m of the Purbeck Group at the site comprises mudstone. Any water present within the Purbeck Group at the Site is likely to be connate (old recharge water) and therefore of a poor quality, with minimal/no resource value (as defined by UKTAG). There is limited published data on the aquifer properties of the Purbeck Group in the Weald. Five samples from a borehole (into the Lulworth Formation), off the Isle of Wight [SZ 8197 3944], at depths of between 8 and 51.5 m, had porosities ranging from 17.1 to 34.5% and

Group/ Formation	EA Aquifer Designation	Description/Comments
		hydraulic conductivities between 2.0 x 10^{-3} and 1.0 m/d. Four outcrop samples from the Dorset coast had porosities varying from 1 to 12%. The base of the Purbeck Group is defined by the Purbeck Anhydrite, which comprises 20m of Unproductive strata with an extremely low permeability. This provides an effective seal between groundwater within overlying formations from formation water present in the underlying Jurassic Strata.
Jurassic Strata	Principal and Secondary aquifers; Unproductive strata	The Jurassic sequence comprises permeable limestones and sandstones separated by thick successions of mudstones. On a regional scale, the permeable formations are classed as Principal and Secondary aquifers however, because of their depth at this location (>400mbgl), they do not constitute viable groundwater targets. The Portland Group sandstones, and limestone beds within the Kimmeridge Clay Formation are known to contain hydrocarbons and are being targeted for production at the Site. Therefore, any water present can be considered formation water and will be of extremely poor quality with no resource value as defined by UKTAG with elevated salinity and hydrocarbons present.

7.3 Water Quality

7.3.1 Superficial Deposits/ Weald Clay Formation

Groundwater in the Superficial Deposits/weathered bedrock and the Weald Clay Formation is likely to be of variable quality, depending on the interaction with surface water systems. Groundwater present at shallow depth is likely to be relatively fresh, recent recharge water of a suitable quality for drinking or other uses. Water quality is likely to deteriorate with depth. Good quality water in thin limestone and sandstone bands is likely to be limited to outcrop areas (the active zone of circulation). The BGS Horsham geological memoir notes that high concentrations of iron and sulphate are common in groundwater in the Weald Clay Formation, and is consistent with a groundwater system with limited circulation and long residence times.

7.3.2 Tunbridge Wells Sand and Ashdown Formations

The Tunbridge Wells Sand and Ashdown Formations provide good quality water for drinking and other uses where they are at or close to surface. However, at the Site, these formations are concealed by approximately 150m of the Weald Clay Formation. The primary recharge mechanism to the formations is via direct infiltration at the outcrop areas, approximately 5km to the southeast.

The completion report for the Collendean Farm 1 well [Ref. 42] records chloride concentrations of 497 ppm and 568 ppm for the Tunbridge Wells Sand and Ashdown Formations respectively. These data were collected during drillstem tests in 1964 and suggest that groundwater in these formations is highly mineralised (elevated salinity) and of a low quality due to the distance from outcrop and the lack of a significant driving mechanism for groundwater flow.

7.3.3 Jurassic Strata

The Jurassic strata at the Site are confined by over 600m of overlying strata with the nearest outcrop located over 40km away to the south east. The Jurassic strata beneath the Site are known to contain hydrocarbons and are the target for the proposed production operations. Drillstem tests in Collendean Farm 1 recovered extremely saline water from the Portland and Corallian Groups with chloride concentrations in excess of 50,000 mg/l.

Any water present in the Jurassic Formations can therefore be considered formation water and will be of extremely poor quality with no resource value as defined by UKTAG; with elevated salinity and hydrocarbons present.

7.4 Faulting

Faults can act as barriers or conduits for groundwater flow and are therefore an important consideration for the development of a hydrogeological conceptual model and the potential for hydraulic connectivity between geological strata.

When describing oil migration, Ref. 43 states that no overpressure exists within the Weald Basin and there is no relict evidence of palaeo-overpressure, suggesting that fault movement originally provided a pressure release mechanism and that the faults in general were not sealing. It is also described as being likely that fluid movement occurred directly up the fault planes, since throws often appear insufficient to have allowed vertical migration as a result of reservoir-to-reservoir juxtaposition across the faults. This is described as being supported by oil and gas shows commonly being encountered while drilling through fault planes. Movement up these fault planes may therefore have permitted migration of hydrocarbons originally trapped in the source rocks into the shallower sandstone reservoirs (i.e. the formations being targeted by the proposed production wells at the Site).

Seismic data provided by HHDL (Appendix F) shows that few faults penetrate to the surface and that most faults terminate at or close to the base of the Wadhurst Clay Formation or in the deeper formations below this. BGS mapping data shows that there are several minor faults mapped at surface in the Weald Clay Formation in close proximity to the Site (see sub section 6.2.3) .

HHDL's review of regional stress analysis indicates that the major faults have been closed for a significant period since the onset of basin inversion (approximately 38 million years ago). The absence of surface oil seeps and the sub-surface data on pressures and the composition of oils from different reservoirs provide an evidence base that no vertical mixing has taken place recently (for several million years) and therefore the fault structures are sealing.

Furthermore, faulting through low permeability formations, such as the Weald Clay Formation, Wadhurst Clay Formation and the top of the Purbeck Group will be less transmissive due to the argillaceous nature of those formations. It is therefore unlikely that faulting will provide a pathway for transmission of fluids between the deep, water bearing layers and shallow groundwater systems; as evidenced through the differences in water quality discussed in Section 7.3 above.

7.5 Conceptual Hydrogeological Model

The conceptual hydrogeological model for the Site is presented on Figure 4a and 4b and shows that there are five hydrogeological units, namely:

- The Superficial Deposits/weathered bedrock (Unit 1): Unit 1 has low-moderate permeability and limited storage. These strata have the potential to support a shallow groundwater system with a resource value for small, domestic drinking water and other supplies.
- The Weald Clay Formation (Unit 2). Overall, Unit 2 is very poorly permeable (very low hydraulic conductivity), has limited storage, and is considered Unproductive strata. However, thin productive layers within the formation have the potential to support a shallow groundwater system with a resource value for drinking water and other supplies. Due to the thick units of argillaceous strata, vertical hydraulic conductivity within the formation is very low; this unit therefore provides a hydraulic break between shallow groundwater and deeper groundwater in Unit 3 and Unit 4.
- The Tunbridge Wells Sand, Wadhurst Clay and Ashdown Formations (Unit 3). Unit 3 has moderate hydraulic conductivity and storage. Water within these formations is likely to have resource value, although water quality is likely to be poor due to the distance from outcrop and limited throughflow. Permeability and water quality are likely to decrease with depth.
- The Purbeck Group (Unit 4). Unit 4 has limited hydraulic conductivity and limited storage. The predominantly argillaceous sequence through the Purbeck Group (particularly the top of the formation) and the anhydrite at the base of the formation provides a hydraulic break between groundwater in Unit 3 and hydrocarbon bearing formations in Unit 5.
- The Jurassic Strata (Unit 5). Unit 5 has low-moderate hydraulic conductivity and limited storage. Formations from the Portland Group downwards contain hydrocarbons and formation water with no resource value. Poorly permeable clay and mudstone horizons separate the hydrocarbon bearing strata.

There is no movement of water between the different hydrogeological units and the principal recharge mechanism for water to each unit is where the formations outcrop at surface. It is unlikely that faulting will provide a direct pathway for transmission of fluids between the deep, Jurassic water bearing units and shallow groundwater systems, as evidenced through differences in water quality between units.

8 ENVIRONMENTAL SETTING

The environmental setting of the Site and surrounding area is described in the following sections. The locations of the features described below are displayed on Figures 5-8.

8.1 Surface Water Features

Drainage at the Site is expected to be to the south/southwest towards the unnamed stream and Spencer's Gill via field drains. These watercourses drain into the River Mole to the east. Several ponds are mapped along the course of the unnamed stream and are in hydraulic connection with surface water drainage at the Site.

Numerous small ponds are located upslope of the Site. These features are not in hydraulic connection with surface water runoff from the Site due to the topography and are located on bedrock which is higher in the stratigraphic sequence.

8.2 Protected Rights

8.2.1 Licensed Abstractions

There are no licensed abstractions within a 3km radius of the Site as confirmed through a search of the Environment Agency's abstraction licence database made on 08/10/18. The closest licensed abstraction is from the Tunbridge Wells Sand Formation at Whitworth Road, Crawley, approximately 5km southeast of the Site. This well is licensed to abstract 130m^3/day.

8.2.2 Deregulated Licences

There are no deregulated abstractions within 3km of the Site as confirmed through a search of the Environment Agency's abstraction licence database made on 08/10/18.

8.3 Private Water Supplies

A search of the Reigate and Banstead Council, Mole Valley District Council and Crawley Borough Council registers of private water supplies (PWS) shows there are no records of PWS within 3km of the Site. However, it is recognised that the Council's registers may be incomplete and unrecorded PWS may be present at rural and outlying properties. Eight (8) such potential locations have been included on Figure 5 based on a review of Ordnance Survey maps however, none of these are in close proximity to the Site.

A point marked "well" on OS mapping data approximately 700m southwest of the Site at Brittleware Farm does not correspond to any licenced abstractions or registered PWS. This is the closest potential unregistered PWS to the Site.

8.4 BGS Records

There are three (3) BGS water well records within 3km of the Site, as shown in Table 6 below and displayed on Figure 5 and on a geological base map on Figure 6. The records suggest that it may be possible to obtain small supplies from the Weald Clay Formation, with artesian conditions being encountered in some cases. There are a

number of boreholes in the Horley area (3 – 5km distance from the Site, see Appendix D) which have historically obtained small supplies from the Weald Clay Formation. There are no records related to boreholes targeting deeper formations.

None of the BGS records are associated with a licensed abstraction or PWS and based on the age of the records, most of the boreholes are likely to be disused. The exception is borehole TQ24/26 constructed in 2000, which could potentially be in use as a PWS. However, this borehole is located 4.5km from the Site. Field verification would be required to confirm whether any of the historic boreholes are still in use.

Table 6 BGS Water Well Records

Ref. on Fig. 5	BGS Ref.	Location	NGR	Approx. Distance from Site (km)	Approx. Elevation (mAOD)	Depth (m)	Year	Aquifer/Details
WW1	TQ24/27	Nags Head Pumping Station, Earlwood	525000/ 145000	1.4	71	14.2	1958	Weald Clay Fm. Water came from the top 4m with a rest water level at 1m bgl (70m AOD).
WW2	TQ24/22	17-23 Balcombe Road, Gatwick	527500/ 142400	2.5	56	Unknown	1973	Weald Clay Fm* Artesian conditions noted with overflow at surface of $5m^3$/day.
WW3	TQ24/9	Elm Cottage, Horley	528100/ 144030	2.8	55	20.4	Unknown	Weald Clay Fm Well was dry, now sealed and unused.

* The scanned paper borehole record for this well shows the aquifer as Tunbridge Wells Sand- this appears to have been corrected to Weald Clay Formation in the BGS GeoIndex database.

8.5 Groundwater Dependant Terrestrial Ecosystems (GWDTE's)

Sensitive water dependant features were researched using the Natural England Magic database [Ref. 44] in October 2018. No Groundwater Dependent Terrestrial Ecosystems (GWDTEs) have been identified within 3km of the Site. There are no Ramsar sites, Special Areas of Conservation (SAC), Special Protection Areas (SPA), World Heritage Sites, Areas of Outstanding Natural Beauty (AONB) within a 3km radius.

The Site is not within a SSSI. The closest such site is Glover's Wood, an ancient and semi-natural woodland, located approximately 2.8km to the southwest. This Site is not groundwater dependent (although it does contain a small stream) and is not in hydraulic connection with the Proposed Development.

The Site is not within a Local Nature Reserve. The nearest such site is Edolph's Copse located approximately 1.8km southwest. This site is a woodland which includes a mix of ancient semi natural woodland, old secondary woodland and some more recent secondary woodland. This feature is not groundwater dependant.

8.6 Source Protection Zones

The Site is not within a Source Protection Zone (SPZ). The nearest mapped SPZ is located 5.4km to the north of the Site.

8.7 Drinking Water Safeguard Zones

The Site is within a Drinking Water Safeguard Zone for surface water (DWSZ SWSGZ4016. EA area: West Thames) for a number of pesticides, nitrite, Benzo-A-Pyrene and turbidity.

8.8 Nitrate Vulnerable Zones (NVZs)

The Site is within The River Mole Nitrate Vulnerable Zone (S451) for surface water. NVZs are areas designated as being at risk from agricultural nitrate pollution; they include about 58% of land in England. An NVZ may be designated for a surface water catchment or groundwater catchment. There are legal requirements for the management of land which falls inside an NVZ relating to the application of nitrate-based fertilisers and storage of organic manures.

8.9 Discharge Permits

Discharges of effluent from domestic or industrial sources have the potential to introduce contaminants in to the surface water and groundwater system. There are 59 discharge permits within a 3km radius of the Site, one of which relates to the existing Horse Hill well site itself. The locations of the discharges are shown on a location plan on Figure 7. 35 of the discharge permits relate to domestic discharges, including the closest locations (DP2-5) which are located between 300m and 600m east (and downgradient) from the well site compound.

8.10 Landfill Sites and Pollution Events

Landfills and pollution incidents or events also have the potential to introduce contaminants into the surface water and groundwater system. Information on historic and active landfills, and recorded pollution events within a 3km radius of the Site has been obtained from the Environment Agency. There are no registered landfill sites currently operating within 3km of the Site but there are several disused historic landfills. These locations are downgradient of the Site, as shown on a location plan on Figure 8.

There are five pollution events recorded within 3km of the Site, also shown on Figure 8. Three of these events were recorded as having no impact on the water environment, one had a minor impact and one had a major impact. The major impact event occurred in 2002 on the River Mole close to Gatwick Airport.

8.11 Abandoned Well- Collendean Farm 1

Collendean Farm 1 is a historic hydrocarbon exploration borehole located approximately 850m northwest of the Site. The location of the well at surface is stated by the Oil and Gas Authority (OGA) as E524811 N144300 and is shown on Figure 5 (note work carried out by HHDL locates it at E524738 N144364). The well was drilled by ESSO Petroleum Company Limited in 1964 to a depth of approximately 1.7km BOD. The OGA state the well's regulatory completion date as 08/12/1964 and the wellbore mechanical status as "Abandoned Phase 3" (plugged and fully abandoned). This suggests the well was decommissioned in accordance with best practice available at that time.

9 HYDROGEOLOGICAL RISK ASSESSMENT

9.1 Assessment Methodology

The HRA has been carried out following a Source-Pathway-Receptor (S-P-R) approach taking into consideration the following guidance:

- Defra's Green Leaves III guidelines for environmental risk assessment and management [Ref. 10];
- The EA's approach to groundwater protection [Ref. 11] and technical guidance [Ref. 13, Ref. 13];
- Guidance on the preparation of environmental risk assessments for shale gas operations in the UK [Ref. 45]; and
- Recommendations made by The Royal Academy of Engineering and the Royal Society in their review of shale gas extraction in the UK [Ref. 46].

Note that whilst the proposed development at the Site comprises a conventional oil and gas development, Ref. 45 and 46 are still relevant in the context of the management of deep subsurface activities. In particular, a risk assessment should address risks across the entire lifecycle of the proposed development. Risks should also be considered beyond the immediate footprint of the Site and should consider impacts to a distance which is sufficient to capture all significant impacts that require an understanding of the geological and hydrogeological setting. In this case, receptors have been considered based on a review of relevant baseline data within a 3km radius of the Site.

Guidance suggests that the risk assessment may take a tiered approach [Ref. 10]. Low risk, straightforward systems may be assessed with a Tier 1 qualitative approach and more complex aspects with risks that cannot be fully mitigated may need a complex quantitative approach. The selection of the risk assessment approach is therefore iterative, and the choice of approach should be based on how complicated the system is, how high the risks are and how easily, and fully, the risks can be mitigated.

The activities associated with the proposed development are well understood and the mitigation measures that are in place (or will be put in place) will follow guidance for the operation of onshore oil and gas industries, and are well defined, tested and known to work. There is a good understanding of the geology, hydrology and hydrogeology at the Horse Hill Site. Furthermore, an assessment of produced water reinjection (Appendix C) demonstrates that water reinjection is the best environmental option (BEO) at this location. Therefore, a semi-quantitative (Tier 1/2) assessment is appropriate to assess the risks associated with the Proposed Development.

The assessment method, scoring and risk calculation is presented in Appendix E.

9.2 Hazard Identification and S-P-R Linkages

The hazards associated with the Proposed Development, and potential S-P-R linkages are presented in Table 7. Hazards are similar across a number of the phases of the Proposed Development they have been grouped together for the purpose of this assessment and include:

- Flushing of contaminated soils during construction and restoration works.
- Spillage of fuels and lubricants used by plant and equipment required to carry out the construction and operational activities associated with the development.
- Creation of vertical pathways during construction of well cellars and groundwater monitoring boreholes.

- Loss of drilling muds, additives, cement grout and well treatment fluids during drilling and workover operations.
- Spillage/leakage of recovered hydrocarbons, produced water containing NORM, and chemicals stored at or transported to/from the Site.
- Migration of natural gases, hydrocarbons and produced water containing NORM from deep formations.
- Well casing failure and leakage of well treatment fluids, natural gases, hydrocarbons and produced water containing NORM water from the wellbore.
- Spillage/leakage of foul water and sewage from staff facilities.
- Produced water reinjection.

These hazards have the potential to impact upon the following receptors:

- The surface water drainage system to the south of the Site, including directly and indirectly:
    - Drainage channels to the south and southwest of the Site.
    - The unnamed stream to the south of the Site.
    - 2 ponds along the course of the Unnamed stream near Rushmeads Cottage.
    - Spencer's Gill.
    - The River Mole.
- The Superficial Deposits/weathered bedrock aquifer (Secondary Aquifer).
- Productive horizons within the Weald Clay Formation (Secondary Aquifer)
- The Tunbridge Wells Sand Formation and Ashdown Formation (Secondary Aquifers).
- The Purbeck Group (Secondary Aquifer) with limited/no resource value.
- Jurassic strata containing formation water with no resource value.

In the absence of field verification data, the potential private water supplies identified in Section 8.3 are also considered as receptors in the risk assessment.

S-P-R linkages have been assessed based on the preceding hydrogeological conceptual model. Table 7 shows that there are potential pollutant linkages with all the above receptors. Where pathways are not considered to exist, these have been justified in Table 7.

9.3 Risk Assessment Summary

A risk assessment has been carried out based on the identified hazards following the methodology presented in Appendix E. A risk assessment summary is presented in Table 7.

As described in the sub-sections below, the risk assessment considers the significance of a hazard occurring, based on receptor sensitivity, magnitude of impact, and the likelihood of a hazard occurring.

9.3.1 Receptor Sensitivity

The sensitivity of surface and groundwater receptors has been assigned according to the criteria presented in Table 1 of Appendix E, as follows:

- The off-site surface water drainage system ultimately reaches the River Mole which is a "main river" and an important water body in the area. Therefore, the surface water drainage system has been collectively assessed as having a high sensitivity.
- The superficial deposits and Weald Clay Formation (Secondary aquifer) have the potential to provide potable water to a small population and are therefore assessed as having a medium sensitivity. The same sensitivity is applied to potential private water supplies that may be targeting these formations.
- The Tunbridge Wells Sand Formation and Ashdown Formation aquifers (Secondary Aquifers) could potentially provide a water supply for agricultural and industrial use and therefore are assessed as having a medium sensitivity.
- Water bearing strata within the Purbeck Group and deeper Jurassic strata are likely to contain poor quality water. These receptors are therefore assessed as having a low sensitivity.

9.3.2 Magnitude of Impact

The magnitude of impact has been assigned with reference to Table 2 of Appendix E, as follows:

- Contamination of the surface water drainage system and subsequently Spencer's Gill and the River Mole by the Proposed Development could result in a major change in attributes and would have a high magnitude of impact.
- Contamination of the superficial deposits aquifer (Secondary Aquifer), productive horizons within the Weald Clay Formation aquifer (Secondary Aquifers), and the Tunbridge Wells Sand Formation and Ashdown Formation aquifers (Secondary Aquifers), would reduce the economic value of these features. Therefore, the magnitude of impact to these features would also be medium. A medium magnitude of impact is also applied to any potential private water supplies.
- Contamination of water bearing strata within the Purbeck Group or deeper Jurassic strata would have no significant impact on their quality or economic value, as these strata contain formation water and hydrocarbons with limited or no resource value. Therefore, the magnitude of impact to these features would be very low.

9.3.3 Potential Significance of Effect

The Potential Significance of Effect is defined by combining the Receptor Sensitivity and Magnitude of Impact according to the matrix in Table 3 of Appendix E. It follows that there are **potentially**:

- Major effects to the surface water drainage system.
- Moderate effects to the superficial deposits/weathered bedrock aquifer (Secondary Aquifer), productive horizons within the Weald Clay Formation (Secondary Aquifer) and any potential private water supplies targeting these units.
- Moderate effects to the Tunbridge Wells Sand Formation and Ashdown Formation aquifers (Secondary Aquifers).
- Negligible effects to water bearing strata within the Purbeck Group and deeper Jurassic strata (limited or no resource value).

9.3.4 Embedded Risk Mitigation

The significance of effect recognises the potential effects which may arise but does not take account of embedded mitigation measures to avoid or prevent hazards occurring, either by breaking the pathway between the potential sources of pollution and the receptors and/or reducing the likelihood of the hazards occurring.

The existing Site incorporates the following measures, which will not be changed as a result of the proposed development:

- The existing well site is lined with a continuous very low permeability HDPE membrane which passed QA/QC testing on installation in 2014. The lining includes an open containment ditch encircling the Site which extends up and onto a containment bund beyond.
- The wellsite can accommodate all the rainfall-runoff generated in a 1 in 100-year storm event (plus climate change allowance) without discharging.
- Foul water and sewage from office/welfare facilities will be collected in self-contained wastewater tanks which are emptied and removed from the Site as required.
- The existing wells (HH-1 and HH2/2z) have been constructed in accordance with oil and gas industry best practice and regulations (Offshore Installations and Wells (Design and Construction, etc) Regulations 1996; BSOR, 1995). The wells are currently suspended (plugged with cement barriers) and incorporate cemented steel casings which isolate the well bores from shallow groundwater systems.

All new drilling cellars will be tied into the existing containment system, new wells will follow the same construction standards and will incorporate cemented steel casings to isolate shallow groundwater systems.

The above measures provide significant mitigation that reduces the likelihood of hazards occurring. Further mitigation has also been incorporated into each of the proposed development phases, as summarised in Table 8 below. Mitigation of the risks associated with Produced Water Reinjection is considered in detail in Appendix C.

The effectiveness of the mitigation will be demonstrated through routine integrity testing of the wells and a scheme of groundwater and surface water monitoring as detailed in Appendix G.

9.3.5 Likelihood of Occurrence

The Likelihood of Occurrence has been considered with reference to Table 4 of Appendix E, taking account of the hydrogeological conceptual model, embedded mitigation summarised in Table 8 and reasonably assuming that HHDL will obtain the necessary environmental permit(s) from the Environment Agency to authorise the activities associated with the Proposed Development.

For each of the identified hazards, Table 7 shows that:

Mobilisation of contaminated soils and Spillage of fuels and lubricants and other materials

The surface water drainage system and superficial deposits/weathered bedrock aquifer is unlikely to be affected by mobilisation of contaminated soils, or spillages of fuels and other fluids during the construction and operation of the Site. This is because primary, secondary and tertiary containment systems are in place at the site to prevent uncontrolled runoff or discharge of surface water into the drainage system during all phases of the development.

Once the HDPE liner is in place across the whole Site, and the new drilling cellars, underground structures and groundwater monitoring boreholes are installed, the pathway for contaminated surface water to infiltrate to the underlying soil/rock is effectively broken.

Leakage of domestic sewage and wastewater from welfare facilities

It is very unlikely that the surface water drainage system and superficial deposits/weathered bedrock aquifer would be affected by leakage of domestic sewage because domestic wastewater will be self-contained, with no connection to the Site drainage system. All wastewater will be removed by tanker from the Site under contract. An extreme set of circumstances would therefore be needed for wastewater to be accidentally discharged to the surface water system.

Loss of drilling muds, additives and grout

It is very unlikely that the surface water drainage system and superficial deposits/weathered bedrock aquifer would be affected by loss of drilling muds, additives and grouts during drilling operations or workovers. This is because the drilling cellars protect these units and the only way in which they can be impacted would be via an uncontrolled discharge of spilt fluids from the Site drainage system.

There is a moderate likelihood for loss of drilling muds, additives and grouts to productive horizons within the Weald Clay Formation (and any potential PWS targeting these formations), the Tunbridge Wells Sand Formation and Ashdown Formation, the Purbeck Group and deeper Jurassic strata during drilling. This means that it is equally likely/unlikely and reflects the position that it is not possible to predict potential losses in those units before drilling commences.

Migration of well treatment fluids, gases and produced/formation water containing NORM from the wellbore and/or production formations

Based on the proposed well design and well management procedures, it is very unlikely that there will be any migration of fluids or gases from the wellbore into any of the formations penetrated by the production or injection wells as a result of a well casing failure.

Higher likelihoods are associated with produced water reinjection.

Produced Water Reinjection

The reinjection of produced water will be carried out for production support and injection rates will not exceed the fracture gradient of the Portland Group (see Appendix C). Based on the hydrogeological setting it is unlikely that produced water would migrate to overlying strata or cause an indirect discharge to groundwater bearing formations above the Portland Group. Faults are very unlikely to act as conduits for fluid migration between the injection formations and the shallow groundwater system or the Tunbridge Wells Sand and Ashdown Formations.

