APPENDIX 8 – HYDROGEOLOGICAL RISK ASSESSMENT

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URS

Hydrogeological Risk Assessment

Ebbertson Moor 4 Wellsite, Sawdon, North Yorkshire

Final Report
August 2012

46404000 / HRA-EM4-MARP0001

Prepared for

Viking UK Gas Limited

Revision Schedule

Hydrogeological Risk Assessment
August 2012

Rev	Date	Details	Prepared by	Reviewed by	Approved by
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1 Introduction

1.1 Background

This report has been prepared on behalf of Viking UK Gas Limited in accordance with URS proposed scope of works reference 03106609-SNN-2 issued via e-mail by Dr. Sean Needham (URS) to Mr Philip Silk of Petroleum Safety Services Limited on 18 May 2012. Authorisation to proceed was received from Mr Philip Silk on 18 June 2012 (via e-mail) and the works were undertaken under Viking UK Gas Limited Purchase Order #POR 001561, dated 12 June 2012.

The current report provides a hydrogeological risk assessment (HRA) for the proposed drilling of up to two appraisal wells at Ebbertson Moor 4, Sawdon. The site covers 1.05 ha and is located approximately 6km to the west of Scalby, near Scarborough, North Yorkshire at national grid reference 495190, 488950 (refer to Figure 1). The site is located within the North Yorkshire Moors National Park.

It is understood that Viking UK Gas Ltd will soon be applying for planning permission for the construction of a temporary drilling site with associated access, to drill up to two appraisal boreholes for the purpose of mineral exploration (natural gas). Following site construction it is proposed to drill a borehole to a depth of approximately 2190 m below ground level) through hydrocarbon (natural gas) bearing formations. Various tests to evaluate the underground formations and reservoir characteristics are proposed including a 90 day extended well test. If no commercial quantities of natural gas are found then the site will be restored. However, if economic quantities of natural gas is found a new planning application will be made for extraction of gas (production).

Although not directly sought for the current application, pre-application consultees such as the Environment Agency or Yorkshire Water Services Ltd have previously (February 2012) commented on the application for a similar well site proposed by Viking UK Gas Ltd, located approximately 1.5km to the west and within identical shallow geological terrain. Such comments will outline the respective consultees position and concerns with regards the water environment in the vicinity of the current site. Key comments deemed to be relevant to the current HRA include;

Environment Agency (2012a):

- *“The site is located on top of Jurassic Age Lower Calcareous Grit, which forms part of the Corallian Group. The Corallian is classed as a principal aquifer, an aquifer that is capable of supporting large water supplies It is highly vulnerable to any potentially polluting activity. At greater depth is the Sherwood Sandstone and the Magnesian Limestone, which are also classed as principal aquifers”.*
- *“This site currently falls outside the Source Protection Zone designed to protect the Scarborough drinking water supply boreholes. However, the Source Protection Zones have been revised and when the new zones are adopted in April 2012*[1]*, the site will now lie within Zone 2. Source Protection Zones are used to identify those areas close to drinking water sources where the risk of harm from contamination of groundwater is greatest”.*
- *“It is vital that the proposed development does not adversely affect the quality of water within the underlying Corallian Group aquifer. For this reason:”*

[1] URS note that new SPZ maps for the area of the site were published on the EA website sometime during June 2012.

  - *"1)a) No oil-based drilling methods should be used in strata shallower than, and including, the Corallian Group aquifer".*
  - *"1)b) No oil-based drilling methods should be used in strata deeper than the Corallian Group aquifer unless all shallower strata are cased off and pressure tested to ensure no loss of drilling fluid into the shallower strata". .*
- *"There must be no discharge of foul or contaminated drainage from the site into either the groundwater or any surface waters:"*
- *"Any facilities, above ground for the storage of oils, fuels or chemicals shall be sited on an impervious base and surrounded by impervious walls. The volume of the bunded compound should be at least equivalent to the capacity of the tank plus 10%".*
- All planned activities should be compliant with Environment Agency guidance outlined in GP3 (Groundwater Protection Policy and Practice).