9.4 Risk Analysis

A qualitative risk analysis has been carried out in accordance with Table 5 of Appendix E. This shows that all the risks reduce to low, very low or none.

Risks can be further reduced through applying the additional mitigation measures presented in Table 7. On this basis, the residual risks associated with the Proposed Development then reduce to very low or none.

Detailed mitigation measures related to produced water reinjection are provided in Appendix C. The mitigation measures are designed in accordance with Environment Agency Science Report SC150027 'Reinjection of fluids to deep geological formations' [Ref. 14] to ensure no induced seismicity or excessive overpressure could arise that would cause geomechanically impacts or transmission between hydraulic units to occur.

The findings of the risk assessment reflect the high level of embedded mitigation that is incorporated into the design of the well site and the construction and management of the wells. Mitigation measures will be prescribed through the environmental permitting process and the effectiveness of the mitigation will be demonstrated through a scheme of groundwater and surface water monitoring that will be agreed with the Environment Agency as part of that process.

Table 7 Risk Assessment Summary

Hazard	Phases					Source (S)	Pathway (P)	Receptors (R)	S-P-R Linkage	Receptor Sensitivity	Magnitude of Impact	Potential Significance of Effect	Likelihood of Occurrence	Risk Analysis (with embedded mitigation)	Additional Mitigation	Likelihood of Occurrence After Additional Mitigation	Residual Risk
	Phase 1 - Existing Well Site Modifications & New Construction	Phase 2 - Well Management & Drilling	Phase 3 - Production & Well Management	Phase 4 - Abandonment & Decommissioning	Phase 5 - Site Restoration & Aftercare												
Mobilisation of contaminated soils	X				X	Made ground and contaminated soils and shallow groundwater at the Site	Runoff to surface waters; downwards leakage through liner and underlying soils/rock	SW drainage system	Y	High	High	Major	Unlikely	Low	Earthworks and excavations will not be carried out during heavy rainfall. Temporary bunds formed to prevent uncontrolled runoff to surface water.	Very Unlikely	Very Low
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	N	Productive horizons within the Weald Clay Formation are separated from surface by Unproductive strata.							
								Potential Private Water Supplies	N	The identified potential PWS are either upgradient of the Site or separated from the Site by watercourses.							
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	N	These hydrogeological units are separated from surface by the Weald Clay Formation.							
								Purbeck Group (secondary aquifer, limited resource value)	N								
								Water bearing strata in the Jurassic (no resource value)	N								
							Creation of vertical pathways through construction of drilling cellars, underground water storage tank, groundwater monitoring boreholes	SW drainage system	Y	High	High	Major	Unlikely	Low		Very Unlikely	Very Low
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	N	The proposed excavations/drilling works are shallow (<5m deep). Productive horizons within the Weald Clay Formation are seperated from surface by Unproductive strata.							
								Potential Private Water Supplies	N	The proposed excavations/drilling works are shallow (<5m deep). The identified potential PWS are either upgradient of the Site or separated from the Site by watercourses.							
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	N	The proposed excavations/drilling works are shallow (<5m deep). These hydrogeological units are separated from surface by the Weald Clay Formation.							
								Purbeck Group (secondary aquifer, limited resource value)	N								
								Water bearing strata in the Jurassic (no resource value)	N								
Spillage of fuels and lubricants and other materials	X	X	X	X	X	Plant and machinery	Runoff to surface waters; downwards leakage through liner and underlying soils/rock	SW drainage system	Y	High	High	Major	Unlikely	Low	Plant and equipment will be regularly inspected for leakage. Spill kits will be available on site to deal with any unexpected spills	Very Unlikely	Very Low
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	N	Productive horizons within the Weald Clay Formation are separated from surface by Unproductive strata.							
								Potential Private Water Supplies	N	The identified potential PWS are either upgradient of the Site or separated from the Site by watercourses.							
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	N	These hydrogeological units are separated from surface by the Weald Clay Formation.							
								Purbeck Group (secondary aquifer, limited resource value)	N								
								Water bearing strata in the Jurassic (no resource value)	N								

Hazard	Phases					Source (S)	Pathway (P)	Receptors (R)	S-P-R Linkage	Receptor Sensitivity	Magnitude of Impact	Potential Significance of Effect	Likelihood of Occurrence	Risk Analysis (with embedded mitigation)	Additional Mitigation	Likelihood of Occurrence After Additional Mitigation	Residual Risk
	Phase 1 - Existing Well Site Modifications	Phase 2 - Well Management & Drilling	Phase 3 - Production & Well Management	Phase 4 - Abandonment & Decommissioning	Phase 5 - Site Restoration & Aftercare												
Leakage of domestic sewage and waste water from welfare facilities	X	X	X	X	X	Welfare facilities at the Site	Runoff to surface waters; downwards leakage through liner and underlying soils/rock	SW drainage system	Y	High	High	Major	Very Unlikely	**Very Low**	N/A - embedded mitigation already provides the highest possible mitigation	Very Unlikely	**Very Low**
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Very Unlikely	**None**		Very Unlikely	**None**
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	N	Welfare facilities use sealed tanks with no discharge to the Site drainage system. Productive horizons within the Weald Clay Formation are separated from surface by Unproductive strata.							
								Potential Private Water Supplies	N	The identified potential PWS are either upgradient of the Site or separated from the Site by Spencers Gill/other watercourses.							
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	N	These hydrogeological units are separated from surface by the Weald Clay Formation.							
								Purbeck Group (secondary aquifer, limited resource value)	N								
								Water bearing strata in the Jurassic (no resource value)	N								
Loss of drilling muds, additives and grout		X	X	X		Fluids used during drilling process	Migration from the wellbore into permeable formations; transmission along faults	SW drainage system	Y	High	High	Major	Very Unlikely	**Very Low**	Drilling fluids will be thickened where necessary to prevent fluid losses	Very Unlikely	**Very Low**
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Very Unlikely	**None**		Very Unlikely	**None**
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	Y	Medium	Medium	Moderate	Moderate	**Low**		Unlikely	**Very Low**
								Potential Private Water Supplies	Y	Medium	Medium	Moderate	Moderate	**Low**		Unlikely	**Very Low**
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	Y	Medium	Medium	Moderate	Moderate	**Low**		Unlikely	**Very Low**
								Purbeck Group (secondary aquifer, limited resource value)	Y	Low	Very Low	Negligible	Moderate	**None**		Unlikely	**None**
								Water bearing strata in the Jurassic (no resource value)	Y	Low	Very Low	Negligible	Moderate	**None**		Unlikely	**None**
Leakage/spills of hydrocarbons, fuels, produced water containing NORM and other fluids stored on, or transported to/from, the wellsite		X	X	X		Storage tanks and pipework used during production operations	Runoff to surface waters; downwards leakage through wellsite liner and underlying soils/rock	SW drainage system	Y	High	High	Major	Unlikely	**Low**	Road tankers and storage tanks will be regularly inspected for leakage. Spill kits will be available on site to deal with any unexpected leakage. Traffic management implemented to minimise potential for tanker collisions	Very Unlikely	**Very Low**
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Unlikely	**Very Low**		Very Unlikely	**None**
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	N	Productive horizons within the Weald Clay Formation are separated from surface by Unproductive strata.							
								Potential Private Water Supplies	N	The identified potential PWS are either upgradient of the Site or separated from the Site by watercourses.							
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	N	These hydrogeological units are separated from surface by the Weald Clay Formation.							
								Purbeck Group (secondary aquifer, limited resource value)	N								
								Water bearing strata in the Jurassic (no resource value)	N								

Hazard	Phases					Source (S)	Pathway (P)	Receptors (R)	S-P-R Linkage	Receptor Sensitivity	Magnitude of Impact	Potential Significance of Effect	Likelihood of Occurrence	Risk Analysis (with embedded mitigation)	Additional Mitigation	Likelihood of Occurrence After Additional Mitigation	Residual Risk
	Phase 1 - Existing Well Site Modifications & New Construction	Phase 2 - Well Management & Drilling	Phase 3 - Production & Well Management	Phase 4 - Abandonment & Decommissioning	Phase 5 - Site Restoration & Aftercare												
Migration of well treatment fluids, gases and produced/formation water containing NORM from the wellbore and/or production formations		X	X	X		Produced water reinjection	Vertical migration through overlying formations; transmission along geological faults; interaction with abandoned Collendean Farm 1	SW drainage system	Y	High	High	Major	Unlikely	Low	Produced water reinjection will take place for production support only. Produced water injection rates will be designed and controlled to ensure no excessive overpressure that could cause transmission between hydraulic units along faults.	Very Unlikely	Very Low
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Potential Private Water Supplies	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	Y	Medium	Medium	Moderate	Unlikely	Very Low		Very Unlikely	None
								Purbeck Group (secondary aquifer, limited resource value)	Y	Low	Very Low	Negligible	Unlikely	None		Very Unlikely	None
								Water bearing strata in the Jurassic (no resource value)	Y	Low	Very Low	Negligible	Moderate	None		Unlikely	None
						Fluids injected into the wellbore during workovers; natural gases in the formation; produced water reinjection	Leakage through well casings and along anullii	SW drainage system	Y	High	High	Major	Very Unlikely	Very Low	N/A - embedded mitigation already provides the highest possible mitigation	Very Unlikely	Very Low
								Superficial Deposits/Weathered Bedrock (Secondary Aquifer)	Y	Medium	Medium	Moderate	Very Unlikely	None		Very Unlikely	None
								Productive horizons within the Weald Clay Formation (Secondary aquifer)	Y	Medium	Medium	Moderate	Very Unlikely	None		Very Unlikely	None
								Potential Private Water Supplies	Y	Medium	Medium	Moderate	Very Unlikely	None		Very Unlikely	None
								Tunbridge Wells Sand Formation/Ashdown Formation (Secondary Aquifers)	Y	Medium	Medium	Moderate	Very Unlikely	None		Very Unlikely	None
								Purbeck Group (secondary aquifer, limited resource value)	Y	Low	Very Low	Negligible	Very Unlikely	None		Very Unlikely	None
								Water bearing strata in the Jurassic (no resource value)	Y	Low	Very Low	Negligible	Very Unlikely	None		Very Unlikely	None

Table 8 Embedded Mitigation

Development Phase	Embedded Mitigation
Phase 1- Existing Well Site Modifications	• Collection of foul water and sewage from welfare facilities in sealed storage tanks which will be emptied and removed from Site by an appropriate contractor. • Spill response protocol. • Minimal disturbance of existing granular working platform as part of the existing well site modifications. • QA/QC testing during installation of HDPE liner system in new drilling cellars and following rathole/mousehole installation. • Protection of the HDPE liner above and below with 300g/m^2 geotextile non-woven fleece geotextile material. • Protection of the HDPE liner with a compacted stone granular working platform. • Testing and repairs of defective welds in the HDPE liner by certified welding technicians. • Setting of a concrete slab around the drilling cellars to which the HDPE liner is sealed. • Testing of the seal in the drilling cellar by hydrotesting with water; disposed off-site via tanker to a permitted waste facility. • Construction of groundwater monitoring boreholes outside the lined part of the Site. Construction of boreholes in accordance with Environment Agency best practice.
Phase 2- Well Management and Drilling	• Detailed planning of well trajectories to avoid interaction with Collendean Farm 1 abandoned well. • Well construction in accordance with oil and gas industry best practice and regulations (Offshore Installations and Wells (Design and Construction, etc) Regulations 1996; BSOR, 1995). Inspection of the well design, construction and maintenance by an independent well examiner. • Well designs incorporate cemented steel casings to at least 390mbgl (top of Purbeck Group). • Design, management and monitoring of drilling fluids (muds) to minimise losses from the wellbore to geological formations. Use of water based muds to depths of 400mbgl. Oil based muds only used below this depth. • Blow out prevention equipment used to prevent uncontrolled movement of fluids within the wellbore. • Primary, Secondary and Tertiary Containment System for produced fluids, fuels and chemicals: enclosed tanks and pipework; concrete bunding (in line with CIRIA guidance) /tanking /kerbing; HDPE liner. • Removal of dirty surface water via tanker during drilling operations. Clean water will be discharged to the local surface water system via an interceptor, as specified in an Environmental Permit. • Collection and disposal off-site of extractive waste including drilling muds, cement, drill cuttings and spent chemicals. • Collection of foul water and sewage from welfare facilities in self-contained sealed storage tanks which will be emptied and removed from Site by an appropriate contractor.
Phase 3- Production and Well Management	• Primary, Secondary and Tertiary Containment System (see above) • Drainage of clean surface water to the local surface water system via an oil interceptor system, in accordance with an Environmental Permit. Water from process areas will be reinjected with produced water for production support.

	• Produced water will be reinjected to production formations at rates that will not exceed the fracture gradient of the formation (see Appendix C). Rates will be specified as part of the environmental permitting process and controlled to ensure there is no potential for produced water reinjection to cause induced seismicity or indirect discharge to groundwater bearing formations. • Blow out prevention equipment used to prevent uncontrolled movement of fluids within the wellbore. • Removal of dirty surface water via tanker during workover operations. Clean water will be discharged to the local surface water system via an interceptor, as specified in an Environmental Permit. • Collection of foul water and sewage from welfare facilities in self-contained sealed storage tanks which will be emptied and removed from Site by an appropriate contractor.
Phase 4- Plugging, Abandonment and Decommissioning	• Well abandonment to UK oil and gas industry standards in accordance with Well Decommissioning Guidelines, Issue 6 – June 2018. Oil and Gas UK (or equivalent at the time of decommissioning). • Inspection of the well abandonment and maintenance by an independent well examiner. • Removal of dirty surface water via tanker during workover operations. Clean water will be discharged to the local surface water system via an interceptor, as specified in an Environmental Permit. • Collection of foul water and sewage from welfare facilities in self-contained sealed storage tanks which will be emptied and removed from Site by an appropriate contractor.
Phase 5- Site Restoration and Aftercare	• Removal of any/all contaminated materials from Site before HDPE liner is removed. • Rapid soil placement and re-vegetation • Collection of foul water and sewage from welfare facilities in self-contained sealed storage tanks which will be emptied and removed from Site by an appropriate contractor.

10 FLOOD RISK ASSESSMENT

10.1 Overview

This Flood Risk Assessment (FRA) has been undertaken with reference to the National Planning Policy Framework (NPPF) 2018 [Ref. 15] and the accompanying online resource, National Planning Practice Guidance (NPPG): Flood Risk and Coastal Change 2014 [Ref. 16].

The principal objectives of this assessment are to demonstrate that the Proposed Development activities will:

- Result in no net loss of floodplain storage;
- Not impede water flows; and
- Not increase the risk of flooding at the well site or elsewhere.

10.2 Flood Risk Planning Policy and Guidance

10.2.1 Environment Agency Flood Zones

An extract of the Environment Agency Flood Map for Planning (Rivers and the Sea) for the Site and local surrounding area is presented on Figure 9.

The Site is situated wholly within Flood Zone 1 (Less than a 1 in 1,000 year (0.1%) annual chance of flooding from rivers and the sea).

10.2.2 Flood Risk Vulnerability Classifications

The Proposed Development is classified as a 'Less Vulnerable' development with its activities focused on the production of oil and associated infrastructure and facilities. As defined in Planning Practice Guidance, 'Less Vulnerable' development is appropriate within Flood Zone 1.

10.2.3 Strategic Flood Risk Assessment

District-wide information on flood risk has been obtained from Reigate and Banstead Borough Council Strategic Flood Risk Assessment (SFRA) – 2012 [Ref.47]. The SFRA provides a detailed and comprehensive assessment for the extent and nature of past and present risk of flooding and its implications for land use in the district.

10.3 Flood Risk Consideration

10.3.1 Risk of Flooding from the Sea (Tidal)

The Site is significantly inland and not at risk of flooding from the sea. Local watercourses are not tidally influenced.

10.3.2 Risk of Flooding from Rivers and Streams (Fluvial)

The Site is wholly located within Flood Zone 1 (Figure 9) and therefore considered to be at very low risk of flooding from fluvial sources. This is consistent with the Site's location in the headwaters of the catchment. The SFRA historical flood records identify no flooding at the Site. The SFRA records show flooding in town of Horley as a result of river flooding. This is a significant distance away from the Site.

Based on the above, the overall risk of flooding from fluvial sources to the Site is considered to be very low.

10.3.3 Risk of Flooding from Surface Water (Pluvial)

Surface water flooding occurs when rainwater does not drain away or soak into the ground but lies on or flows over the ground surface. Areas that are most vulnerable to surface water flooding are low lying areas where surface water runoff can accumulate.

The updated Environment Agency Flood Map for Surface Water (uFMfSW) classifies the risk from surface water flooding using the following four categories:

- **High** – Greater than or equal to a 1 in 30 year (3.3%) chance in any given year;
- **Medium** – Between a 1 in 100 year (1%) and 1 in 30 year (3.3%) chance in any given year;
- **Low** – Between a 1 in 1,000 year (0.1%) and 1 in 100 year (1%) chance in any given year;
- **Very Low** – Less than a 1 in 1,000 year (0.1%) chance in any given year.

An extract from the EA Surface Water Flood Map for the Site and local vicinity is presented on Figure 10. The well site compound is shown to be generally at very low to no risk from surface water flooding although some parts of the access track are shown as low risk.

The proposed development will capture and manage surface water runoff on the Site according to the surface water drainage scheme outlined in Section 3, with a discharge at the Greenfield runoff rate. No infiltration of surface water to the subsoils below will occur due to the use of a very low permeability of the HDPE membrane incorporated into the construction of the well site.

Based on the above, the overall risk from pluvial flooding to / from the Site is considered to be low/very low, provided that surface water is managed appropriately.

10.3.4 Risk of Flooding From Groundwater

Groundwater flooding is the emergence of groundwater at the ground surface. Groundwater flooding occurs in response to a combination of already high groundwater levels (usually during mid or late winter) and intense or unusually lengthy storm events.

There is a very low risk of groundwater flooding at the Site because:

- The Site is within the headwaters of the catchment and is directly underlain by low permeability soils/rock with a low potential to transmit groundwater.

- The unnamed stream to the south/south west of the Site is fed by land drains and possibly springs close to Brittleware and Greenstead Hall Farms (625m and 900m southwest of the Site respectively). These drain away from the Site towards Spencer's Gill, a tributary of the River Mole.
- Surrey County Council Local Flood Risk Management Strategy (LFRMS) identifies no potential risk of groundwater flooding at the Site [Ref. 48].
- The SFRA indicates no records of groundwater flooding affecting properties within the local area.
- The proposed development will use a very low permeability HDPE liner across the Site as outlined in Section 2 that provides a hydraulic break between the Site and any groundwater in the underlying soils/rock.

10.3.5 Risk of Flooding To / From Artificial Waterbodies

The Environment Agency's Risk of Reservoir Failure map [Ref. 49] shows that there is no residual risk of flooding to the Site from a large, raised reservoir in the event of a structural failure or breach. The Reservoirs Act 1975 defines a large reservoir as one that holds over 25,000m^3 of water.

There are no small reservoirs upstream or downstream of the Site. There are no canals upstream or downstream of the Site.

Based on the above, there is a no risk of flooding to / from the Site from artificial waterbodies.

10.3.6 Risk of Flooding to/ from Sewers

There are no proposed connections from the Site to public sewers. There are no public sewers in close proximity to the Site and therefore no risk of flooding from public sewers.

10.3.7 Risk of Flooding to/ from Roads

Runoff generated over roads in the local area is managed by the respective road drainage systems and therefore the risk of flooding from roads to the Site is considered very low. Surface water shall be managed within the enclosed, bunded well site area as described in Section 2. Therefore, the risk of flooding from the Site to roads is considered very low.

10.3.8 Risk of Flooding Post-Restoration

The Site will be returned to pre-development condition with hardstanding areas dismantled and removed. The HDPE membrane will be removed, and the subsoil will be cultivated in strips. There will be no change in runoff pathways or runoff volumes compared to pre-development levels.

Based on the above, there is very low risk of flooding to / from the Site from Post-Restoration.

10.4 Risk from Flooding from the Proposed Development

A summary of the flood risk to the well site is presented in Table 9.

Table 9 Flood Risk Summary

Flood Source	Potential Risk				
	No Risk	Very Low	Low	Medium	High
Tidal	X				
Fluvial		X			
Pluvial			X*		
Groundwater		X			
Artificial Waterbodies	X				
Public Sewer	X				
Post-Restoration		X			

*There is a low risk of pluvial flooding to some parts of the access track. The rest of the Site is at no or very low risk

To reduce the risk of flooding, the Site has been designed by HHDL's Consulting Engineers to contain incident rainfall and release it into the environment when it is safe to do so. Any water which is not suitable for discharge is to be contained on-site and removed by tanker for treatment and/or disposal at an Environment Agency permitted waste facility. This system acts as a SuDS (Sustainable Drainage System) by storing rainfall runoff and releasing stored water slowly into the local watercourse.

The well site can contain a 1 in 100-year storm event with a 10% climate change allowance, without discharging as detailed in Ref. 19. As such, the Proposed Development does not increase the risk of off-site flooding and if necessary, can hold and slowly release the volumes of water generated from an extreme storm.

10.5 Summary

- The Site is wholly located within Environment Agency Flood Zone 1 (very low probability from fluvial and tidal sources).
- The proposed development is acceptable in Flood Zone 1 based on the NPPF and other related guidance.
- The risk from surface water flooding is considered to be Low/Very Low. Surface runoff will be managed in accordance with the proposed surface water drainage scheme.
- The overall risk from groundwater, river flooding and post-restoration is considered to be Very Low.
- The risk of flooding from the well site activity will be mitigated by controlled discharge and the water storage capacity on the well site.

The FRA demonstrates that the Site carries No Risk to Low Risk from all sources of flooding and the Proposed Development will not increase the risk of flooding off-site.

11 SUMMARY

A hydrogeological conceptual model has been developed based on a detailed review of background information including the Site setting, local hydrology (surface water systems), geology and hydrogeology.

The hydrogeology at the Horse Hill well site is dominated by surface water and shallow groundwater within low permeability weathered bedrock. The shallow groundwater system historically provided small amounts of water for local water supplies. Approximately 150m of the low permeability Weald Clay Formation is present directly beneath the Site, which separates the shallow groundwater system from deeper water bearing formations. The Weald Clay Formation may contain some thin sandstone and limestone layers but with limited potential to contain useful groundwater.

The Tunbridge Wells Sands Formation and Ashdown Formation is present beneath the Weald Clay Formation and whilst not exploited locally, these formations have the potential to contain groundwater that (with treatment) could be useful for industrial or other uses.

The top of the Purbeck Group comprises approximately 70m of unproductive argillaceous bedrock. This, together with 20m of the very low permeability, unproductive Purbeck Anhydrite at the base of the Purbeck Group provides a hydraulic break between potentially useful groundwater, and formation water in the underlying Jurassic strata with limited or no resource value. Water within these units is likely to be old recharge water with elevated salinity.

Geological faults are unlikely to provide a pathway for transmission of fluids between the deep, hydrocarbon bearing layers and shallow groundwater systems.

Using the conceptual model, a hydrogeological risk assessment (HRA) has been carried out taking account of the Environment Agency's technical guidance which examines the risk to a wide range of receptors. The risk assessment shows that with mitigation measures in place, the residual risk for all the identified hazards reduces to either 'very low' or 'none'.

The findings of the HRA are a result of the very high level of embedded mitigation within the design and construction of the existing well site compound and the existing and proposed wells, combined with additional mitigation that will be provided through the implementation of robust environmental management systems. Mitigation measures with respect to produced water reinjection take account of Environment Agency guidance to ensure no induced seismicity or excessive overpressure could arise that would cause geomechanically impacts or transmission between hydraulic units to occur.

The effectiveness of the mitigation measures will be demonstrated through a scheme of monitoring that will be agreed with the Environment Agency and incorporated within an environmental permit.

A flood risk assessment (FRA) has been carried out taking account of the National Planning Policy Framework (NPPF) and the accompanying online resource, National Planning Practice Guidance (NPPG): Flood Risk and Coastal Change 2014. The FRA demonstrates that the Proposed Development will not have a detrimental impact on drainage and flooding at or from the Site, providing that surface water is managed appropriately.

Envireau Water
26/02/2021

12 REFERENCES

Ref.1 Andrews, I.J. 2014 The Jurassic shales of the Weald Basin: geology and shale oil and shale gas resource estimation. British Geological Survey for Department of Energy and Climate Change, 89pp. (UNSPECIFIED)

Ref.2 Envireau Water, November 2018. Hydrogeological and Flood Risk Assessment. Horse Hill Well Site, Surrey.

Ref.3 Environment Agency consultation response. Letter from the Environment Agency to Surrey County Council. Ref. WA/2019/126164/01-L01, 8th February 2019.

Ref.4 Instruction for Advice Pursuant to geological/Geotechnical Consultancy Contract. Letter from Peter Brett Associates to Surrey Country Council. Re. 21482/024/CBH/DA/RHT/VKR/SK, 7th February 2019.

Ref.5 Instruction for Advice Pursuant to geological/Geotechnical Consultancy Contract. Letter from Peter Brett Associates to Surrey Country Council. Re. 21482/024/CBH/DA/RHT/JP/SK, 5th June 2019.

Ref.6 HHDL Response. Letter from Zetland Group to Surrey County Council. Ref. ZG-103, 2nd April 2019.

Ref.7 HHDL Response. Letter from Zetland Group to Surrey County Council. Ref. ZG-103, 18th June 2019.

Ref. 8 Hydrogeological and Flood Risk Assessment. Horse Hill Well Site, Surrey. Document reference: RPT HRAFRA Horse Hill Production V2. July 2019.

Ref. 9 Schedule 5 Notice – Consolodated (sic) – Formal Issue. Environment Agency 2020.

Ref.10 Green Leaves III - Guidelines for Environmental Risk Assessment and Management: Green Leaves III. Revised Departmental Guidance Prepared by Defra and the Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, Cranfield University November 2011.

Ref.11 The Environment Agency's approach to groundwater protection. Version 1.2. Environment Agency, February 2018.

Ref.12 Groundwater risk assessment for your environmental permit. Environment Agency, Updated April 2018. https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

Ref.13 Onshore Oil and Gas Sector Guidance. Environment Agency, Updated January 2020. https://www.gov.uk /guidance/onshore-oil-and-gas-sector-guidance

Ref.14 Environment Agency Science Report SC150027. Reinjection of fluids to deep geological formations, September 2017.

Ref.15 National Planning Policy Framework. Published March 2014, updated June 2019. Ministry of Housing, Communities and Local Government.

Ref.16 National Planning Practice Guidance (NPPG): Flood Risk and Coastal Change. Published March 2014, updated October 2019. Ministry of Housing, Communities and Local Government.

Ref.17 Site Condition Report. Horse Hill Developments Ltd. Document Number: HHDL-EPR-HHP-SCR-006

Ref.18 I L W Walton, SLR Consulting. CIRIA. Containment systems for the prevention of pollution (C736) 2014. Secondary, tertiary and other measures for industrial and commercial premises.

Ref.19 Envireau Water, 2018. Horse Hill Condition 6 Report. Report Reference: \\env-sql\Workingfiles\PhilHam\unionsquare.envireauwater.co.uk\RPT HRA FRA HHDL.docx

Ref.20 The Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 (DCR).

Ref.21 The Borehole Site and Operations Regulations 1995 (BSOR).

Ref. 22 Waste Management Plan. HH-PR-Q10. Revision 8. Horse Hill Developments Limited.

Ref.23 2018 01 31 Confirmed hazardous substances list. Water Framework Directive UK TAG. https://www.wfduk.org/tagged/hazardous-substances

Ref.24 Well Decommissioning Guidelines, Issue 6 – June 2018. Oil and Gas UK.

Ref.25 Ordnance Survey Historic Maps- 1874, 1897, 1944, 1991 viewed at: https://www.old-maps.co.uk/#/

Ref.26 Soilscapes (Cranfield University) Cranfield Soil and AgriFood Institute. Accessed February 2021. http://www.landis.org.uk/soilscapes/

Ref.27 Flood Estimation Handbook Web Service. Accessed January 2021. https://fehweb.ceh.ac.uk/

Ref.28 Reigate, Sheet 286. 1978. Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series.

Ref.29 Horsham, Sheet 302. 1972. Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series.

Ref.30 TQ24SE (Horley). 2003. British Geological Survey (1:10,000 series).

Ref.31 Gallois, R.W.; Worssam, B.C.; Thurrell, R.G.; Penn, I.E.; Anderson, F.W.; Monkhouse, R.A.; British Geological Survey. 1993. Geology of the country around Horsham: memoir for 1:50000 geological sheet 302 (England and Wales)

Ref.32 Dines, H.G.; Edmunds, F.H.; Chatwin, C.P.; Stubblefield, C.J.. 1933. The geology of the country around Reigate and Dorking: Explanation of one-inch geological sheet 286, new series.

Ref.33 BGS Onshore GeoIndex. https://www.bgs.ac.uk/geoindex/. Accessed January 2021.

Ref.34 UK Onshore Geophysical Library (UKOGL). https://ukogl.org.uk/map/?e=-2509606,6183394,1599648,8477728andl=0,0,0andsm=trueandb=3. Accessed January 2021.

Ref.35 Horse Hill Developments Limited – Horse Hill 1 Well Completion Report. Figure 4- Formation Tops (scan of page 6 of 18 of report).

Ref.36 Horse Hill Developments Limited – Horse Hill 1 Well Completion Report. Figure 3- Well Summary Sheet (scan of page 5 of 18 of report).

Ref. 37 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive).

Ref.38 Directive 2006/118.0/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (Groundwater Daughter Directive). The Geological Survey of Great Britain for 1964.

Ref.39 UK Technical Advisory Group on the Water Framework Directive, Defining and Reporting on Groundwater Bodies, V6.21/Mar/2011, Final 300312.

Ref.40 Allen, D J, Brewerton, L J, Coleby, L M, Gibbs, B R, Lewis, M A, MacDonald, A M, Wagstaff, S J, and Williams, A T. 1997. The Physical Properties of Major Aquifers in England and Wales. British Geological Survey Technical Report WD/97/34. 312pp. Environment Agency RandD Publication 8.

Ref.41 Jones, H K, et al. 2000. The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report, WD/00/4. 234pp. Environment Agency RandD Publication 68.

Ref.42 Completion Report Collendean Farm 1. Esso Petroleum Company Limited Producing Department. July 1965.

Ref.43 Butler, M., and Pullan, C.P. Tertiary structures and hydrocarbon entrapment in the Weald Basin of southern England. Geological Society, London, Special Publications, 55, 371-391. 1990.

Ref.44 MAGIC map. http://www.magic.gov.uk/magicmap.aspx. Accessed January 2021.

Ref. 45 Department of Energy and Climate Change (2014). Guidance on the preparation of an environmental risk assessment of shale gas operations in Great Britain involving the use of hydraulic fracturing.

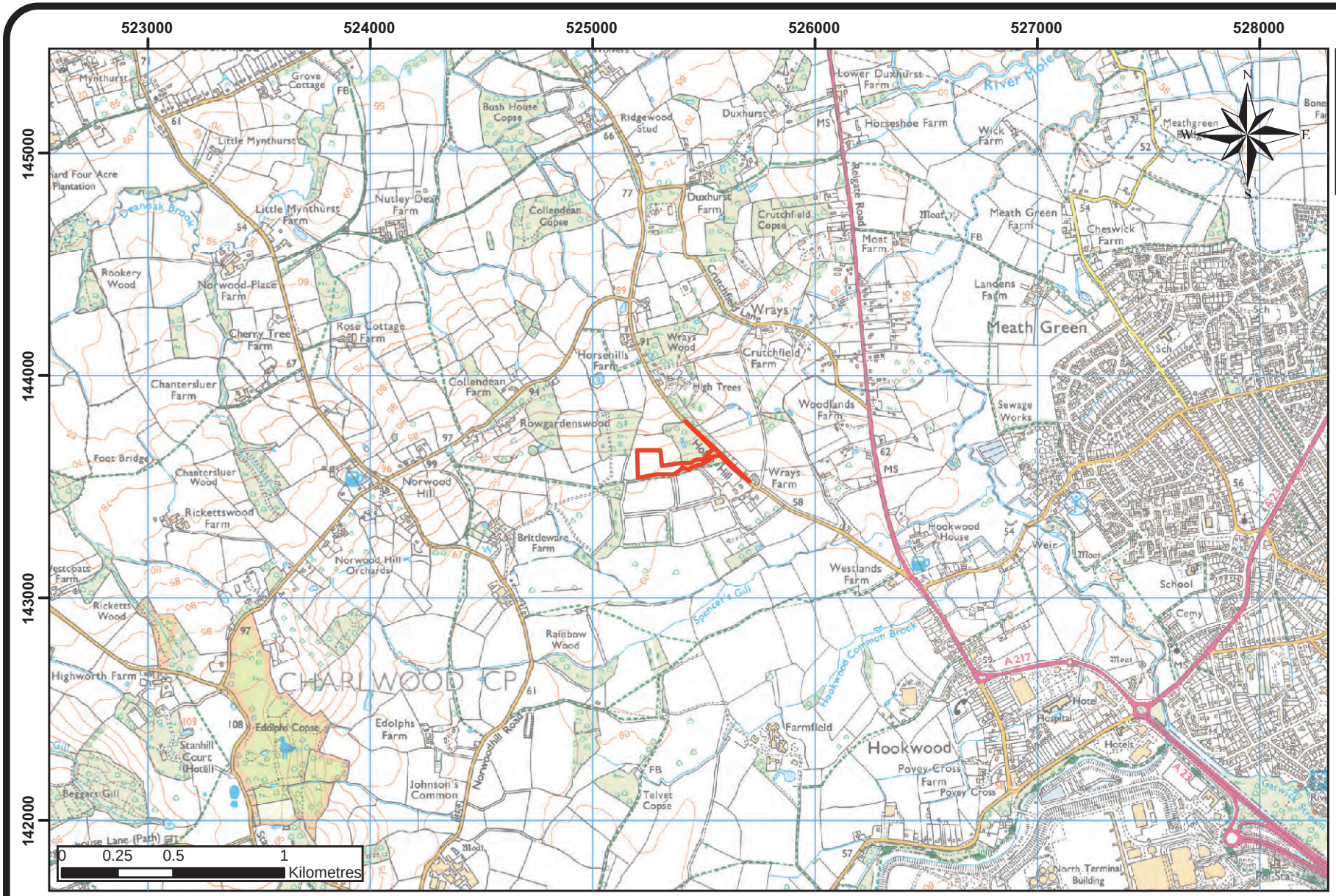
Ref. 46 The Royal Society and The Royal Academy of Engineering (June 2012). Shale gas extraction in the UK: a review of hydraulic fracturing.

Ref.47 Reigate and Banstead Strategic Flood Risk Assessment. Dec 2017.

Ref.48 Surrey Local Flood Risk Management Strategy 2017-2032. Surrey County Council.

Ref.49 Environment Agency, 2021. Flood risk from reservoirs. https://flood-warning-information.service.gov.uk/long-term-flood-risk/risk-types

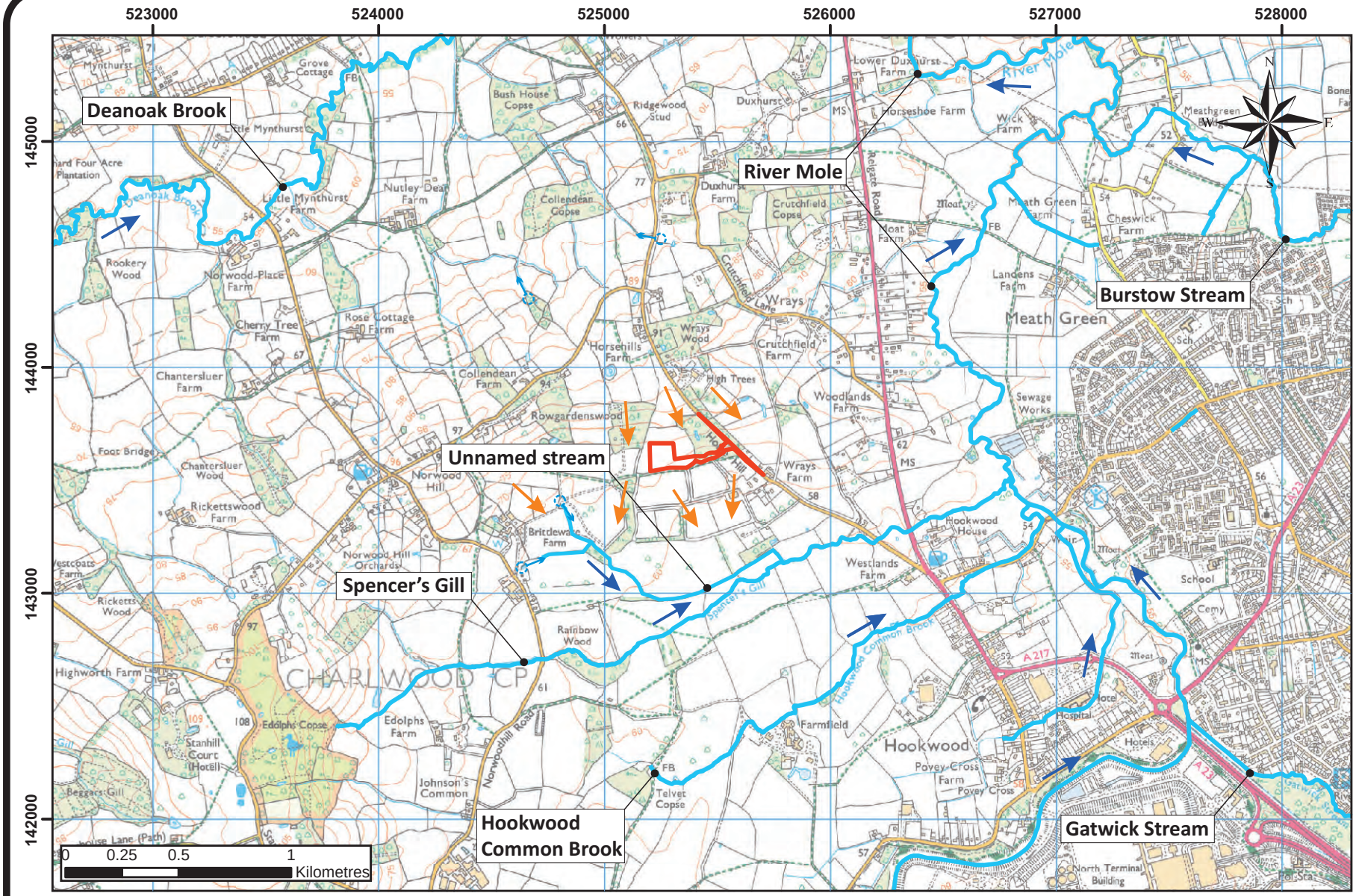
FIGURES



Scale 1:25,000 (at A4)

envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 1 Date: 02/02/2021	**Horse Hill Developments Ltd**
Figure 1	Site Location



KEY

- Application Boundary
- Main river / stream
- Main river / stream flow direction
- Surface water run-off flow direction at the Site
- Issue/spring

Scale 1:25,000 (at A4)

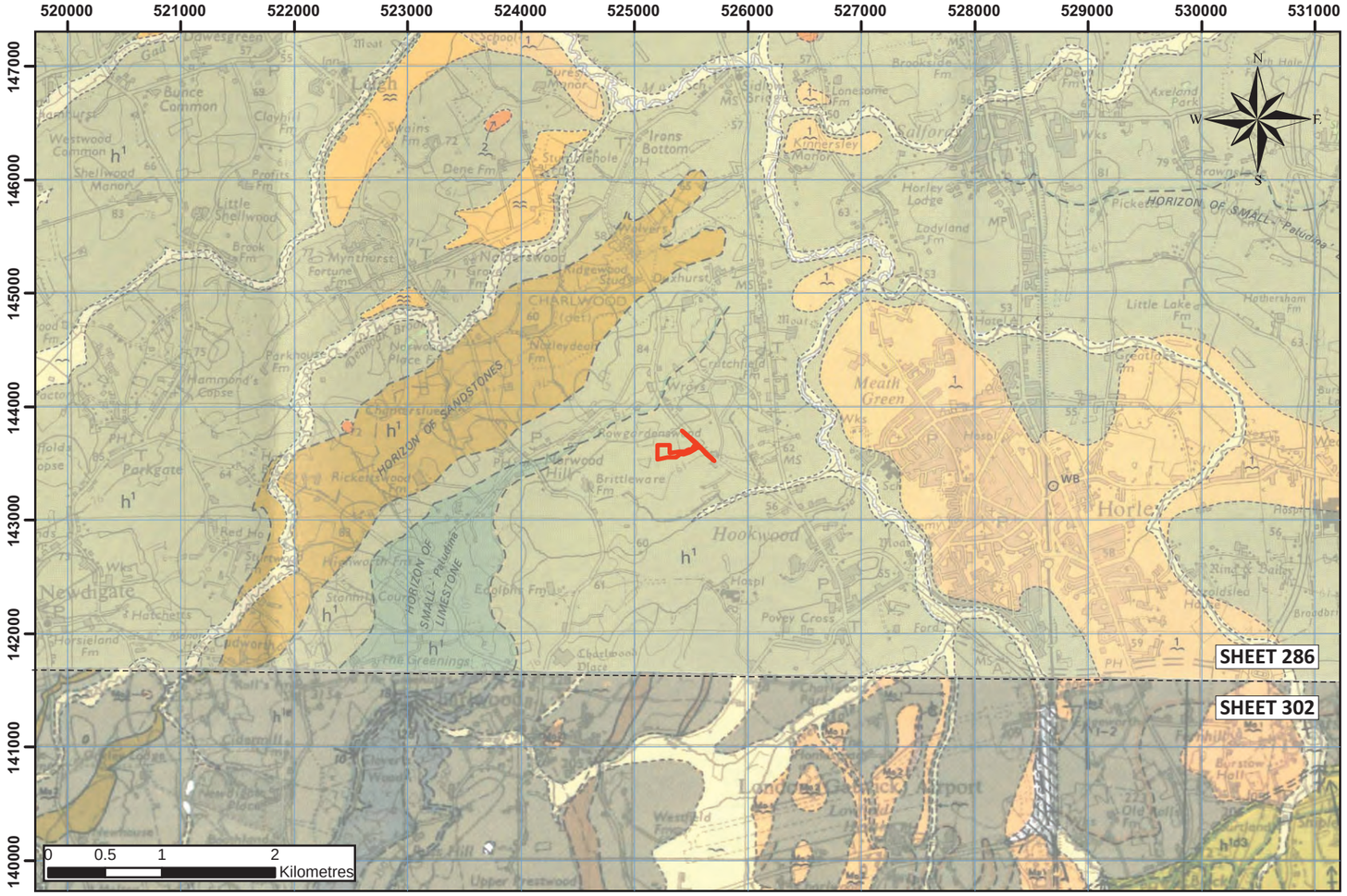
envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 2
Date: 02/02/2021

Horse Hill Developments Ltd

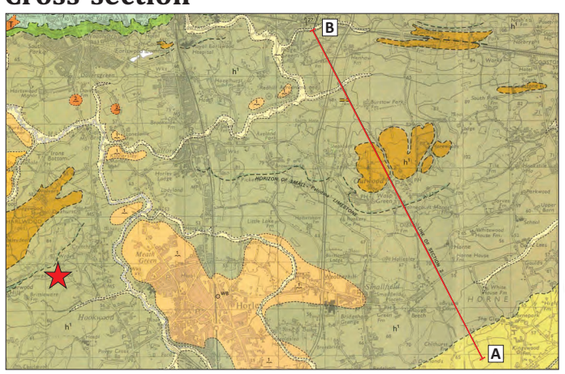
Figure 2

Hydrological Setting

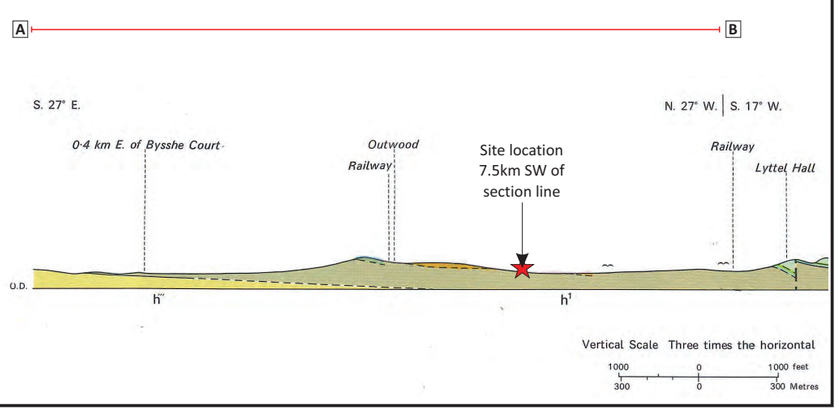


Scale 1: 50,000 (at A3)

Cross-section



Scale 1: 150,000 (at A3)



KEY

Application Boundary

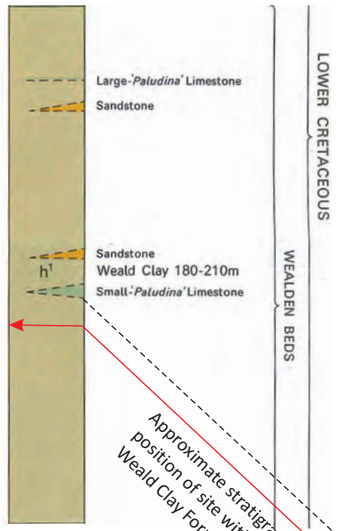
SHEET 286 - SUPERFICIAL DEPOSITS

- Alluvium
- Brickearth
- River Gravels: Low Terrace
- River Gravels: Higher Terrace

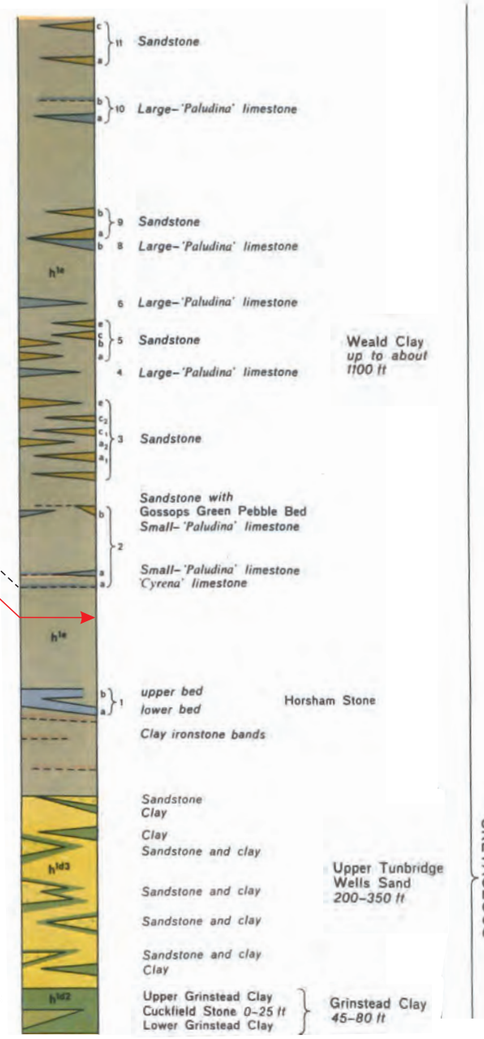
SHEET 302 - SUPERFICIAL DEPOSITS

- Alluvium
- River Mole 1st & 2nd Terraces

SHEET 286 - BEDROCK GEOLOGY*



SHEET 302 - BEDROCK GEOLOGY*



ANNOTATIONS & ILLUSTRATIONS

- 10 — Inclined strata, dip in degrees
- Geological boundary, Drift
- Geological boundary, Solid
- Fault at surface, crossmark indicates downthrow side
- Broken lines denote uncertainty
- WB — Water well or borehole
- Made Ground

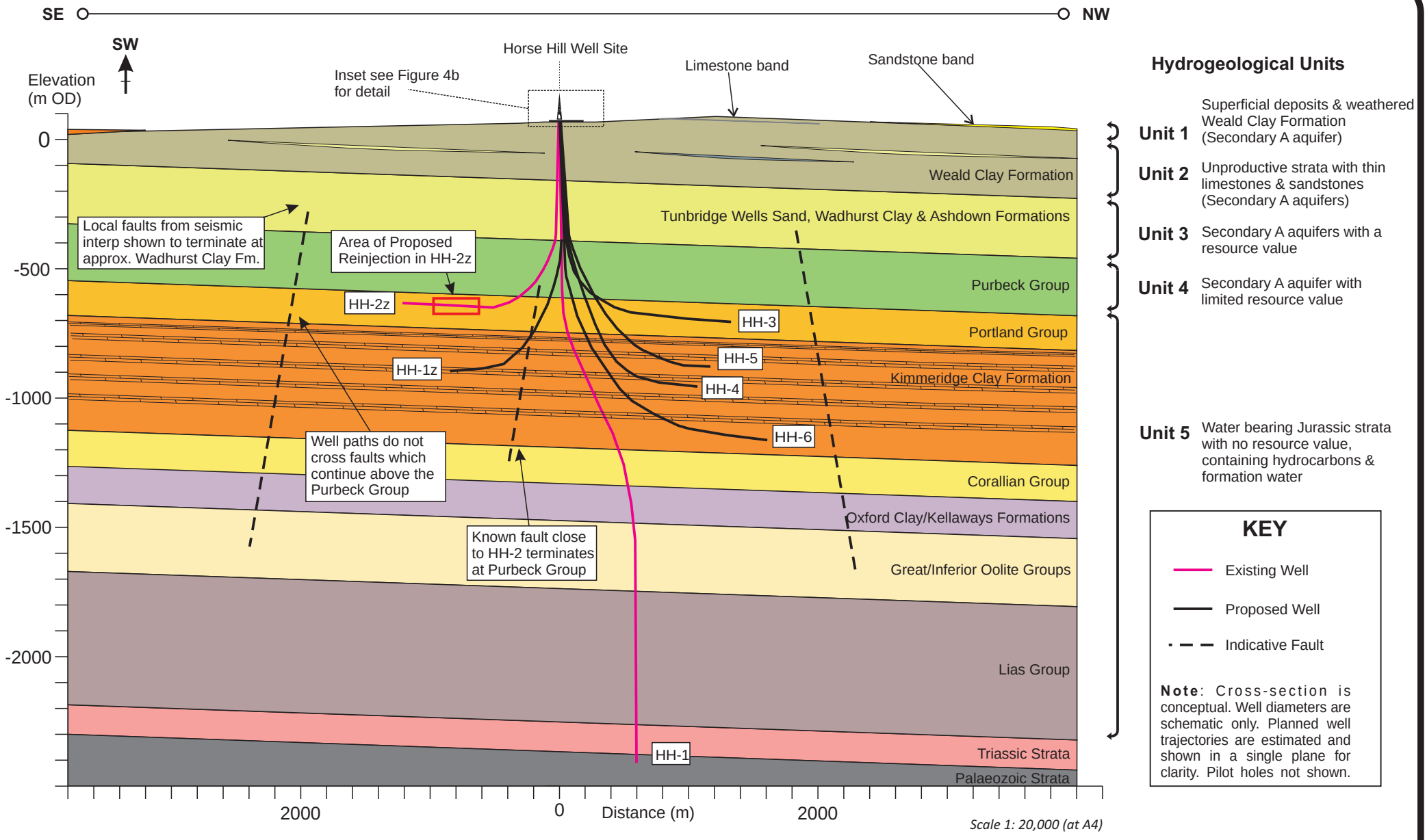
Abbreviation

sst.....Sandstone

***Note: Differing detail of Weald Clay Formation stratigraphy in key reflects the different vintages between Sheet 286 and Sheet 302**

envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 3 Date: 02/02/2021	**Horse Hill Developments Ltd**
Figure 3	Geological Setting