Yorkshire Water Services Ltd (2012) indicated similar concerns to the EA including;

- *"The site lies outside the published groundwater Source Protection Zones for YW's Corallian Limestone abstractions at Irton and Cayton. However, current hydrogeological understanding indicates that the catchment area for the boreholes is likely to be much larger than indicated by the current SPZs . Travel times in the Corallian Limestone have proved to be rapid and the interdependence between the aquifer, the River Derwent and its tributaries is more widely understood. Therefore we would request that the Local Planning Authority considers this site as though it were within the SPZ".*
- *"details to be included within a Hydrogeological Risk Assessment include;"*
  - *"Contingency plans for spillages/leaks on site during setup, drilling, decommissioning and testing"*
  - *"Method statement/drilling operations through the Corallian aquifer and type of mud or other lubrication used."*
  - *"Casing design through the Corallian aquifer and isolation of underlying/overlying strata to prevent cross-mixing."*
  - *"Method statements for pumping and storage of water/hydrocarbons during testing, including disposal of wastes."*

The current report provides a hydrogeological risk assessment of the potential impacts on water resources as a result of the proposed activities during construction and restoration of the site.

In the context of this report, the term 'Hydrogeology' covers the assessment of potential impacts on:

- Groundwater resources and Groundwater quality, and;
- Surface water features.

The following report sections introduce the assessment method and present the baseline conditions, potential impacts and mitigation measures.

2 Assessment Method

The assessment has been undertaken using the Source-Pathway-Receptor model, which is in line with the EA Horizontal Guidance Note H1 – Annex (j) (EA 2010). This model identifies the potential sources or 'causes' of effect as well as the receptors (water resources) that could potentially be affected. However, the presence of a potential effect source and a potential receptor does not always infer an effect, there needs to be a clear mechanism or 'pathway' via which the source can have an effect on the receptor.

The first stage in utilising the Source-Pathway-Receptor model is to identify the causes or 'sources' of potential impact. The sources have been identified through a review of the details of the proposed development, including the size and nature of the development, potential construction methodologies and timescales. This has been undertaken in the context of local conditions relative to water resources near the site, such as topography, geology, climatic conditions and potential sources of contamination.

The next stage is to undertake a review of the potential receptors, that is, the water resources themselves that have the potential to be affected. The identification of potential water resource receptors has been undertaken through a review of baseline data.

The last stage is to determine if there is an exposure pathway or a 'mechanism' allowing an effect to potentially occur between source and receptor.

Once potential effects on water resources are identified, it is necessary to determine how significant the effects are likely to be, to enable the identification of potential mitigation measures that can counteract negative effects. The effect on the receptors depends largely on the sensitivity of the receptor and the magnitude of effect experienced.

An assessment of the significance of each effect has been undertaken based on the methodology provided in the Web-based Transport Analysis Guidance; specifically the Water Environment Sub-Objective WebTAG Unit 3.3.11 (Department of Transport 2003). This provides an appraisal framework for taking the outputs of the Environmental Impact Assessment process and analysing the key information of relevance to the water environment. The guidance is based on guidance prepared by the Environment Agency and builds on the water assessment methodology in Design Manual for Roads and Bridges (DMRB) 11:3:10 (Highways Agency 2008). Although this method was designed primarily for transport projects it is applicable to and widely used for other development types.

Receptor Sensitivity

The sensitivity or importance of each water resource (the receptor) is based on its considered value, for example its value as an ecological habitat, as a source of drinking water or as a recreational resource (see Table 1).

Table 1 Importance of Water Resource

Importance	Criteria	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 a protected Special Area of Conservation (SAC) or Special Protection Area (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 Site of Special Scientific Interest (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 is then established based on the likely degree of impact relative to the nature and extent of the proposed development (see Table 2). It is important to consider at this stage that potential impacts can be beneficial as well as adverse which would be highlighted within an Environmental Impact Assessment EIA[2] were this to be required as part of the planning application. The derivation of magnitude is carried out independently of the importance of the water resource.

[2] Not all planning applications require an EIA to be undertaken.

Table 2 **Magnitude of Impact**

Magnitude of Impact	Criteria	Examples
High	Impact results in a shift in a water bodies potential 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 on water bodies attribute.	- 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 the use / 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

Once the magnitude of an impact is derived, the significance of the potential effect can then be derived by combining the assessments of both the importance of the water resource and the magnitude of the impact in a simple matrix (see Table 3 below).