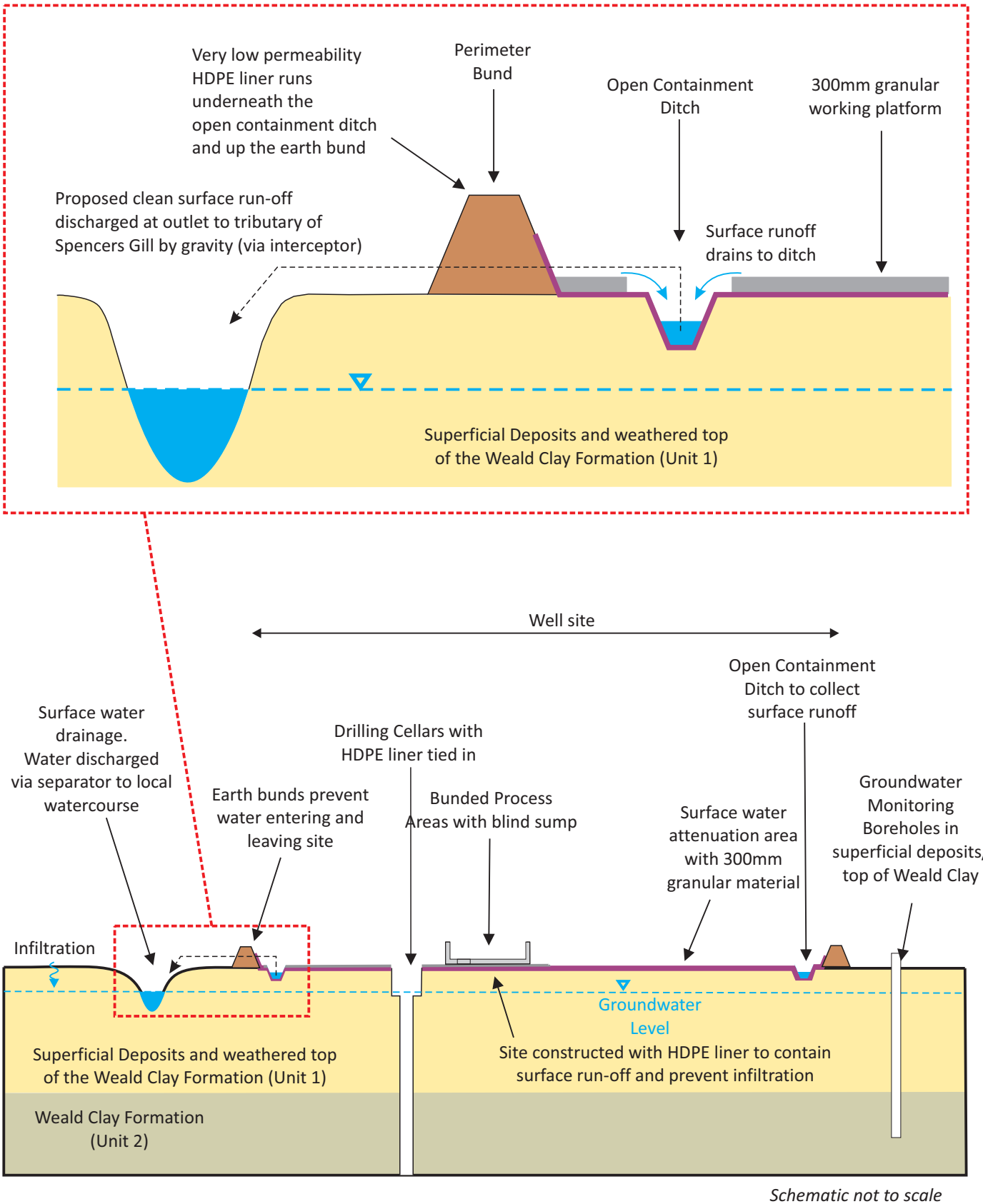
envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 4a
Date: 18/01/2021

Horse Hill Developments Ltd

Figure 4a

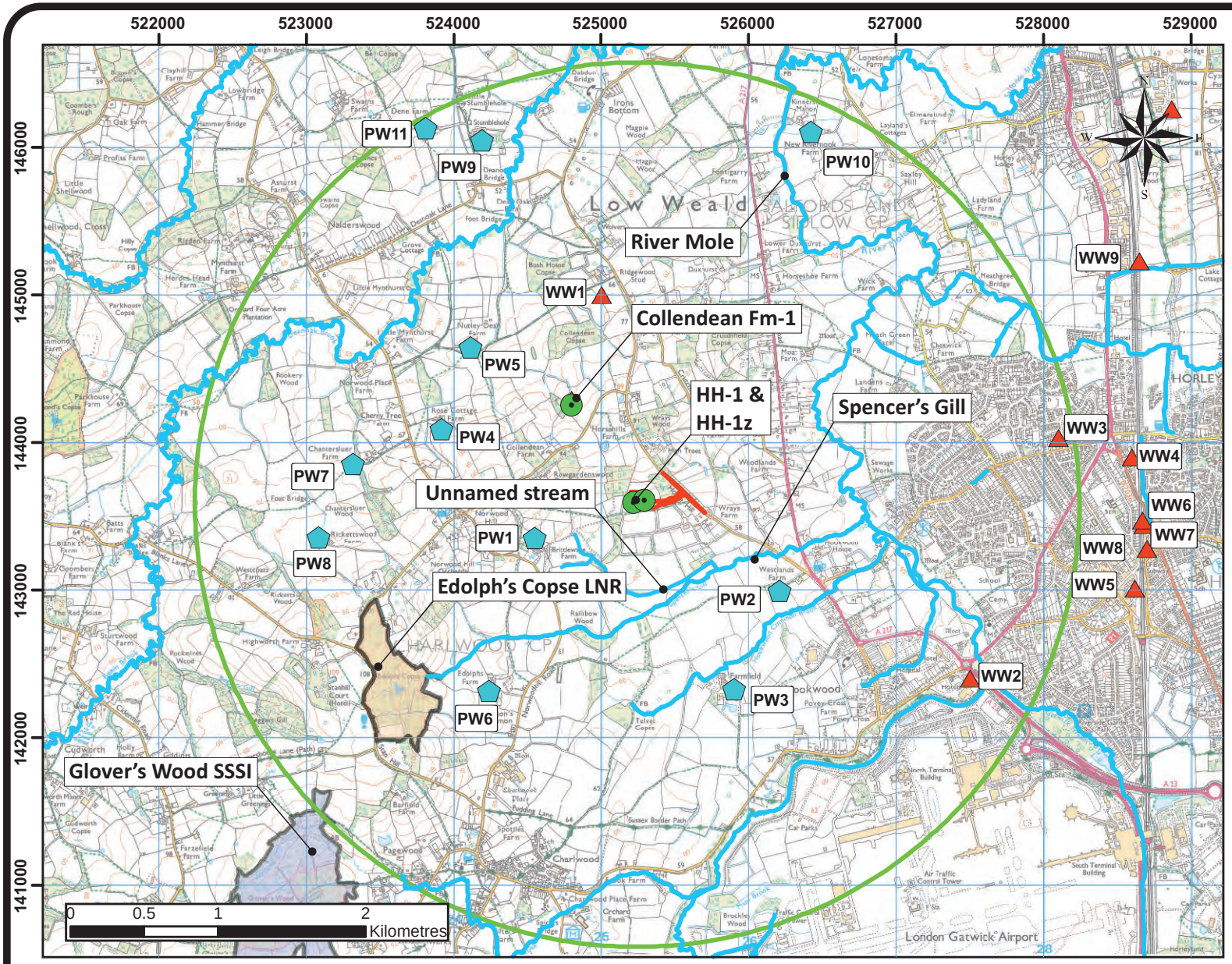
Hydrogeological Conceptual Model - Deep Geology & Wells



Schematic not to scale

envireau WATER

Ref: P18-022\UKOG Horse Hill 2018\FIG 4b Date: 27/11/2018	**Horse Hill Developments Ltd**
Figure 4b	Hydrogeological Conceptual Model - Site & Shallow Geology



Scale 1:40,000 (at A4)

KEY

- Application Boundary
- Main river / stream
- 3km radius
- BGS water well record
- Hydrocarbon well
- Potential private water supply
- Local Nature Reserve (LNR)
- Site of Special Scientific Interest (SSSI)

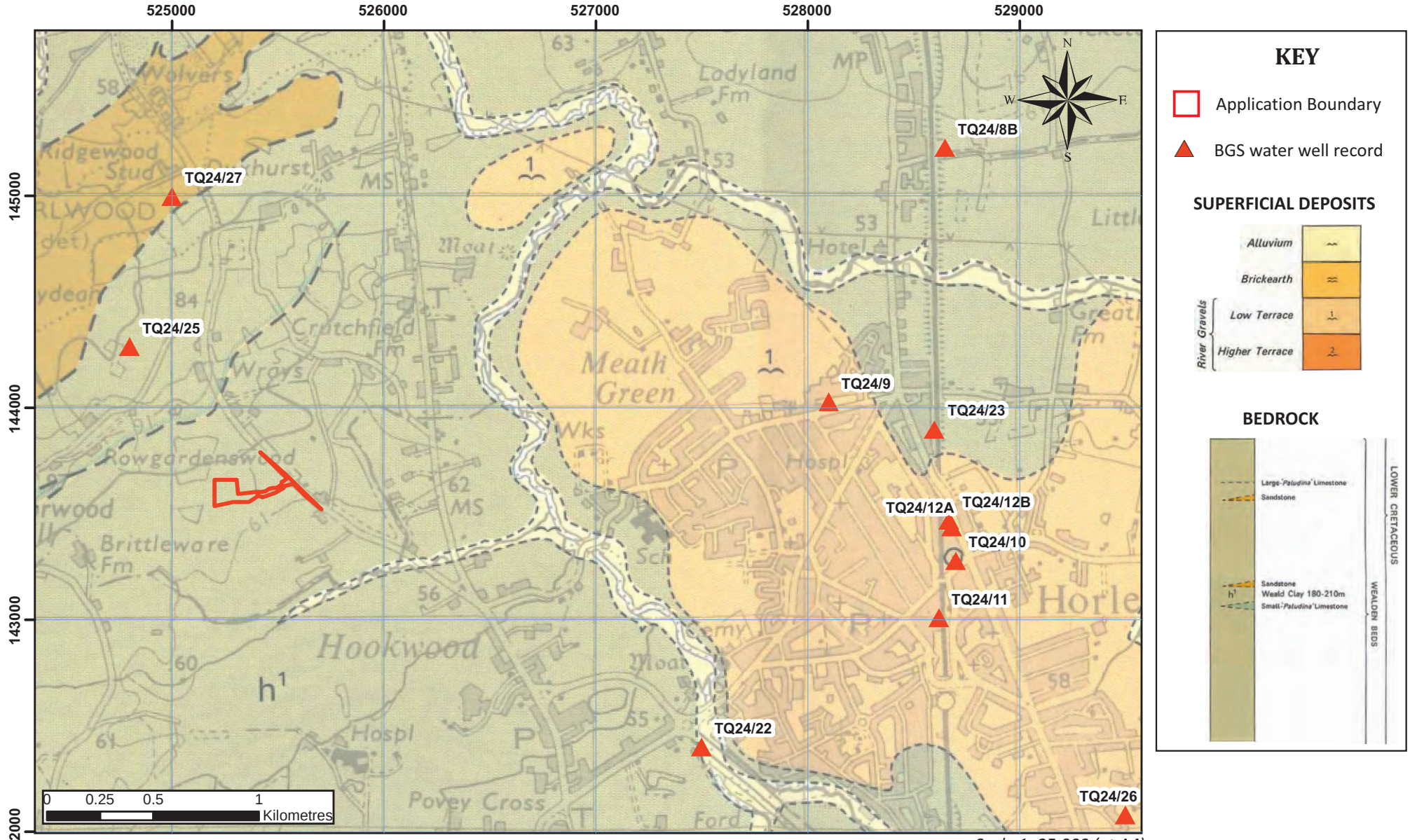
envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 5
Date: 02/02/2021

Horse Hill Developments Ltd

Figure 5

Environmental Setting



KEY

- Application Boundary
- BGS water well record

SUPERFICIAL DEPOSITS

- Alluvium
- Brickearth
- River Gravels
  - Low Terrace
  - Higher Terrace

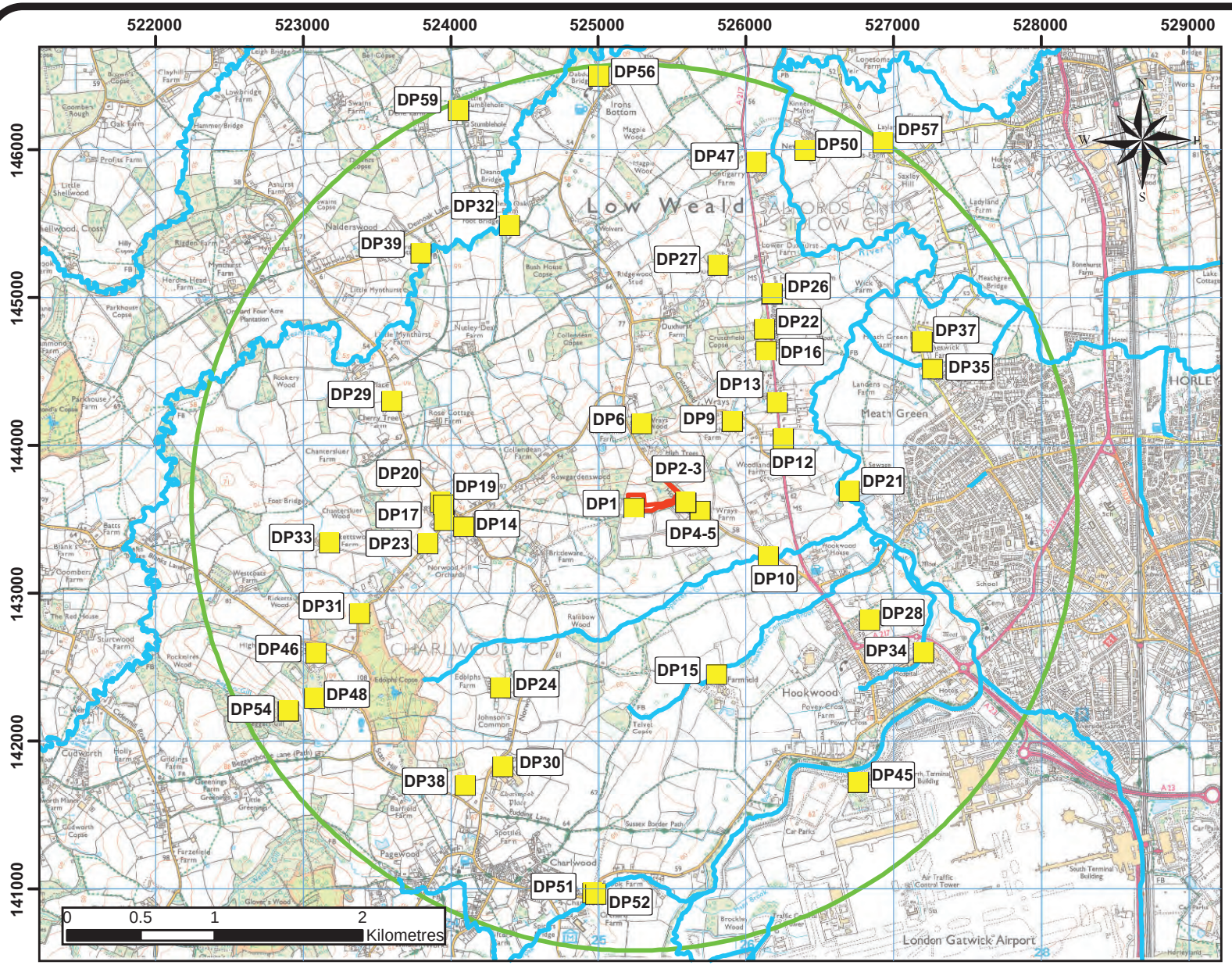
BEDROCK

- Large-'Paludina' Limestone
- Sandstone
- Sandstone
- Weald Clay 180-210m
- Small-'Paludina' Limestone
- LOWER CRETACEOUS
- WEALDEN BEDS

Scale 1: 25,000 (at A4)

envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 6 Date: 02/02/2021	**Horse Hill Developments Ltd**
Figure 6	BGS Water Well Records



KEY

- Application Boundary
- Environment Agency Discharge Permit

Scale 1:40,000 (at A4)

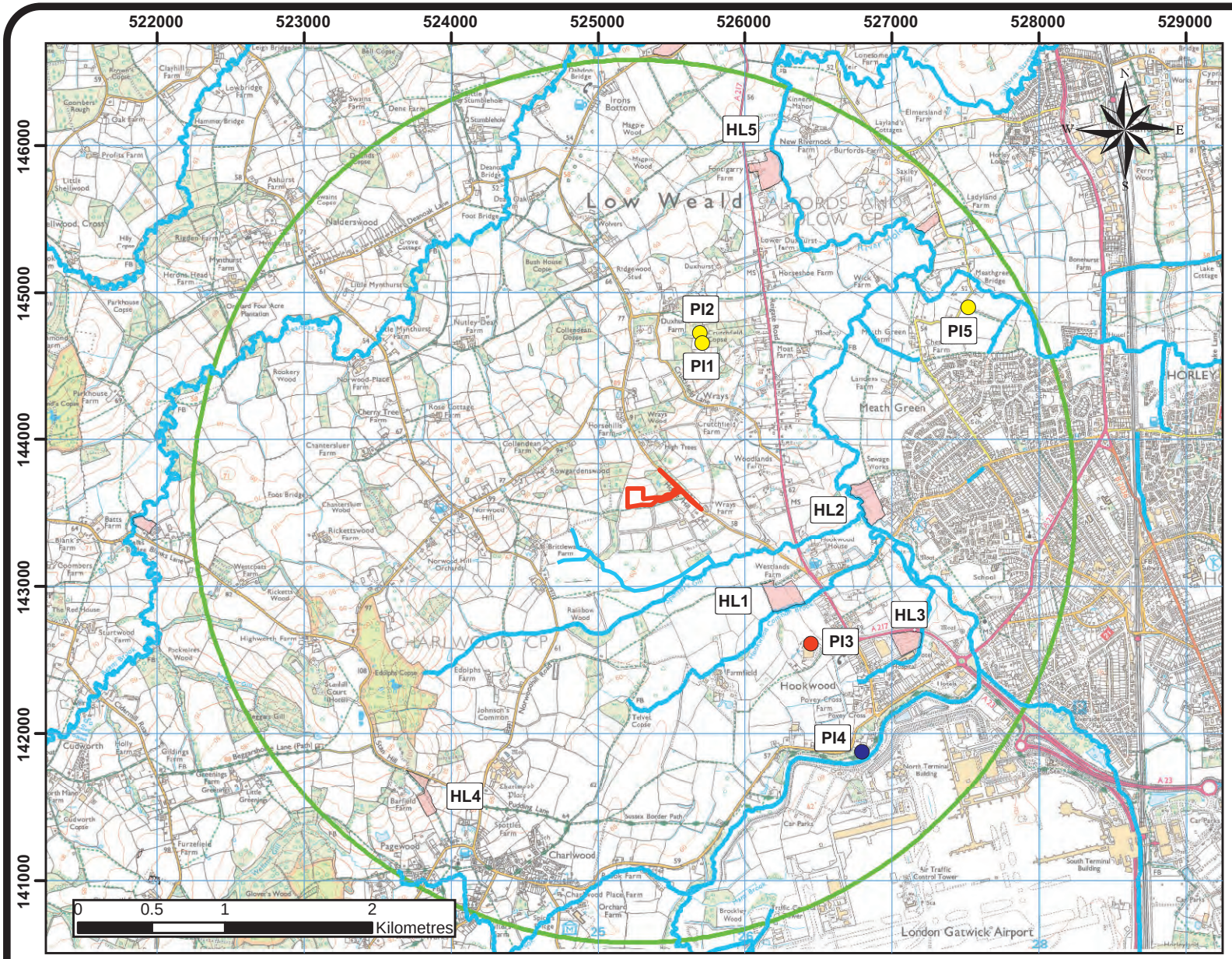
envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 7
Date: 02/02/2021

Horse Hill Developments Ltd

Figure 7

Discharge Permit Locations



KEY

- Application Boundary
- Main river / stream
- 3km radius
- Historic landfill site

Recorded pollution incident*:

- category 1 (no impact)
- category 2 (significant)
- category 3 (minor)
- category 4 (major)

**Event categorised on impact to the water environment, thus not incorporating impacts to land or air*

Scale 1:40,000 (at A4)

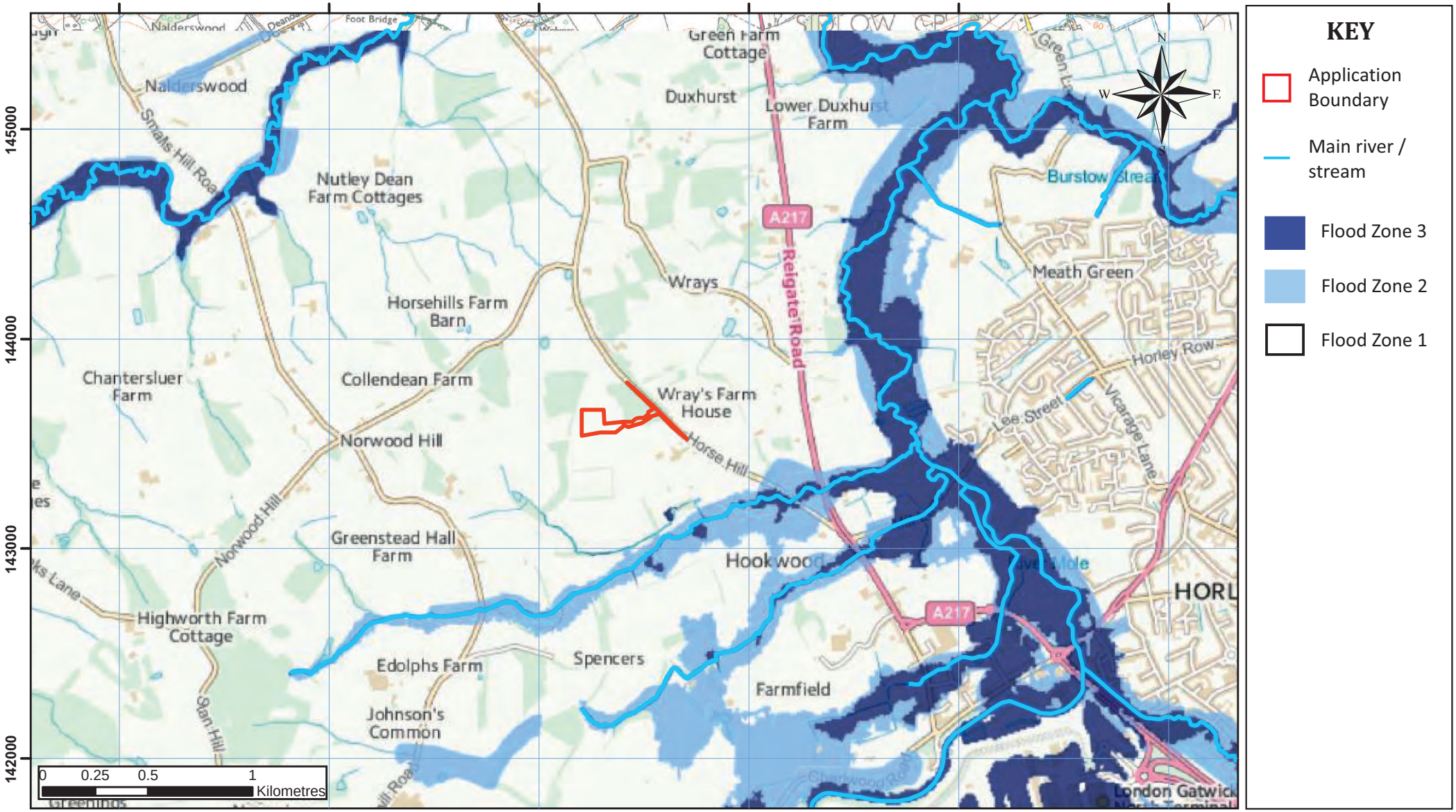
envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 8
Date: 02/02/2021

Horse Hill Development Ltd

Figure 8

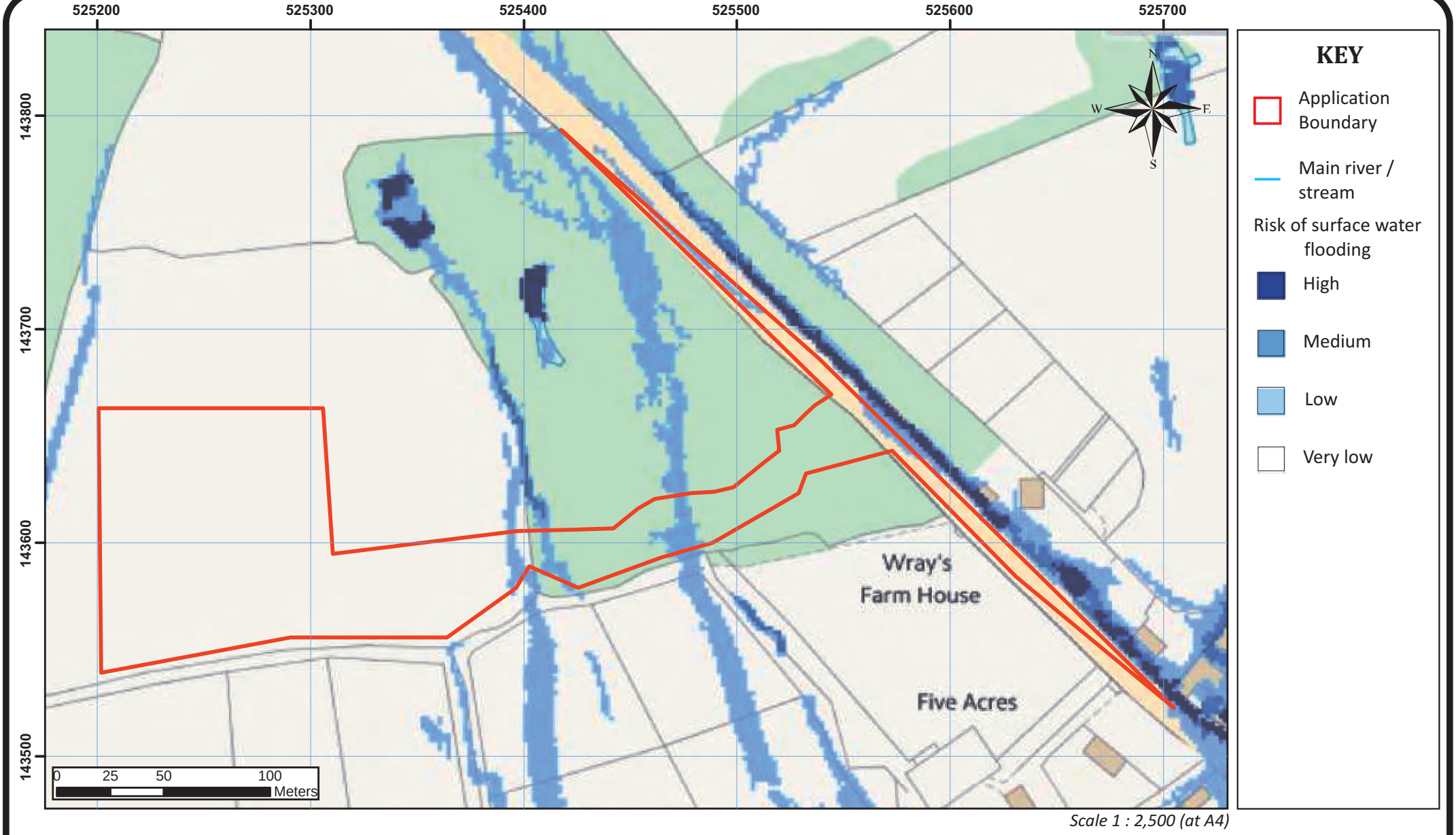
Landfill Sites and Pollution Events



Scale 1 : 25,000 (at A4)

envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 9 Date: 02/02/2021	**Horse Hill Development Ltd**
Figure 9	Environment Agency Flood Map for Planning (Rivers and the Sea)

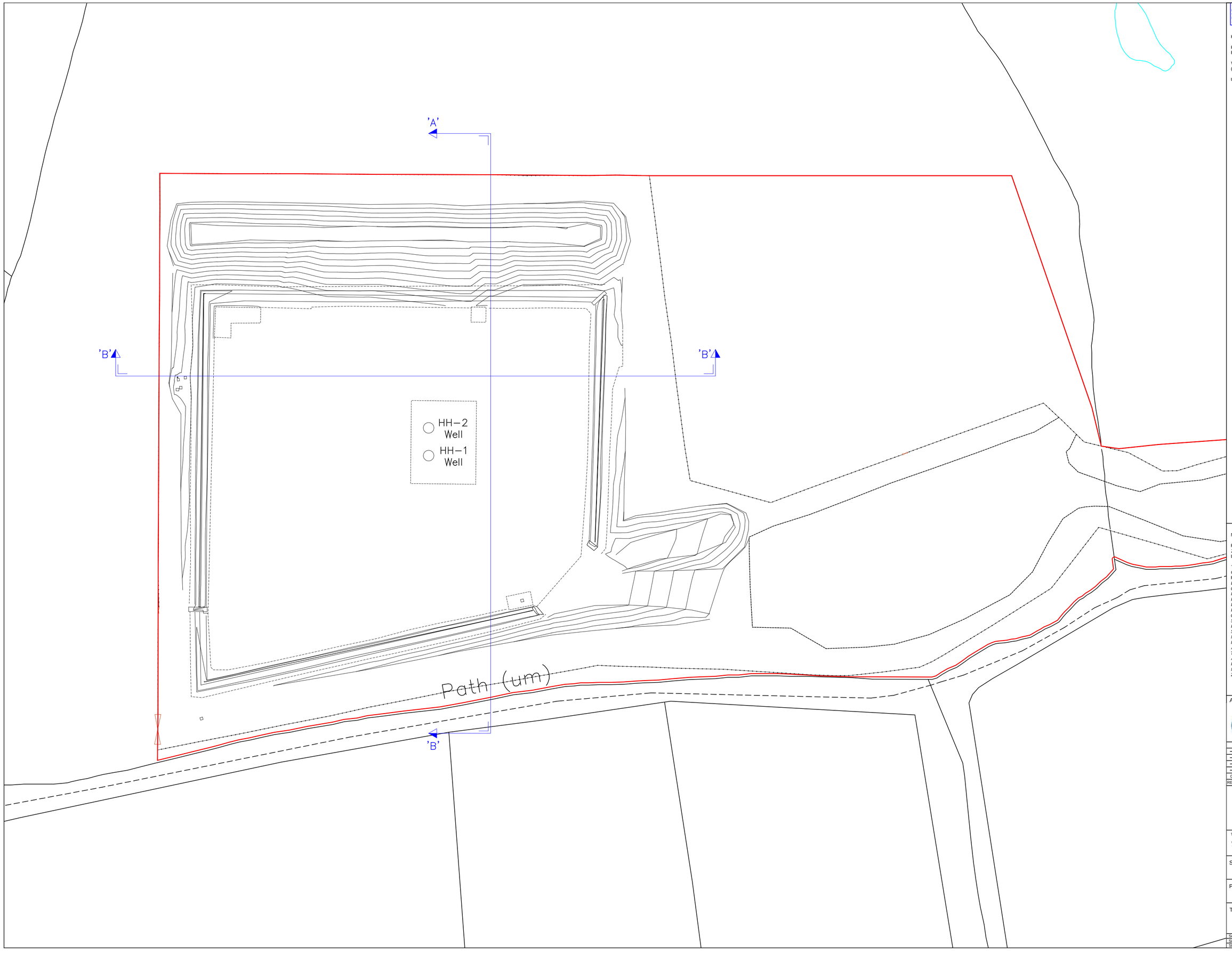


Scale 1 : 2,500 (at A4)

envireau WATER

Ref: P20-040\HHDL Horse Hill Permit\FIG 10 Date: 02/02/2021	**Horse Hill Development Ltd**
Figure 10	Environment Agency Risk of Surface Water Flooding

APPENDIX A
EXISTING SITE LAYOUT



KEY:

PLANNING APPLICATION BOUNDARY

WATER FEATURES (PONDS, DRAINS)

UNMADE PUBLIC FOOTPATH — Path (um)

NOTES:

FOR SECTIONS, REFER TO DRAWING NO.: ZG-HHD-HH-PROD-PA-07 (EXISTING SECTIONS LOOKING NORTH & LOOKING WEST).

THIS PLAN WAS APPROVED BY SURREY COUNTY COUNCIL WITHIN PLANNING PERMISSION RE16/02556/CON: *THE RETENTION OF THE EXISTING EXPLORATORY WELL SITE AND VEHICULAR ACCESS ONTO HORSE HILL; THE APPRAISAL AND FURTHER FLOW TESTING OF THE EXISTING BOREHOLE (HORSE HILL-1) FOR HYDROCARBONS, INCLUDING THE DRILLING OF A (DEVIATED) SIDE TRACK WELL AND FLOW TESTING FOR HYDROCARBONS; INSTALLATION OF A SECOND WELL CELLAR AND DRILLING A SECOND (DEVIATED) BOREHOLE (HORSE HILL-2) AND FLOW TESTING FOR HYDROCARBONS; ERECTION OF SECURITY FENCING ON AN EXTENDED SITE AREA; MODIFICATIONS TO THE INTERNAL ACCESS TRACK; INSTALLATION OF PLANT, CABINS AND EQUIPMENT; ALL ON SOME 2.08HA, FOR A TEMPORARY PERIOD OF THREE YEARS, WITH RESTORATION TO AGRICULTURE AND WOODLAND. THE APPROVED PLAN IS REFERENCED "PROPOSED SITE RETENTION MODE DRAWING NO. P16 DATED: 13TH OCTOBER 2016".*

APPLICANT:

HORSE HILL DEVELOPMENTS LTD

REVISION HISTORY

REV	DATE	BY	DETAILS	APR
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	NOV18	JF	ORIGINAL FOR ISSUE	JF

ZETLAND GROUP
FROM CONCEPTION TO COMPLETION

ZETLAND GROUP LIMITED
23A MILTON STREET, SALTBURN BY THE SEA, TS12 1DZ
T: +44(0)1287 625650 E: info@zetlandgroup.com W: www.zetlandgroup.com
Registered in England No. 9586345. Registered office: 23A Milton Street, Saltburn by the Sea, TS12 1DZ

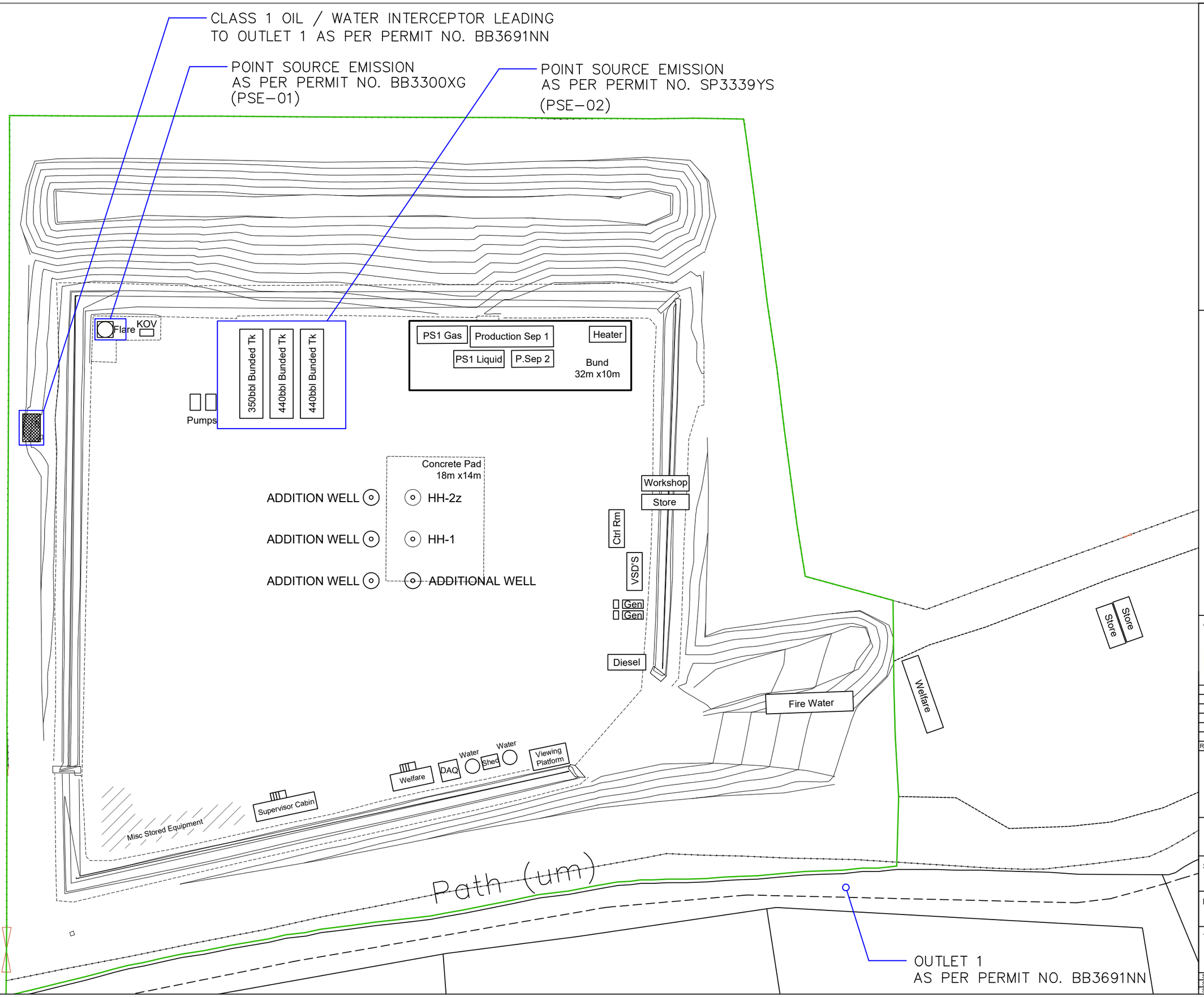
SITE: HORSE HILL WELL SITE, HORSE HILL, HOOKWOOD, HORLEY, SURREY, RH6 0RB

PROJECT: APPLICATION FOR PLANNING PERMISSION (HYDROCARBON PRODUCTION)

TITLE: EXISTING LAYOUT PLAN (1 of 3) EXISTING WELL SITE

Scale:	1:500	DWG. No:
Size:	A2	ZG-HHD-HH-PROD-PA-04
Sheet:	1 of 1	

APPENDIX B
PROPOSED SITE LAYOUT



KEY:

SITE BOUNDARY

PERMITTED ACTIVITES

UNMADE PUBLIC FOOTPATH — Path (um)

NOTES:

APPLICANT:

HORSE HILL DEVELOPMENTS LTD

REVISION HISTORY				
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	JAN21	JF	ORIGINAL FOR ISSUE	JF
REV	DATE	BY	DETAILS	APR

ZETLAND GROUP
FROM CONCEPTION TO COMPLETION
ZETLAND GROUP LIMITED
THE INNOVATION CENTRE, VIENNA COURT, KIRKLEATHAM BUSINESS PARK, REDCAR, TS10 5SH
T: +44(0)1642 777726 E: info@zetlandgroup.com W: www.zetlandgroup.com
Registered in England No. 03844405. Registered office: The Innovation Centre, Vienna Court, Kirkleatham Business Park, Redcar, TS10 5SH

SITE: HORSE HILL WELL SITE, HORSE HILL, HOOKWOOD, HORLEY, SURREY, RH6 0RB

PROJECT: APPLICATION FOR ENVIRONMENTAL PERMIT (HYDROCARBON PRODUCTION)

TITLE: INDICATIVE LAYOUT PLAN - HYDROCARBON PRODUCTION

Scale:	1:500	DWG. No:
Size:	A3	ZG-HHD-HH-PROD-EPR-SP-03
Sheet:	1 of 1	

APPENDIX C
PRODUCED WATER REINJECTION

PRODUCED WATER REINJECTION

HORSE HILL WELL SITE, SURREY

For

Horse Hill Developments Ltd
Suite 3B Princes House
38 Jermyn Street
London
SW1Y 6DN

By

Envireau Water
Aske Stables
Aske
Richmond
North Yorkshire
DL10 5HG

Tel: 01748 889 268
E mail: info@envireauwater.co.uk
Web: www.envireauwater.co.uk

Ref: P20-040 HHDL Horse Hill Permit\ RPT PW Reinjection
February 2021

TABLE OF CONTENTS

APPENDICES

Appendix A Injection Well Schematics for HH-2z

Revision	Details	Completed by	Date	Checked by	Date
REV01	Draft For Client Comment	PH	09/06/19	JED	10/06/19
REV02	Client Issue	PH	19/07/19	PJ	25/07/19
REV03	Update following Sch.5 notice	SC	25/02/21	PH	26/02/21

PRODUCED WATER REINJECTION

HORSE HILL WELL SITE, SURREY

1 INTRODUCTION

Horse Hill Developments Limited ("HHDL") is in the process of developing their Horse Hill well site ("the Site") for oil production. The intention is to produce oil from the Portland Group and Kimmeridge Clay Formation beneath the Site and reinject produced water back to the Portland Group, together with surface water runoff from process areas, for production support.

This report was originally issued in 2018 and has been updated in February 2021, taking account of the Environment Agency's comments provided as part of EPR Schedule 5 Notice [Ref. 1].

This report presents a detailed assessment of the proposed reinjection activity to support the environmental permit process and should be read in conjunction with the HRA for the Site [Ref. 2].

This document takes account of the findings of the HRA [Ref.2] and considers:

- A concept for the reinjection of produced water, in the context of the established regulatory framework;
- Details of the geological structure and the geomechanical properties of the formation into which reinjection will take place;
- Details of the proposed HH-2z injector well;
- Details of how the reinjection activity will be carried out and monitored; and
- An assessment of the risk that the reinjection activity poses to groundwater resources and the subsequent requirements for groundwater monitoring.

This report takes account of the mitigation and management approaches discussed in the Environment Agency Science Report SC150027 'Reinjection of fluids to deep geological formations' [Ref. 3], to minimise or remove the conditions that could give rise to geomechanical impacts, and the risks of impacts to groundwater receptors.

Since the Proposed Development does not involve hydraulic fracturing ('fracking'), this document does not present a fault reactivation study.

2 PRODUCED WATER REINJECTION

2.1 Concept

HHDL propose to reinject produced water to the Portland Group, which will also be targeted by oil production wells at the Site. The produced water may be reinjected together with treated surface water collected from bunded process areas at the Site for production support.

2.2 Regulatory Framework

Since it is proposed to reinject produced water to the same geological formation that will be targeted by the oil production wells at the Site, this can be permitted under Article 11(3)(j) of the Water Framework Directive (WFD) [Ref. 4, 5], which states that Member States may authorise:

> *"injection of water containing substances resulting from the operations for exploration and extraction of hydrocarbons or mining activities, and injection of water for technical reasons, into geological formations from which hydrocarbons or other substances have been extracted…"*

Injection of water collected from bunded process areas at the Site is also permissible under Article 11(3)(j) of the WFD, since the water will be injected for production support. The reinjection concept is an established approach in the Weald Basin and given the other fluid management approaches available [Ref. 3], is considered best environmental option (BEO) at the Site.

Water collected from bunded process areas will be visually inspected for contamination and treated to prevent biological growth (e.g. with sodium hypochlorite). If contamination is observed or known spills/releases of fluids have occurred in the bunded process areas, the affected water will not be used for reinjection and will be removed from Site by a licensed waste contractor.

2.3 Well Design and Integrity

2.3.1 Standards

The Oil and Gas Authority (OGA) regulates the licensing of exploration and development of the UK's onshore oil and gas industries. However, from a well integrity and site safety perspective, it is the Health & Safety Executive (HSE) that is the relevant regulator for overseeing that safe working practices are adopted by onshore operators as required under the Health and Safety at Work etc. Act 1974, and regulations made under the Act. These specifically are:

- The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 (DCR) [Ref. 6], which apply to all wells drilled with a view to the extraction of petroleum, regardless of whether they are onshore or offshore. The regulations are primarily concerned with well integrity.
- The Borehole Site and Operations Regulations 1995 (BSOR) [Ref. 7], which apply to all gas operations and are primarily concerned with the health and safety management of the wellsite.

Well records must be reviewed by an independent well examiner to assess the well design, construction and maintenance and ensure that good industry practice is followed throughout their life-cycle and decommissioning.

Reinjection wells will be designed and constructed in line with HHDL's Well Planning Design & Operating Standards [Ref. 8] and construction details will be provided to the Environment Agency before reinjection commences.

2.3.2 Well Design

The existing HH-2z well will become a dedicated reinjection well in the Portland Group. If, as oil production progresses, further production support is required then HH-3 may also be converted to a reinjection well. The exact requirements for reinjection will be determined from the results of drilling and testing (including injectivity tests), together with operational data gathered during the production process.

The design for HH-2z as a produced water reinjection well is illustrated in Appendix A.

The same principles would be applied to HH-3 and the final design would be agreed with the Environment Agency as part of a pre-operational condition within the environmental permit.

The key components of the well designs with respect to reinjection are:

- All wells will be cased into the Purbeck Group with a cemented steel casing. This ensures that any strata above the Purbeck Group remain isolated from the production/injection formations during construction and operation.
- The wells will be lined with steel tubing below the Purbeck Group. This will be perforated in the Portland Group to form an injection line and facilitate produced water reinjection.
- The steel tubing will be designed to withstand corrosion associated with injection activities.
- A safety valve will be installed on the injection line.

In accordance with the BSOR regulations, the proposed construction contains a minimum of two barriers within the system to ensure well integrity and prevent fluids migrating between different geological units, as shown in the schematic in Appendix B and summarised as follows:

Primary Well Barrier
Within the overall well system, the primary barriers are the wellhead, tested casings, linings and tubing strings consisting of (premium) threaded pipe, connections and cemented casing strings within the well. Each are pressure tested appropriately following installation and any cementing in line with the well casing design to ensure adequate sealing and zonal isolation. In addition, and as part of the primary barrier envelope, each of the casings is routinely monitored at surface as part of ongoing well integrity maintenance (see Section 2.6.2).

Secondary Well Barrier
The secondary form of protection is provided by a mechanical barrier; a surface controlled "sub-surface safety valve" installed on the injection line that is hydraulically held in the open position (a fail safe close device). The valve will shut in the event of a problem and raise an alarm to notify the operator. This valve is tested every twelve months for integrity, by testing the valve in the closed position. It must meet the API-14(B) standards as a minimum [Ref. 9].

2.4 Injection Formation

HHDL has carried out an appraisal of the geology and geomechanics at the Site [Ref. 10] and a review of local seismic data and faulting in order to develop their reinjection proposals. The appraisal is based on data previously collected during exploration at Horse Hill and also takes account of data acquired at other locations in the Weald Basin including Brockham and Collendean Farm. The geological appraisal and seismic review can be summarised as follows:

- Seismic data collected in the 1960s to 1980s correlates with the geology encountered in the Collendean Farm-1 well and existing Horse Hill wells. The location and thickness of the Portland Group has been accurately established beneath the Site.
- A review of local seismic data shows that the area is not heavily faulted and few faults penetrate to the surface. HHDL seismic interpretations show that faults affecting the target production/reinjection formations do not penetrate upwards beyond the Wadhurst Clay Formation.
- The wells do not cross any faults which could act as a pathway between the production/reinjection formations and groundwater in the Ashdown Formation and Tunbridge Wells Sand Formation, nor the shallow groundwater system in the weathered top of the Weald Clay Formation.
- The strata above the production/reinjection formations include the Purbeck Group which is > 200m thick, is predominantly argillaceous and contains a thick bed of impermeable anhydrite at its base. This unit will be sealing where penetrated by faults.
- The Horse Hill wells target Jurassic strata which are separated from the strata targeted by the Collendean Farm-1 well by a series of east – west trending faults.
- Regional stress analysis indicates that the major faults have been closed for a significant period. The absence of surface oil seeps and sub-surface data on pressures and the composition of oils from different reservoirs demonstrate that no vertical mixing has taken place for several million years. Consequently, it is considered that the geological faults are sealing.
- Data from well tests carried out in the Portland Group in 2015 and 2016 show that the mean porosity of the formation is approximately 13% and the permeability is in the region of 2mD (~$2x10^{-15}$ m^2). This compares favourably to information obtained from other wells targeting the same formation in the Weald Basin.
- The minimum formation pressure recorded in the Portland Group at the HH-1 well is 844 psia (approximately 5.9 MPa or 58 bar) but will reduce with ongoing production.
- Analysis of the stress regime shows that the maximum principal stress orientation is NW-SE. The minimum principal stress or "formation fracture pressure" in the Portland Group, as measured empirically using data from relevant wells across the Weald Basin, is approximately 1,600 psia (approximately 11MPa or 110 bar).

2.5 Injection Rates and Pressures

In order to maintain oil production levels, produced water and treated surface water collected from bunded process areas may be injected into the Portland Group, at injection rates necessary to achieve oil recovery. The actual achievable production rates will determine the required injection rate; however, it is intended that the injection rate will balance the production/recovery rate.