Effects which are assessed to be major or moderate are considered to be significant; those that are minor and negligible are not considered to be significant.

Table 3 **Significance of Effect**

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

3 Baseline Conditions

3.1 Site Description

The planning application is for a site (including access road) of 1.7 ha located in the parish of Brompton-by-Sawdon in North Yorkshire (National grid reference 495190, 488950). The location of the site and extent of the study area is shown in Figure 2. The study area of this report is the site together with the territory up to 2 km radius from the site boundary.

The site lies within the North Yorkshire Moors National Park in an area locally known as the Tabular Hills, a range of generally west to east trending hills with a north facing scarp slope and a gradual decline in elevation southwards towards the Vale of Pickering. The Tabular Hills are deeply incised by a series of north south trending valleys and rivers, including the River Derwent.

The site is located at an elevation of approximately 200m AOD (above ordnance datum) and close (approx 600m) to a north facing scarp slope which forms the southern edge of the River Derwent Valley. The elevation of the Derwent valley floor varies between 60 and 40m AOD. Topography at the site gradually declines to the southeast, falling to an elevation of 190m AOD at a distance of approximately 600m from the site,

The mean annual rainfall is estimated at between 700 and 900mm/a based on the regional long term average (1971 to 2000) annual rainfall map for North East England (refer to http://www.metoffice.gov.uk/climate/uk/averages/regmapavge.html#neengland and the long term 1971–2000 annual average rainfall of 729.4mm recorded at High Mowthorpe (175m ASL) located approximately 20km to the southwest of the Ebbertson Moor 4 wellsite.

3.2 Surface Water and Drainage

The river Derwent is the closest major river to the site, located approximately 1km to the north and flows in a southerly direction through the Tabular hills towards the Vale of Pickering. Notable tributaries to the Derwent that are located close to the site include Troutsdale Beck which flows along the foot of the north facing scarp slope before merging with the Derwent at approximately NGR SE 9480 9000. Notable surface water features are highlighted on Figure 2.

Numerous small unnamed streams and springs are also noted on the slopes of the Derwent valley, with the springs likely to be located at contacts between more permeable and non permeable strata. The closest spring to the site noted on OS maps is located at NGR SE 9500 8940, approximately 450m to the north-northwest of the site.

The closest unnamed stream to the site is located at NGR SE 9562 8920 on the north facing scarp slope approximately 350m to the east-northeast of the site.

On the south facing dip slope there are various surface water features, with the closest feature located approximately 1,300m to the south east (unnamed watercourse feeding into Jenny Spring at SE 968 877), other features include a surface water feature called Foss Gill approximately 1,350m to the south and Long Grain located 1,400m to the south west. All these features flow in a southerly direction.

These streams and springs form the headwater tributaries of the River Derwent which after passing through the Vale of Pickering joins the River Ouse near Drax (SE of Selby).

The Derwent Catchment Abstraction Management Strategy (Environment Agency 2006) indicates that the River Derwent close to the site is over abstracted (refer to Figure 3).

3.3 Geology

The superficial and bedrock geology of the southern portion of the North Yorkshire Moors and the northern portion of the Vale of Pickering is illustrated in Figure 4, and a more site specific map in presented as Figure 5.

The site is located on Upper Jurassic Period, Lower Calcareous Grit Formation rocks which form the basal member of the Corallian Group. The outcrop patterns of the Jurassic rocks in the area are relatively complex due to faulting and folding within the region (Jones *et al* 2000). In general the Jurassic strata are broadly categorised as follows:

- Upper Jurassic: includes alternating marine calcareous and oolitic limestones (**Corallian Group**) overlain by clays (Ampthill and Kimmeridge clays). The base units of the Upper Jurassic comprise the Oxford Clay Formation, Osgodby Formation calcareous sandstone) Corallian Group and the Cornbrash (limestone & mudstone) which unconformably lies on the Middle Jurassic Strata.
- Middle Jurassic sequence comprises a thick sequence of fluvial, estuarine and deltaic rocks including mudstones, siltstones, shales, sandstones and limestones. The majority of these strata are classified as the Ravenscar Group.
- Lower Jurassic sequence comprises predominantly shales and clays of the Lias Group which contain alternating limestones, ironstones, siltstones and sandstones.