Based on the permeability of the formations, the injectivity of injection wells is expected to be good and high pressure injection will not be required. HHDL will carry out injectivity tests on the Portland Group to establish the

fracture gradients prior to reinjection. The downhole injection pressure will be limited to 90% of the formation fracture pressure. Consequently, injection will always be lower than the fracture pressure so the rock fracture pressure gradient cannot be exceeded.

2.6 Operational Procedures

Copies of HHDL's operating procedures [Ref. 8, 11, 12] have been reviewed by Envireau Water and will be provided to the Environment Agency separately as part of the environmental permitting process.

2.6.1 Injection

The reinjection of produced water and treated surface water from process bunds will be controlled by HHDL's operating procedures, as follows:

- Continuous pressure monitoring is carried out on the injection line to ensure that the maximum injection pressures are not exceeded. Alarms and failsafe devices are used to ensure that injection stops if it reaches the maximum pressure (90% of the formation fracture pressure).
- Tubing and annulus pressures are monitored under a routine well integrity monitoring program.
- During the life of the injection well, injection rates may decrease due to mechanical clogging (through the injection of fines) or chemical clogging (build-up of precipitates such as carbonate scale). In this case, the injectivity of the well will be restored by reperforating or the use of chemical treatments, e.g. acid washing as described in the HRA [Ref.2].

2.6.2 Well Integrity

The DCR and BSOR regulations (Ref. 6, 7] require operators to ensure well integrity through appropriate monitoring and maintenance. HHDL's procedure for monitoring and maintenance at the Site will include the following:

- Continuous pressure monitoring is used to determine the mechanical integrity of production tubing, casings and annuli and other well equipment. Maximum allowable surface pressures will be assigned to all equipment to establish the safe working range of pressures for normal operation.
- Wellhead seal tests are conducted to test the mechanical integrity of the sealing elements (including valve gates and seats) and determine if they are capable of sealing against well pressure.
- The results of pressure tests are reviewed by an independent well examiner annually and can be made available to the Environment Agency.
- Production and reinjection rates are regularly monitored and the data analysed to identify any unusual trends. This will enable ongoing monitoring of the net fluid balance within the reservoir to ensure adequate reservoir management. All production and reinjection figures will be recorded and can be made available to the Environment Agency.
- Reinjection operations are reviewed at least every 12 months to ensure these conform within established parameters and are in accordance with the well design, well plan, and any permit requirements.
- The regular inspection of equipment and monitoring of pressures and production/reinjection rates ensure that any abnormal conditions can be investigated and where necessary, appropriate remedial action taken. The true status of each well is entered into the DECC UK Oil Portal [Ref. 13].

3 HYDROGEOLOGICAL RISK

3.1 Impact Assessment

The HRA [Ref. 2] concluded that there are very low risks associated with produced water reinjection on the basis that injection pressures are controlled to ensure they do not exceed the fracture gradient of the reinjection formation, and robust operating procedures are in place to manage the reinjection activity. This is consistent with the Environment Agency Science Report SC150027 'Reinjection of fluids to deep geological formations' [Ref. 3], which states that water reinjection activities in the UK are generally low risk when adequate mitigation is in place to prevent geomechanical impacts arising.

In the case of the Proposed Development at the Site, the potential conditions that could give rise to geomechancial impact include:

- Injection pressures exceed the formation fracture pressure, resulting in fracturing of the formation or fault reactivation;
- Poor design and construction of the reinjection well leading to well integrity issues and creation of vertical pathways between the reinjection formation and groundwater resources in overlying strata;
- Poor decommissioning of nearby historic hydrocarbon wells, leading to vertical pathways between the reinjection formation and groundwater resources in overlying strata;
- Induced seismicity leading to creation of vertical pathways and damage of above ground structures not built to withstand seismic activity; and
- Poor regulatory oversight and unacceptable design and construction quality, and operating procedures.

The information presented in this report takes account of these potential conditions, as described in the following subsections.

3.1.1 Fracturing

The geological appraisal [Ref. 10] confirms that the proposed injection pressures will not exceed the estimated fracture gradient of the Portland Group. Further injectivity tests will be carried out to confirm the fracture gradient in the target formations before injection begins. Therefore, the reinjection activity cannot cause fracturing.

3.1.2 Well Integrity

All the wells at the Site will conform to the current standards for design, construction and operation. Robust operating procedures will be in place to control the reinjection activity and monitor well integrity. This mitigates against the potential for vertical pathways between the injection formation and any overlying, groundwater bearing formations to be created through inadequate construction.

3.1.3 Historic Wells

Information available for the decommissioning of the nearby Collendean Farm-1 well presented in the HRA [Ref. 2] suggests that the well was decommissioned in 1964 in accordance with the best practice available at that time; and was plugged at several locations to isolate different geological units. The geological appraisal [Ref. 10] shows the

historic well is separated from the produced water reinjection well by a series of east – west trending faults, which are unlikely to be transmissive. It is therefore highly unlikely that the Collendean Farm-1 well could act as a pathway for vertical migration of produced water.

3.1.4 Induced Seismicity

The geological appraisal [Ref. 10] demonstrates that there is no potential for fracturing of the injection formation or fault reactivation. Ongoing monitoring of injection pressures and the net fluid balance within the reservoir will ensure adequate reservoir management to mitigate against induced seismicity and potential damage to above ground structures.

3.1.5 Regulatory Oversight

The reinjection activity will be continuously monitored by HHDL and regulated by the HSE and the Environment Agency. The high level of regulatory scrutiny further mitigates against unacceptable design and construction quality, and operating procedures.

3.2 Risk Validation

A very high level of embedded mitigation will be incorporated into the design, construction and operation of any produced water reinjection wells at the Site. This means there is effectively no potential for conditions that would give rise to geomechanical impacts from the proposed reinjection activity.

The additional information presented in this report confirms the 'very unlikely' likelihood assigned to the risk of produced water impacting groundwater bearing formations above the Portland Groups in the HRA [Ref. 2]. The 'very low' residual risk associated with produced water reinjection at the Site is therefore valid.

The outcome is consistent with a history of produced water reinjection to support conventional, onshore oil production in the Weald Basin that has taken place without adverse effects.

3.3 Monitoring

HHDL propose to carry out monitoring to confirm there will be no geomechanical impacts associated with produced water reinjection at the Site. In accordance with Environment Agency Science Report SC150027 'Reinjection of fluids to deep geological formations' [Ref. 3] the proposed monitoring will include:

- Injectivity and falloff testing and subsequent periodic re-testing over the lifetime of the well to identify potential pressure build-up (loss of injectivity) or pressure reduction (insufficient injection);
- Provision of a clear and established response in the event of any situation that could cause an unwanted geomechanical impact;
- Ongoing monitoring of agreed injection pressures based on a comprehensive assessment by subsurface engineers during the development of the reinjection strategy;
- Ongoing monitoring of the net fluid balance within the Portland Group to ensure adequate reservoir management;
- Provision of compliant HSE notifications for any new well or amendment to a well; and

- Completion of regular monitoring and mechanical maintenance to identify any potential integrity issues within a well.

The above monitoring will confirm the effectiveness of the proposed mitigation measures and means that uncontrolled injection leading to geomechanical impacts, including indirect discharge to groundwater bearing formations above the Portland Group, cannot occur. Consequently, with the above monitoring in place, the construction of deep monitoring boreholes to monitor groundwater quality in the groundwater bearing formations above the Portland Group is not warranted in this case.

Based on the risk profile of the Proposed Development, groundwater monitoring will therefore focus on the shallow groundwater system, as described in the Groundwater Monitoring Plan for the Site [Ref. 14].

4 CONCLUSIONS

HHDL propose to reinject produced water to the Portland Group, which will also be targeted by oil production wells at the Site. The produced water may be reinjected together with treated surface water collected from bunded process areas at the Site for production support. The technique is consistent with the requirements of the Water Framework Directive and considered the best environmental option (BEO).

HHDL will use a combination of existing and new wells at the Site for produced water reinjection. Existing well (HH2-z) will become a dedicated reinjection well in the Portland Group. As oil production progresses, further production support may be required and HH-3 may be converted to a reinjection well in the Portland Group. The exact requirements for reinjection will be determined from the results of drilling and testing of the new wells and data gathered during the evolving production process, and the details conditioned through pre-operational conditions within the environmental permit.

HHDL has considered the geology and geomechanics at the Site in order to develop their proposals for produced water reinjection. The appraisal has identified the formation fracture pressure (the stress at which the injection formations would fracture) and injection rates have been specified that are well below this value. The geological appraisal and seismic data review shows there are few geological faults that extend to surface and provides further evidence that geological faults are likely to be sealing and unlikely to be transmissive. Therefore, the injection activity will not cause fracturing or fault reactivation.

The design, construction and operation of wells is controlled through existing regulations. Together with robust operating procedures and a regulatory oversight, there is effectively no potential for conditions that would give rise to geomechanical impacts from the proposed reinjection activity.

The additional information presented in this report confirms the 'very unlikely' likelihood assigned to the risk of produced water impacting groundwater bearing formations above the Portland Group in the HRA [Ref. 2]. The 'very low' residual risk associated with produced water reinjection at the Site is therefore valid.

The outcome is consistent with a history of produced water reinjection to support conventional, onshore oil production in the Weald Basin that has taken place without adverse effects.

Monitoring of the reinjection activity, particularly injection pressures and the net fluid balance within the Portland Group to ensure adequate reservoir management, will be carried out to confirm there will be no geomechanical impacts, including indirect discharge to groundwater bearing formations. Based on the risk profile of the reinjection activity, it is therefore justified for groundwater monitoring to focus on the shallow groundwater system.

Envireau Water
26/02/21

REFERENCES

Ref. 1 Schedule 5 Notice – Consolodated (sic) – Formal Issue. Environment Agency, 2020.

Ref. 2 Hydrogeological and Flood Risk Assessment. Horse Hill Well Site, Surrey. Envireau Water Report, November 2018. Updated February 2021.

Ref. 3 Environment Agency Science Report SC150027. Reinjection of fluids to deep geological formations, September 2017.

Ref. 4 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal L 327, 22/12/2000 P. 0001 – 0073.

Ref. 5 Environment Agency Onshore oil and gas sector guidance: 11. Produced water and flowback fluid: re-injection and reuse, February 2019.

Ref. 6 The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996.

Ref. 7 The Borehole Site and Operations Regulations 1995.

Ref. 8 Well Planning Design and Operating Standards Rev 0. Horse Hill Developments Ltd, June 2019.

Ref. 9 API Recommended Practice 14B, Recommended Practice for Design, Installation, Operation, Test, Redress of Subsurface Safety Valve Systems, Sixth Edition, September 2015.

Ref. 10 Horse Hill Oil Field Geological Description. Horse Hill Development Ltd, undated.

Ref. 11 Water Injection Procedure HH-PR-q0051. Horse Hill Developments Ltd, April 2019.

Ref. 12 Routine maintenance of water injection pump. Horse Hill Developments Ltd, April 2019.

Ref. 13 DECC UK Oil Portal. https://itportal.decc.gov.uk/eng/fox/live/PORTAL_LOGIN/login.

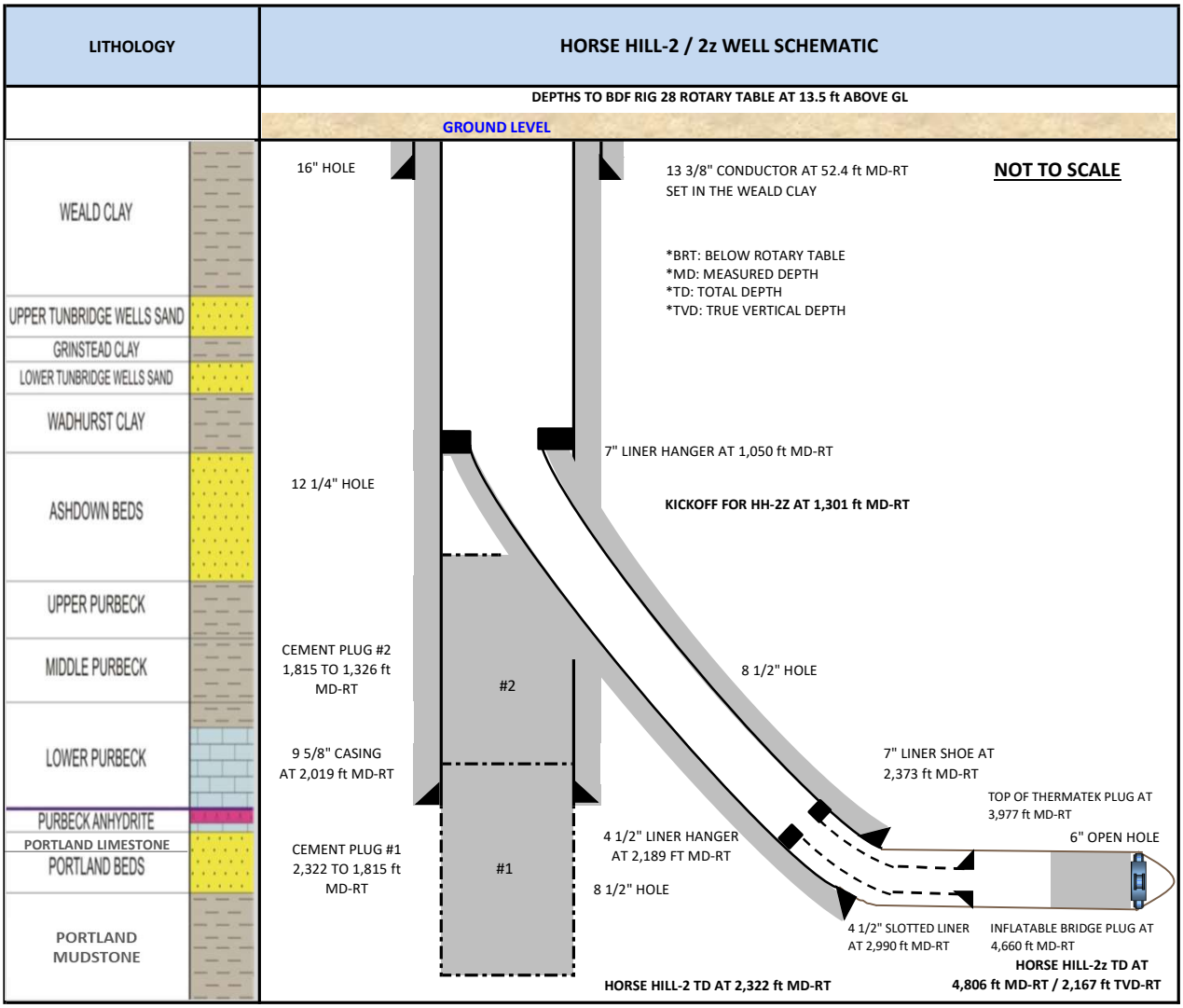
Ref. 14 Groundwater Monitoring Plan. Horse Hill Well Site, Surrey. Envireau Water Report, November 2018. Updated February 2021.

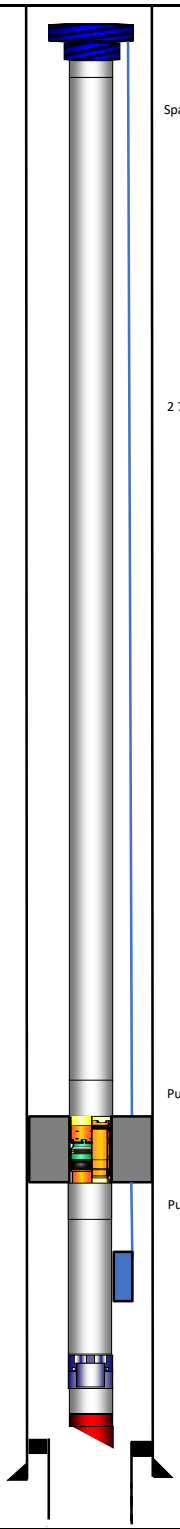
APPENDIX A
INJECTION WELL SCHEMATICS FOR HH-2Z

HORSE HILL DEVELOPMENTS LTD

HORSE HILL DEVELOPMENTS LIMITED

LITHOLOGY	HORSE HILL-2 / 2z WELL SCHEMATIC





Note: The Horse Hill 2z Water Injection Completion Schematic Is Not Drawn To Scale

Spaceout Pups

2 7/8" tubing

Pup

Pup

Portland Sandstone

Note: all depths stated are reference to BDF Rig 28 rotary table

Equipment	ID"	OD"	Depth ft mdbrt
Hanger	2.992"	11" nom	
3 1/2" EUE pin x pin pup joint	2.992"	3.750"	
Crossover 3 1/2" EUE box x 2 7/8" EUE pin	2.441"	4.50"	
Spaceout 2 7/8" EUE Pups	2.441"	3.668"	
2 7/8" 6.5 lb/ft L80 EUE	2.441"	3.668"	
2-7/8" x 7" Packer (Proposed)			~2,000
Downhole PT Gauge (Proposed)			~ 2,050
Tubing Nipple			~2,070
2-7/8" Tubing WEG (Proposed)	1.81"	3.80"	~ 2,100
4-1/2" Liner Top			2,189
7" Liner Shoe			2,373
4-1/2" Slotted Liner Shoe	3.958"	4.937"	2,990
Open hole plugged back TD		6"	3,977

APPENDIX D
BGS RECORDS

BGS Water Well Records

BGS Reference	Location	Easting	Northing	Distance from Site (km)	Approximate Elevation (mAOD)	Depth (m)	Year	Aquifer	Borehole & Testing Details
TQ24/27	Nags Head Pumping Station, Earlwood	525000	145000	1.4	71	14.2	1958	Weald Clay Formation	Water came from the top 4m with a rest water level at 1m bgl (70m AOD); no further details.
TQ24/22	17-23 Balcombe Road, Gatwick	527500	142400	2.5	56	Unknown	1973	Weald Clay Formation*	Artesian conditions noted with overflow at surface of 5m^3/day; no further details recorded.
TQ24/9	Elm Cottage, Horley	528100	144030	2.8	55	20.4	Unknown	Weald Clay Formation	Well was dry, now sealed and unused.
TQ24/23	17-25 Balcombe Road, Horley	528600	143900	3.3	56	45.7	1973	Weald Clay Formation*	Drilled as a potential disposal borehole for surface water; status recorded as "OBH"- observation borehole. Artesian flow recorded.
TQ24/11	Horley Station	528620	143010	3.4	57	79.3	1839	Weald Clay Formation	Borehole disused. Artesian conditions with a rest water level of 64m AOD noted during drilling.
TQ24/12B	Matthews Bros., Horley	528670	143470	3.4	59	76.2	1945	Weald Clay Formation	Yielded water at a rate of 131m^3/day during a 0.5 hour pumping test. The rest water level in the borehole was 52m AOD (5m bgl) and drawdown during testing was 5m.
TQ24/12A	Matthews Bros., Horley	528680	143440	3.4	59	64.9	1912	Weald Clay Formation	Artesian flow recorded from water bearing zones. The rest water level was noted to be at 6m bgl (51m AOD) in 1946.
TQ24/10	Smallfield Laundry, Horley. (Formerly Albert Brewery)	528700	143280	3.4	55	91.4	1895	Weald Clay Formation	Recorded as artesian during drilling and yielding 218m^3/day. In 1947: rest water level 52m AOD (3m bgl) and borehole recorded as being pumped at this rate 5 days per week for a drawdown of 6m.
TQ24/8B	Lanston Monotype Works, Horley	528650	145230	3.7	57	91.4	1930	Weald Clay Formation	A test of unknown duration yielded 284m^3/day with the borehole at a depth of 37m; a test of unknown duration at a depth of 91m yielded 175m^3/day with artesian flow recorded.
TQ24/26	31 The Close, Horley	529500	142080	4.5	58	36	2000	Weald Clay Formation	A small yield of 2.5m^3/hour was obtained with a drawdown of 4.1m.

APPENDIX E
RISK ASSESSMENT METHODOLOGY

Introduction

DEFRA's GL III [Ref. 1] contains generic guidelines for the assessment and management of environmental risks. GL III outlines a staged approach to risk assessment and the document is intended to guide regulatory staff in Government and its agencies, as well as those carrying out assessments, to reach a decision on managing environmental risk.

A hydrogeological risk assessment for the Proposed Development has been carried out with reference to the Source-Pathway-Receptor (S-P-R) approach described in GL III [Ref. 1] and Environment Agency guidance [Ref. 2]. Where S-P-R linkages have been identified, the sensitivity of the receptor, magnitude of impact and significance of effect has been considered in order to assess potential risks.

Ref.2 describes a tiered approach to risk assessment, starting at Tier 1 and progressing to Tier 3. Tier 1 is essentially a qualitative approach and Tier 3 is a highly quantitative approach. The choice of approach should be based on how complicated the system is, how high the risks are, and how easily and fully the risks can be mitigated. As such the selection process is iterative, and in complex systems there may be a mixture of approaches where simple, low risk sub-systems are assessed with a Tier 1 approach and more complex aspects with risks that cannot be fully mitigated may need a complex quantitative approach. The methodology described in this Appendix is for a Tier 1/2 assessment.

Receptor Sensitivity

The sensitivity of water resource receptors is based on their status and considered resource value, as described in Table 1.

Table 1 Receptor Sensitivity

Receptor Sensitivity	Description	Examples
Very High	Water resource with an importance and rarity at an international level with limited potential for substitution.	A water resource making up a vital component of an SAC or SPA under the EC Habitats Directive A water body achieving a status of 'High status or potential' under the WFD Principal aquifer providing potable water to a large population EC designated Salmonid fishery
High	Water resource with a high quality and rarity at a national or regional level and limited potential for substitution.	A water resource designated or directly linked to a SSSI. Principal aquifer providing potable water to a small population A river designated as being of Good status or with a target of Good status or potential under the WFD A water body used for national sporting events such as regattas or sailing events EC designated Cyprinid fishery
Medium	Water resource with a high quality and rarity at a local scale; or Water resource with a medium quality and rarity at a regional or national scale.	Secondary aquifer providing potable water to a small population An aquifer providing abstraction water for agricultural and industrial use
Low	Water resource with a low quality and rarity at a local scale.	A non 'main' river or stream or other water body without significant ecological habitat

Magnitude of Impact

The magnitude of a potential impact on a receptor depends on the nature and extent of the Proposed Development and is independent of the sensitivity of the water resource, as described in Table 2.

Table 2 Magnitude of Impact

Magnitude of Impact	Description	Examples
High	Results in a major change to attributes.	Loss of EU designated Salmonid fishery Change in WFD classification of a water body. Compromise employment source Loss of flood storage/increased flood risk Pollution of potable source of abstraction
Medium	Results in impact on integrity of attribute or loss of part of attribute.	Loss / gain in productivity of a fishery. Contribution / reduction of a significant proportion of the effluent in a receiving river, but insufficient to change its WFD classification Reduction / increase in the economic value of the feature
Low	Results in minor impact to attributes.	Measurable changes in attribute, but of limited size and/or proportion
Very Low	Results in an impact on attribute but of insignificant magnitude to affect use and/or integrity.	Physical impact to a water resource, but no significant reduction/ increase in quality, productivity or biodiversity No significant impact on the economic value of the feature No increase in flood risk

Significance of Effect

The significance of the potential effect is derived by combining the assessments of both the sensitivity of the water resource and the magnitude of the impact in a simple matrix, as presented in Table 3. Effects which are assessed to be major or moderate are considered to be potentially significant, whilst those that are minor or negligible are not.

Table 3 Potential Significance of Effect

Receptor Sensitivity	Magnitude of Impact			
	High	**Medium**	**Low**	**Very Low**
Very High	Major	Major	Moderate	Moderate
High	Major	Moderate	Moderate	Minor
Medium	Moderate	Moderate	Minor	Negligible
Low	Moderate	Minor	Negligible	Negligible

Qualitative Likelihood

The qualitative likelihood of occurrence of a potential impact on a receptor is defined as described in Table 4.

Table 4 Qualitative Likelihood of Occurrence

Qualitative Likelihood of Occurrence	Description	Examples
Highly Likely	High probability of occurrence	Spillage at a poorly maintained and operated facility Uncontrolled activity in or on an aquifer, close to surface water Uncontrolled known discharge
Likely	On balance could occur	Controlled but un-mitigated activity Complex process where failure of a part is likely to lead to release Large area where 100% sealing cannot reasonably be expected
Moderate	Equally likely/unlikely	Unmitigated, low risk Controllable activity Partially contained site
Unlikely	On balance wouldn't occur	Mitigated higher risk Simple, controllable activity Underlain by poorly permeable strata Existing contained site
Very Unlikely	Very low probability of occurrence	Essentially no risk Extreme set of circumstances required to generate low probability Fully mitigated low or medium risk

Qualitative Risk Analysis

The residual qualitative risk is derived by combining the likelihood of occurrence and the significance of effect of a potential impact on a receptor in a simple matrix, as presented in Table 5. Risks which are assessed to be very high, high or medium are considered to be significant, whilst those that are low, very low or none are not significant.

Table 5 Qualitative Risk Analysis

Qualitative Likelihood of Occurrence	Significance of Effect			
	Major	**Moderate**	**Minor**	**Negligible**
Highly Likely	Very High	High	Medium	Low
Likely	High	Medium	Low	Very Low
Moderate	Medium	Low	Very Low	None
Unlikely	Low	Very Low	None	None
Very Unlikely	Very Low	None	None	None

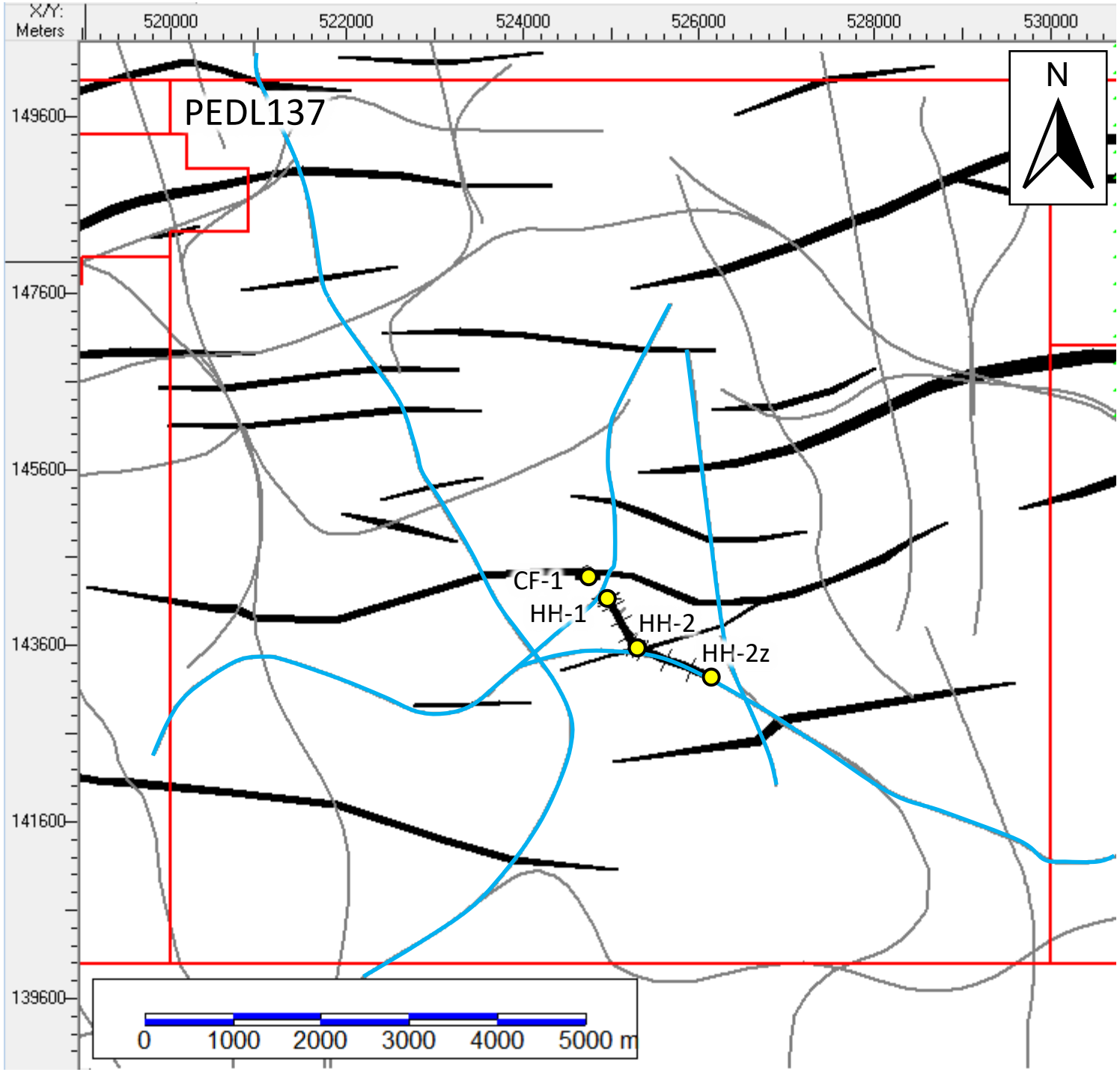
References

Ref. 1: Green Leaves III - Guidelines for Environmental Risk Assessment and Management: Green Leaves III. Revised Departmental Guidance Prepared by Defra and the Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, Cranfield University November, 2011.

Ref. 2: Groundwater risk assessment for your environmental permit. Environment Agency, April 2018. https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

APPENDIX F
INTERPRETED SEISMIC SECTIONS

Figure 3. Seismic lines extending across the HH structure, existing wells and fault framework.



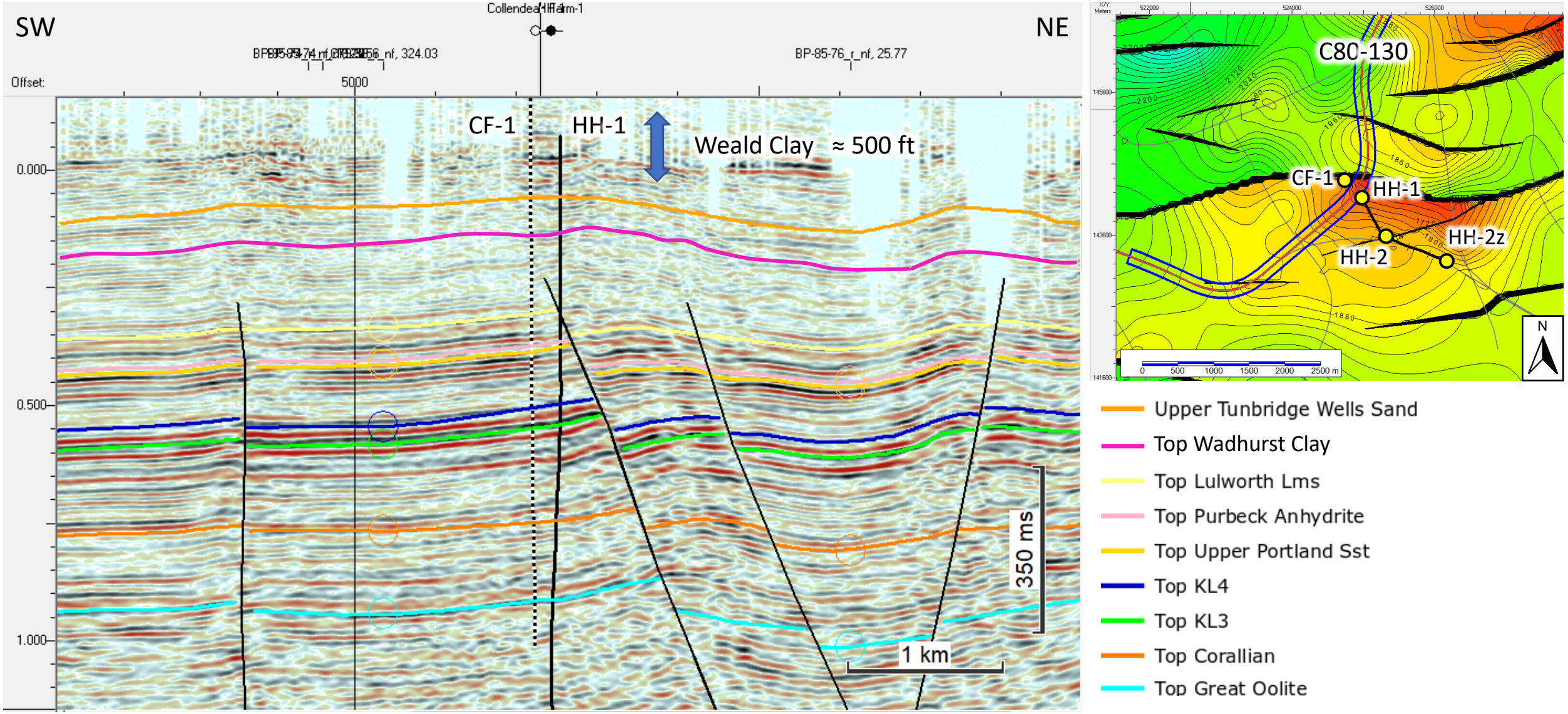


Figure-4. Example of seismic line showing the HH tilted fault block. The HH-1 and CF-1 wells and the interpreted horizons are displayed in the section.

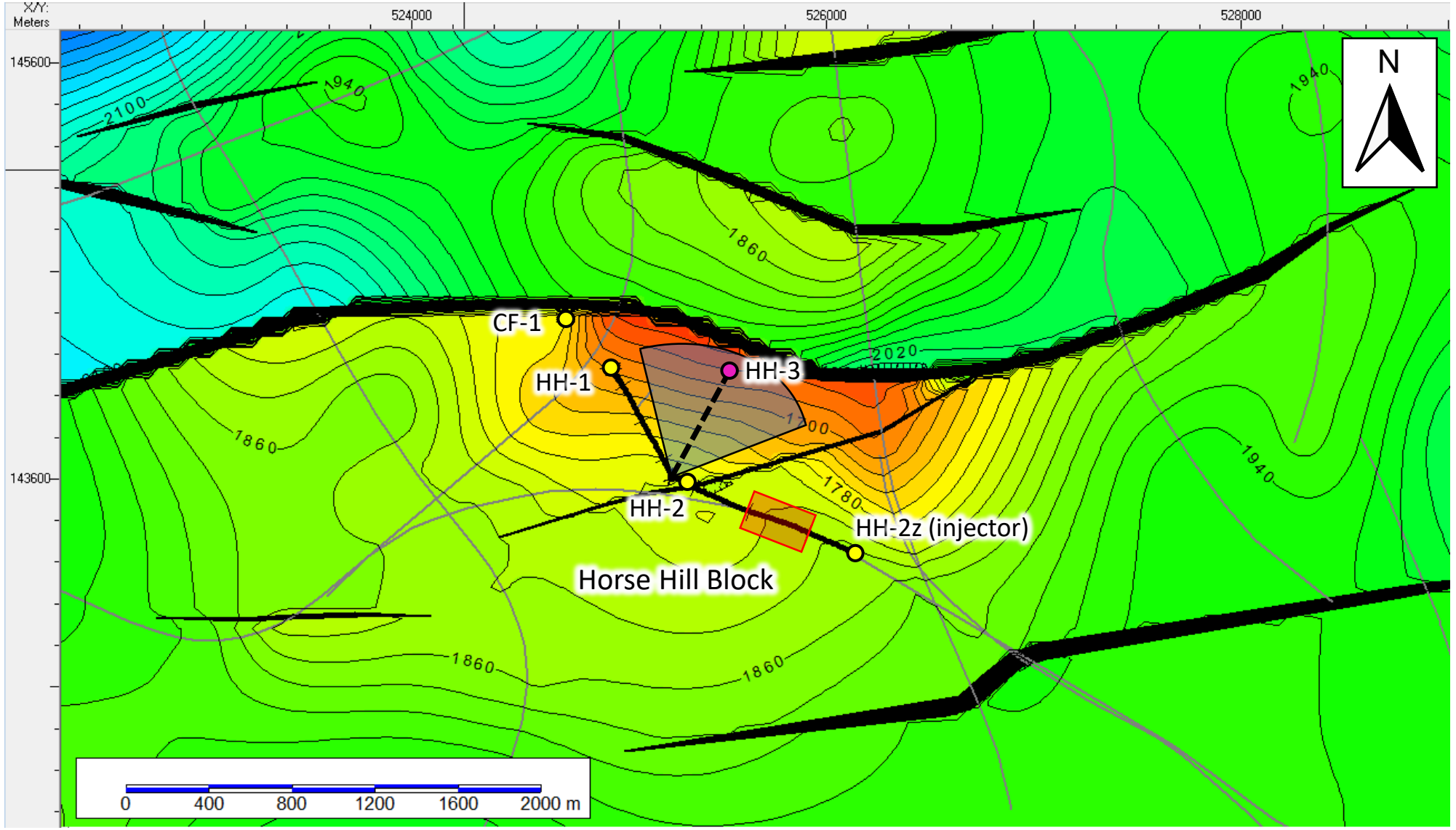
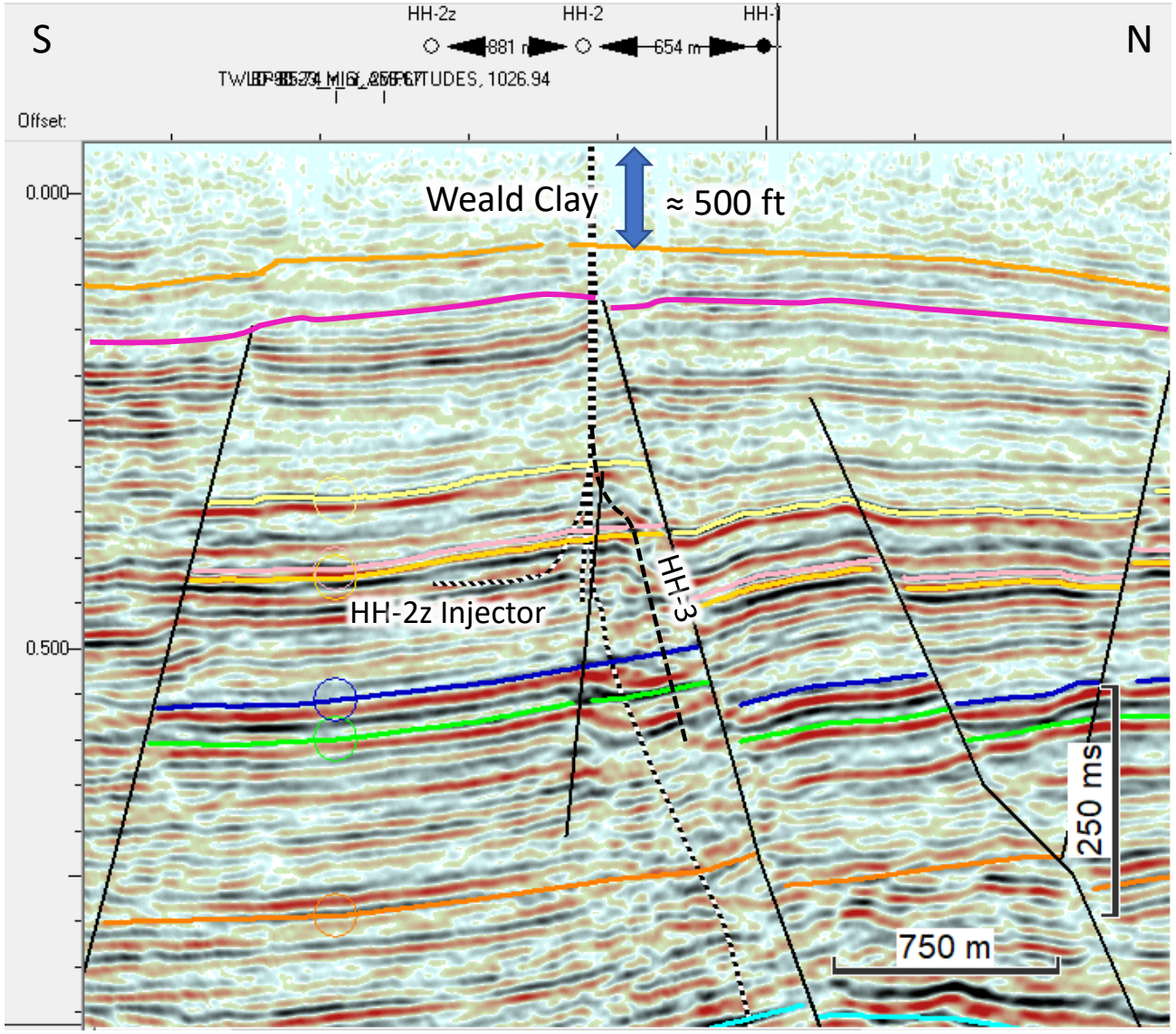
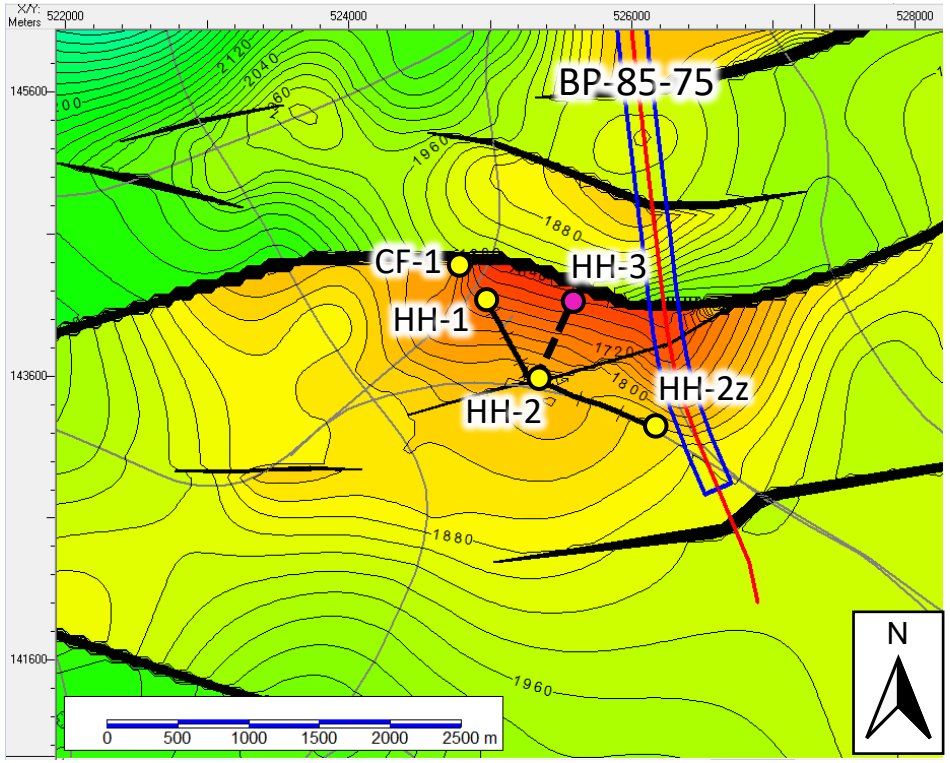


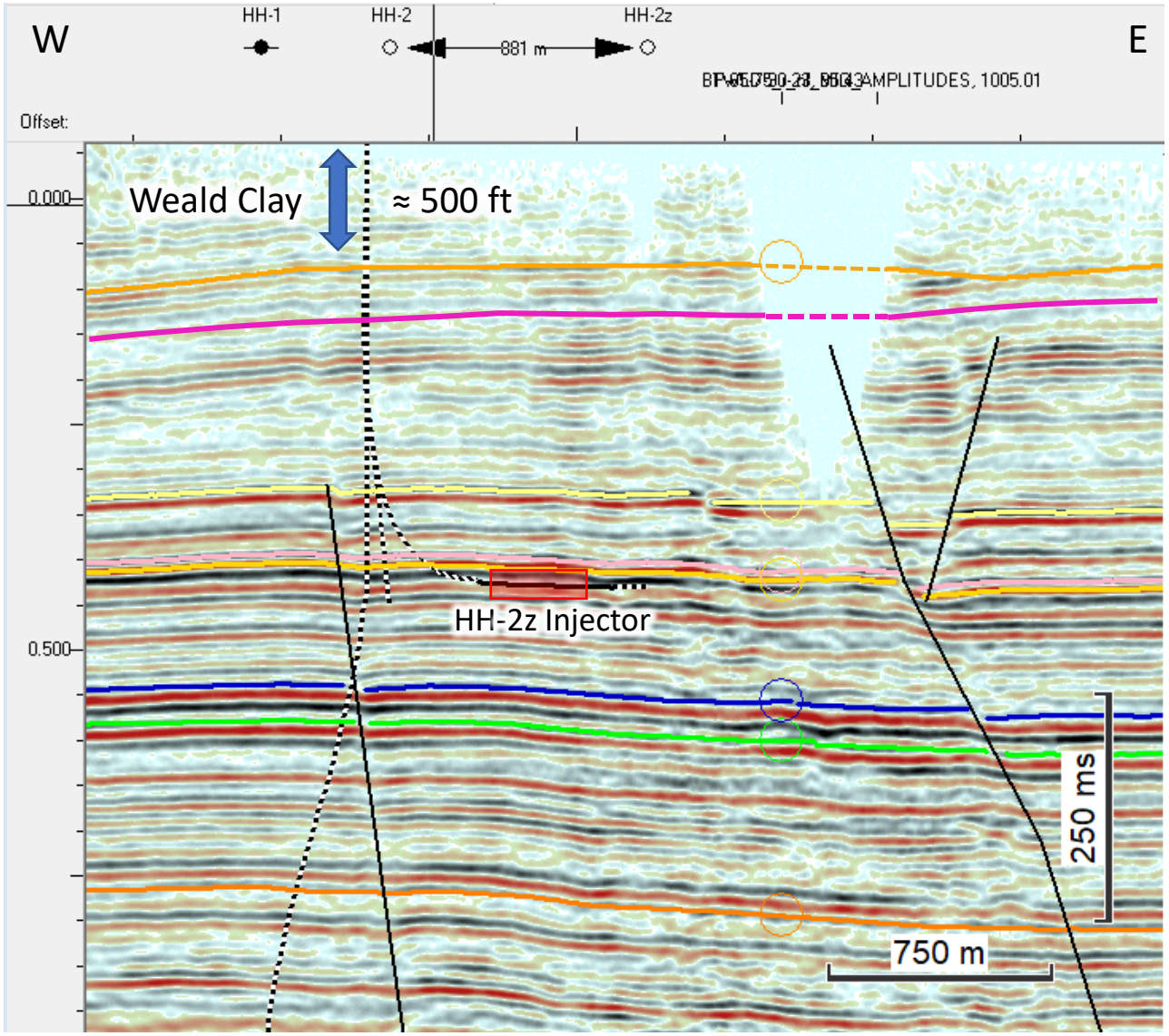
Figure 5. Top upper Portland Sandstone depth map in ft (TVDss). The HH-3 well is a potential infill well targeting the upper Portland Sandstone and the Kimmeridge Clay. The image shows the injection area (red box) within the Portland Sandstone at HH2z. The injection area is located between the 4 ½ inches slotted liner (2990 ft MD) and the Thermatek plug encountered at 3964 ft MD.

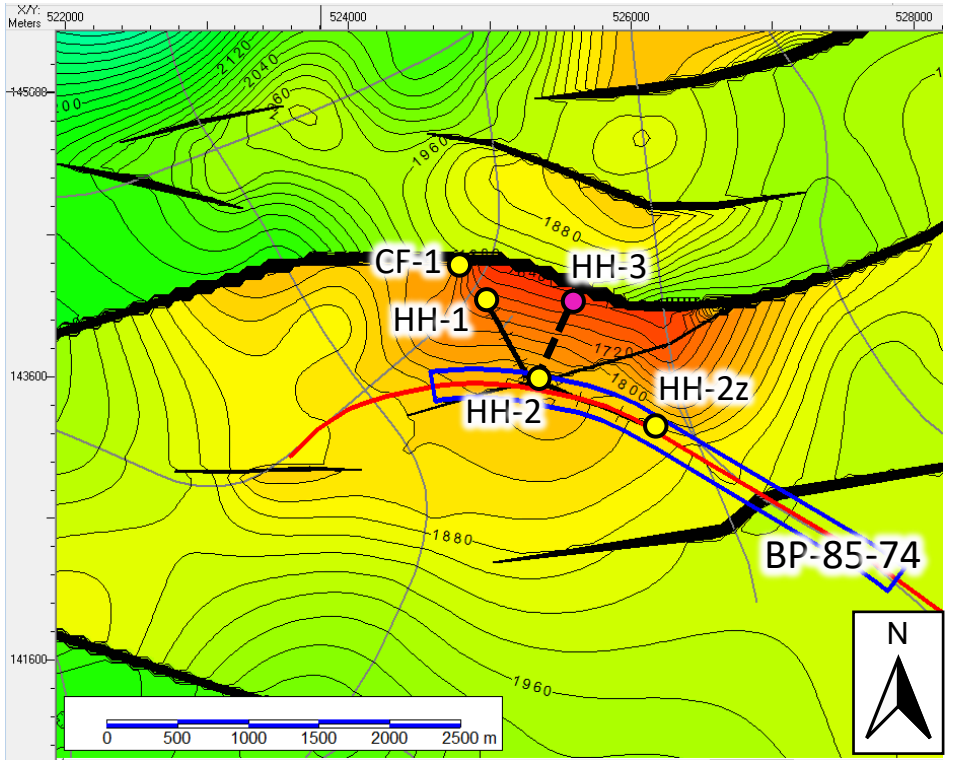




Upper Tunbridge Wells Sand
Top Wadhurst Clay
Top Lulworth Lms
Top Purbeck Anhydrite
Top Upper Portland Sst
Top KL4
Top KL3

Figure-14. Seismic line showing the HH structure and the interpreted fault located between HH-1 and HH-2z. The image shows that the fault terminates against the Lulworth Limestone. The HH-3 infill well is displayed in the image.





Upper Tunbridge Wells Sand
Top Wadhurst Clay
Top Lulworth Lms
Top Purbeck Anhydrite
Top Upper Portland Sst
Top KL4
Top KL3

Figure 15 – Seismic line parallel to the HH-2z injector. The length of the injection area is highlighted by the red box. The fault located to the west of HH-2z terminates against the Lulworth Limestone. The seismic interpretation suggests that the fault located between HH-1 and HH-2z unlikely provides a pathway for transmission of fluids between re-injection and shallow formation containing groundwater.

The structural map shows that the offset generated by the fault between HH-1 and HH-2z in the Portland Sandstone is very small, suggesting that fluid injection from HH-2z would allow to pressure support HH-1 via lateral migration.

Vertical migration of oil from the reservoir formations into the shallower formations, such as the Upper Tunbridge Well Sand, through fault pathways is unlikely in this area, as confirmed by the oil accumulations at Kimmeridge and Portland levels. Moreover, the absence of surface oil seeps and the composition of oils from different reservoirs clearly prove that no vertical mixing has taken place and that even the largest faults must be sealing.

APPENDIX G
GROUNDWATER MONITORING PLAN

GROUNDWATER MONITORING PLAN

HORSE HILL WELL SITE, SURREY

For

Horse Hill Developments Ltd
Suite 3B Princes House
38 Jermyn Street
London
SW1Y 6DN

By

Envireau Water
Aske Stables
Aske
Richmond
North Yorkshire
DL10 5HG

Tel: 01748 889 268
E mail: info@envireauwater.co.uk
Web: www.envireauwater.co.uk

Ref: P20-040 HHDL Horse Hill Permit \ RPT GMP.docm
February 2021

TABLE OF CONTENTS

FIGURES

TABLES

Revision	Details	Completed by	Date	Checked by	Date
REV01	Client Issue	SC	26/11/18	PH	30/11/18
REV02	Update following Sch.5 notice	SC	25/02/21	PH	26/02/21

GROUNDWATER MONITORING PLAN

HORSE HILL WELL SITE, SURREY

1 INTRODUCTION

1.1 Background

Envireau Water has been commissioned by Horse Hill Developments Limited ("HHDL") to prepare a groundwater monitoring plan (GMP) to support the environmental permitting process for a Proposed Development at their Horse Hill well site on land near Horley, Surrey ("the Site"). The Site is located in Petroleum Exploration and Development Licence (PEDL) 137.

The Proposed Development comprises modification of an existing exploratory hydrocarbon well site to facilitate oil production, with a 20 year lifespan.

1.2 Purpose of This Report

This report has been prepared by Envireau Water and presents a scheme of surface water and groundwater monitoring for the Proposed Development at the Site.

This report was originally issued in 2018 and has been updated in February 2021, taking account of the Environment Agency's comments provided as part of EPR Schedule 5 Notice [Ref. 1].

Envireau Water has also produced a hydrogeological risk assessment (HRA) for the Proposed Development [Ref. 2], which forms the basis for the development of the GMP and should be read in conjunction with this report.

North Office, Aske Stables, Aske,
Richmond, North Yorkshire, DL10 5HG
t 01748 889268
e info@envireauwater.co.uk
w www.envireauwater.co.uk

2 SCHEME OF MONITORING

2.1 Justification for Monitoring

The HRA [Ref. 2] shows that there are very low residual risks from the Proposed Development to both groundwater and surface water systems. The findings are a result of the very high level of mitigation embedded within the design and construction of the existing Site, and the planned, future operations. The effectiveness of the mitigation measures will be demonstrated through an appropriate scheme of monitoring that will be regulated by the Environment Agency through an environmental permit.

Monitoring will focus on surface water features and the shallow groundwater system within the weathered bedrock (Weald Clay Formation) close to the site, which are considered the primary receptors to the identified hazards at the Site. Water within these features supports baseflow in local streams and rivers, and also has the potential to be abstracted for domestic and other uses.

Monitoring will not be undertaken in the deeper water bearing formations (e.g. Tunbridge Wells Sand and Ashdown Formations) beneath the Weald Clay Formation because:

- These formations are separated from the surface of the Site by approximately 150m of low permeability strata (Weald Clay Formation). There is no plausible pollutant linkage between these formations and the operations at surface;
- Robust construction and management procedures are in place to ensure the integrity of the hydrocarbon wells to prevent leakage through casings and along annuli;
- Produced water injection, which will take place at depths >600m bgl, will be controlled to prevent formation fracture and migration of fluids to overlying geological strata; and
- There are no water dependent features locally (e.g. private water supplies) targeting groundwater in these formations.

2.2 Groundwater Monitoring Boreholes at the Site

Based on the above justification, it is proposed to install up to three boreholes to a nominal depth of approximately 5m bgl to target the shallow groundwater system. The boreholes will be constructed using cable percussion or rotary drilling. The final depth of the boreholes will depend on the geological conditions encountered. The depth of the boreholes may be extended, where necessary, to ensure the weathered bedrock zone is fully targeted.

Provisional locations for the boreholes are presented on Figure 1. The number and location of the boreholes has been chosen based on the size of the Site and the expected hydraulic gradient within the shallow groundwater system towards the south. The monitoring boreholes will be located within the Site footprint and arranged with two (2) boreholes down hydraulic gradient and one (1) up hydraulic gradient.

Should groundwater not be encountered in a borehole, or the layout be unsuitable for establishing the hydraulic gradient, borehole(s) may be added, removed, abandoned or relocated as appropriate.

An outline design for the monitoring boreholes is presented on Figure 2. The monitoring boreholes will be constructed at a minimum 50mm finished diameter to allow the installation of a water sampling pump or bailer; and completed with headworks to facilitate head space gas sampling in the event it is required.

The boreholes will be purged prior to the first round of sampling using a submersible pump or a bailer, until it runs clear (3 x well volume at a minimum).

2.3 Offsite Water Features

In addition to the monitoring boreholes at the Site, the field drain to the south of the Site and two locations along the unnamed stream/Spencer's Gill (upstream and downstream of where the field drain joins the stream) will be monitored. The provisional locations for surface water monitoring are shown on Figure 3. The exact locations will be dependent on land access.

A field verification exercise will be carried out prior to installation of the monitoring scheme to confirm whether any of the potential PWS identified in the HRA are in existence. If any do exist, they will be risk assessed to determine whether they need to be incorporated into the scheme of monitoring.

2.4 Monitoring Parameters

The scheme of monitoring will comprise water sampling and field and laboratory analysis of the parameters/groups of parameters listed in Table 1.

Table 1 Analysis Parameters

Parameter	Field Analysis	Laboratory Analysis	Justification
Water Level	Yes	No	Determination of the hydraulic gradient.
pH	Yes	Yes	Field analysis of pH, ORP, T, EC, and TDS will be used to measure the stability of the chemical parameters prior to sampling. Values of EC/TDS will be used to corroborate laboratory data as part of data quality assurance.
ORP	Yes	No	
Temperature (T)	Yes	No	
Electrical Conductivity (EC)	Yes	Yes	
Total Dissolved Solids (TDS)	Yes	Yes	
Total Suspended Solids (TSS)	No	Yes	
Dissolved Ions to include: Calcium, Magnesium, Potassium, Sodium, Sulphate, Chloride, Nitrate, Ammonium, Phosphate, Aluminium, Barium, Bicarbonate	No	Yes	These parameters provide a general indication of water quality and can be used to distinguish between surface waters, groundwaters from different geological formations and formation/produced waters from deep formations. They would also pick up dissolution/breakdown products from a number of chemical additives listed in the chemical inventory.
Alkalinity			
Petroleum Hydrocarbons (by carbon banding)	No	Yes	Allows detection of hydrocarbon contamination. Separation by carbon banding allows greater resolution in identifying sources.
Dissolved Methane (groundwater only)	No	Yes	Increases in dissolved methane in groundwater can give an indication of gas release from the well site
Formaldehyde	No	Yes	Indicators of additives/chemicals used during drilling, cementing and workover operational activities.
Acetic acid	No	Yes	

Parameter	Field Analysis	Laboratory Analysis	Justification
Ethylene Glycol	No	Yes	
Ionic and Non-Ionic Surfactants	No	Yes	
Alcohols -Ethanol, Butanol, Propanol	No	Yes	

The analysis parameters reflect the nature of the Proposed Development and take account of the Chemical Inventory associated with the planned operations.

Analysis parameters may be reduced or increased from time to time, if it is justified to do so through a review of monitoring data and with prior agreement from the Environment Agency.

2.5 Monitoring Frequency

2.5.1 Baseline

Monitoring will be carried out monthly for at least three months before the development commences to establish baseline conditions. This is considered a suitable duration over which to establish a baseline at this location due to the overall low permeability of the underlying strata to be targeted by the monitoring boreholes and the limited potential for seasonal variation in water levels and water quality.

2.5.2 Construction Phase

Monthly sampling will be maintained throughout the construction phase of the development.

2.5.3 Production Phase

Monthly sampling will be maintained for the first six months of production. Subject to a review of monitoring data, and agreement with the Environment Agency, monitoring would then be reduced to quarterly intervals.

2.6 Sampling Methodology

Suitably qualified and experienced personnel will be used to carry out the sampling. Water samples will be collected with reference to the British Standard for guidance on sampling of groundwaters [Ref. 3].

The exact sampling methodology for the Site monitoring boreholes will be dependent on the as-built construction of the boreholes. It is expected that a low flow sampling technique (e.g. pneumatic bladder pumps) or bailers will be used to collect groundwater samples. Geochemical conditions will be monitored in the field using field chemistry testing equipment and parameters allowed to stabilise before samples are taken.

Water samples from offsite surface water features will be obtained using appropriate sampling containers. If any PWS are incorporated into the scheme of monitoring, a suitable sampling technique will be established based on the nature/construction of the supplies.

2.7 Analysis

Water samples will be collected by trained personnel with reference to the British Standard for guidance on sampling of groundwaters [Ref. 2] and analysed by a UKAS accredited laboratory.

2.7.1 Field

Suitably qualified and experienced personnel will be used to carry out field analysis. Field water chemistry and water quality data (pH, EC, TDS, ORP and temperature) will be recorded at each monitoring location using calibrated hand-held meters. All equipment will be regularly cleaned, maintained and calibrated in accordance with the manufacturer's guidance.

2.7.2 Laboratory

Analysis of water samples will be carried out in a UKAS accredited laboratory. The exact analysis methods will be confirmed and agreed with the Environment Agency before monitoring begins.

2.7.3 Quality Assurance and Control

During each sampling round, quality assurance samples, comprising at least one blank (distilled water) and one duplicate sample will be collected. Samples will be stored in a cool box and couriered to the laboratory for analysis within 24 hours of sample collection and within all applicable sample stability times.

Laboratory data from each sampling round will be checked by the calculation of ion balance errors. Field chemistry probes will be regularly calibrated according to the manufacturer's recommendations, and records of calibrations kept on file.

2.7.4 Trigger Levels & Erroneous Results

The baseline monitoring data will provide a robust basis against which to monitor natural and anthropogenic changes in water chemistry. Any trends observed will be used to inform the GMP and ensure that it remains appropriate to monitor the activities at the Site.

The baseline data may provide a means for stipulating trigger levels above which further investigations would be carried out to confirm if there was an impact to groundwater. Appropriate levels would be agreed with the Environment Agency at the end of the baseline period.

If erroneous results are detected during review of the data, appropriate re-sampling will be carried out with agreement from the Environment Agency.

2.8 Reporting

Data obtained during each phase of the development will be reviewed following each sampling round and will be reported to the Environment Agency.

The scheme of monitoring may need to be adapted as monitoring data is collected and interpreted, and the local groundwater system is characterised. The scheme of monitoring will be regularly reviewed and, when necessary, a written report submitted to the Environment Agency for approval, detailing the review and any proposals for amendments to the scheme of monitoring. The approved monitoring scheme will be adopted as an Operating Technique by the operator as part of the environmental permit for the Site.

3 SUMMARY

This groundwater monitoring plan has been developed taking account of the risk profile of the Proposed Development and is appropriate for the hydrogeological setting of the Site. The scheme incorporates three (3) shallow groundwater monitoring boreholes and three (3) surface water monitoring locations.

Samples will be collected at each monitoring location by trained personnel with reference to the British Standard for guidance on sampling of groundwaters [Ref. 3]. Baseline conditions will be established over a minimum three-month period prior to the commencement of operations on the Site.

A suite of field and laboratory analyses will be performed on each sample and QA/QC procedures will be in place to ensure the consistency and quality of the results. Each monitoring round will be reported on, compared to the existing data, and reports will be shared and discussed with the Environment Agency.

Envireau Water
26/02/2021

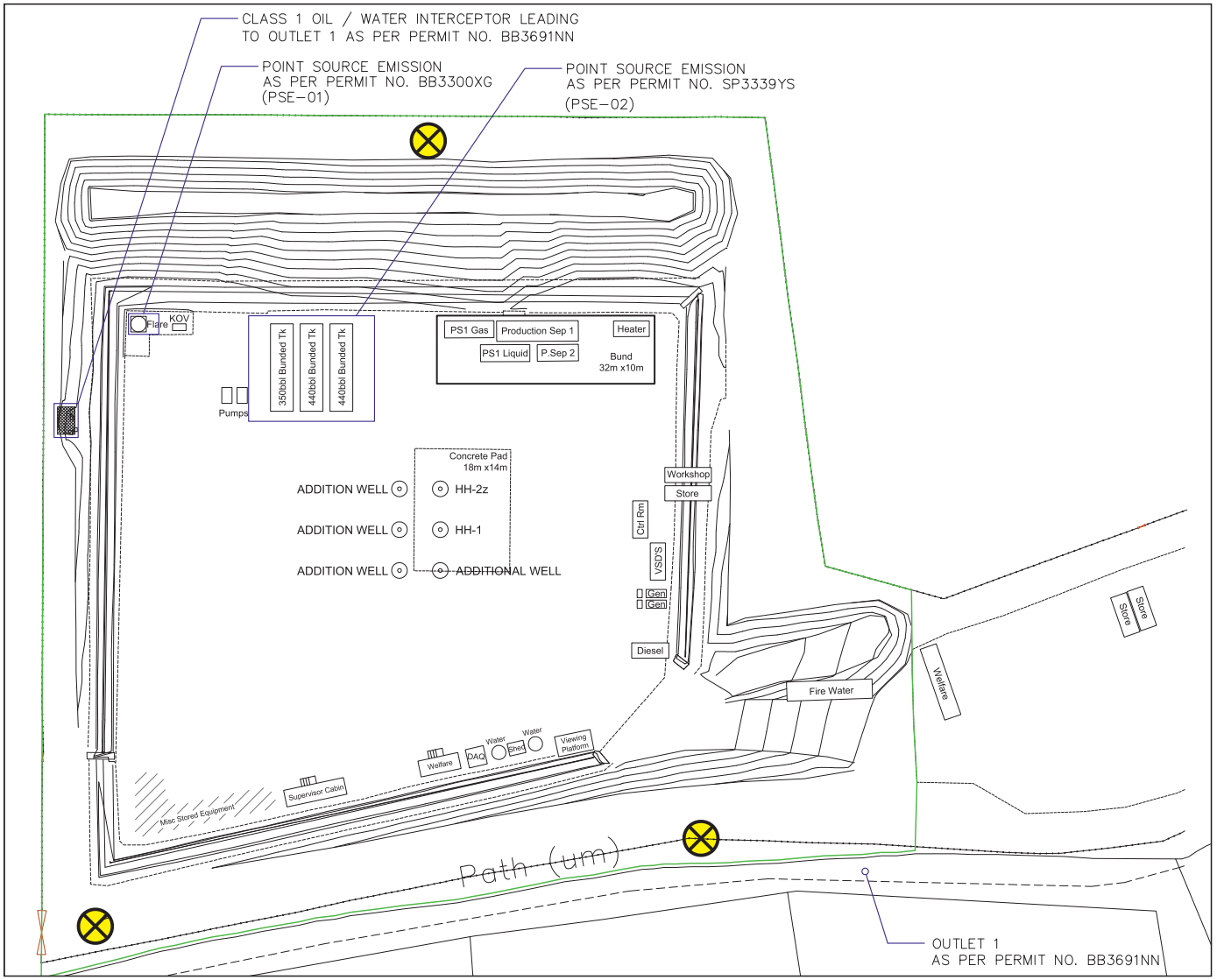
REFERENCES

Ref. 1 Schedule 5 Notice – Consolodated (sic) – Formal Issue. Environment Agency, 2020.

Ref. 2 Hydrogeological Risk Assessment & Flood Risk Assessment – Horse Hill Well Site, Surrey. Report prepared by Envireau Ltd. for Horse Hill Developments Ltd. Envireau Water, November 2018. Updated February 2021.

Ref. 3 BS ISO 5667-11:2009. Water quality- Sampling – Part 11: Guidance on sampling of groundwaters.

FIGURES

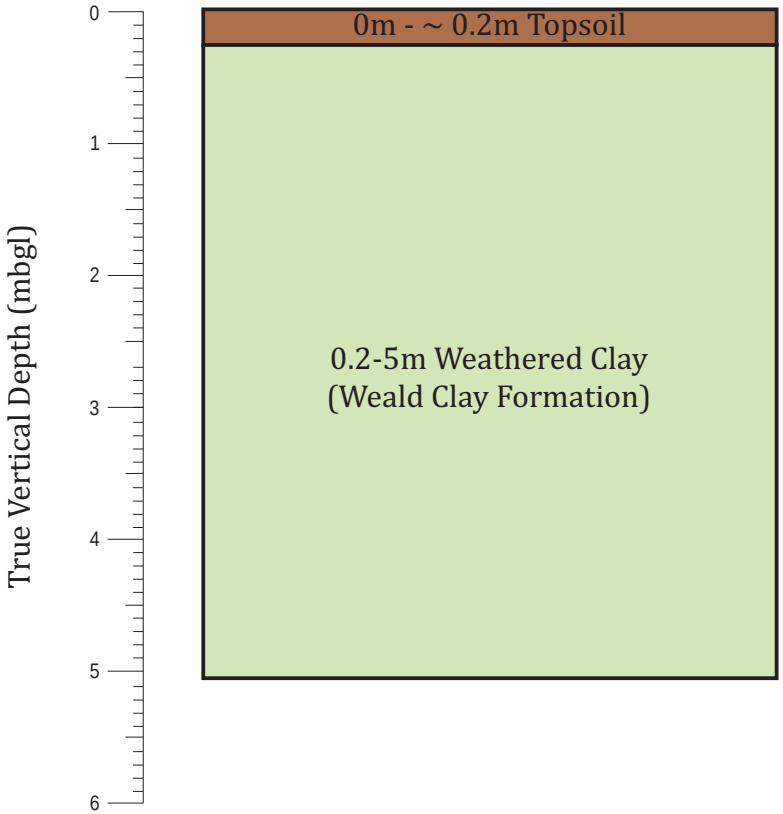


KEY

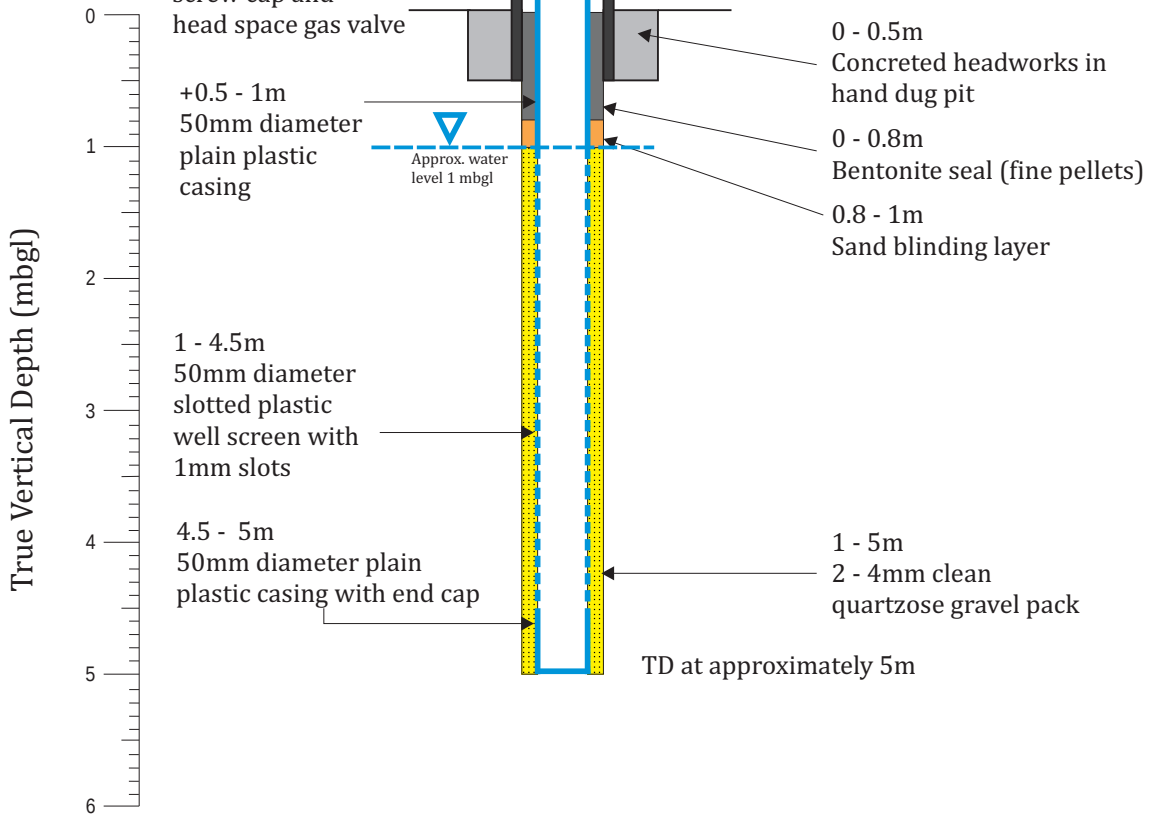
Provisional borehole location

Ref: P20-040/RPT GMP/FIG 1 MBH Locations Date: 10/02/21	**Horse Hill Developments Ltd.**
Figure 1	Monitoring Borehole Provisional Locations

EXPECTED GEOLOGY

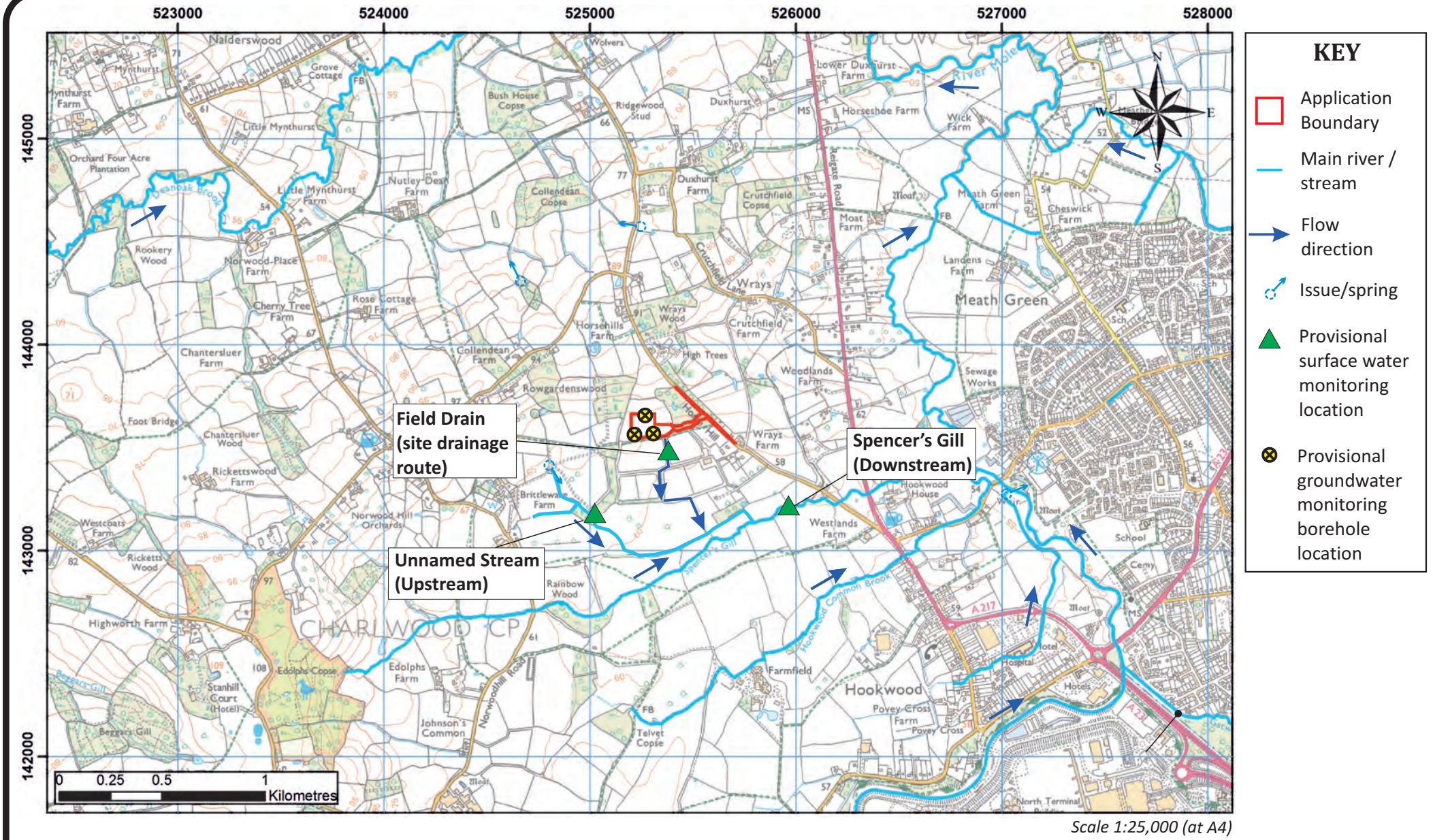


BOREHOLE CONSTRUCTION DETAILS



envireau WATER

Ref: P20-040 /RPT GMP/ FIG 2 Monitoring Borehole Construction Date: 10/02/21	**Horse Hill Developments Ltd**
Figure 2	Outline Monitoring Borehole Design



Scale 1:25,000 (at A4)

envireau WATER

Ref: P20-040/ RPT GMP/FIG Surface Water Monitoring Locations Date: 10/02/21	**Horse Hill Developments Ltd**
Figure 3	Surface Water Monitoring Provisional Locations