The full sequence of Jurassic strata are detailed in Table 4. The Corallian Group consists of three formations (Allen *et al* 1997):

- Corallian Oolite Limestone
- Upper Calcareous Grit
- The Lower Calcareous Grit

The Upper and Lower Calcareous Grit formations are dominated by fine-grained calcareous sandstones or sandy limestones. Both the Grits and the Oolites are variable in composition across the region.

The full geological sequence beneath the Jurassic Age strata to a depth of approximately -2000m AOD in the area of the site has been estimated from the vertical cross section provided in BGS Sheet 54 and is summarised in Table 5. Strata older than the Middle Jurassic period are not exposed in the area of the site and have been proven at depth within boreholes.

Structurally, the Corallian rocks beneath the site lie on the southern limb of the Cleveland anticline centred in the North Yorkshire Moors. The Corallian rocks dip to the south / southeast at an inclination of between 3° and 5° towards the Pickering Syncline where they are juxtaposed against low permeability Kimmeridge Clays due to the large throw of up to 150m across the Helmsley-Ebberston-Filey Fault (refer to Figure 6). The fault acts as a hydrogeological boundary.

Table 4 Detailed Sequence of Upper Jurassic Strata in Area of Site

Period		Mapped Unit	Thickness and Lithology
Upper Jurrasic		Kimmeridge Clay Formation	up to 385m, mudstones (often calcareous) and oil shales
		Ampthill Clay Formation	40 - 50m
	Principal Aquifer	**Corallian Group**	**100 - 150m calcareous sandstones and limestones**
		Oxford Clay	up to 35m
Middle Jurrasic		***Osgodby Formation***	*Hackness Rock 2m calcareous sandstone with interbedded limestones*
			Langdale Beds 2-15m sandstone
			Kellaways Rock 7-16m chamositic sandstone
		Cornbrash Formation	Upper Conbrash shale up to 3m
			Limestone up to 3.5m (shelly in east)
	Ravenscar Group Secondary Aquifer System	***Scalby Formation*** *(formerly Upper Deltaic Series)*	*40 - 70m* mudstones, *siltstones and sandstones*
		Scarborough Formation	*up to 30m limestone, sandstone* and shale
		Cloughton Formation *(formerly Middle Deltaic Series)*	*up to 90m* shales, *sandtsones, subordinate limestones* and thin coals
		Eller Beck Formation	*4.5 - 8m* shales and *ironstones overlain by shaly sandstone*
		Saltwick Formation *(formerly Lower Deltaic Series)*	*up to 60m sandstone* and shale
		Dogger Formation	*up to 12m chamositic sandstone*
Lower Jurrasic	Lias Group	Whitby Mudstone Formation (formerly Upper Lias)	up to 105m mudstone and shale with sandstone beds
		Cleveland Ironstone Formation	*up to 25m* mudstone and siltstone *with beds of Oolitic ironstone*
		Staithes Sandstone Formation	*up to 30m micaceous, calcareous sandstone and sandy limestone*
		Redcar Mudstone Formation (formerly Lower Lias)	up to 285m mudstones and siltstones with subsidiary thin limestones, sandstones and ironstones

Adapted from Allen et al (1997) and BGS Sheet no' 54

Key

Corallian Group	Principal Aquifer (formerly major)
Cornbrash Formation	Secondarfy Aquifer (formerly minor)
Clay, Mudstone formations	Non aquifer (impermeable)

Table 5 Deeper Geological Strata beneath the Area of the Site

Age	Name	Approximate Depth to Formation (m below ground level)	Approximate Thickness (m)	Generic Description	Generic Aquifer Classification
Lower Jurrasic	Lias Group	280	440	Predominatly Mudstones and Shales	Non Aquifer
Triassic	Mercia Mudstone Group	720	330	Mudstones with gypsum and thin sandstone beds	Non Aquifer
	Sherwood Sandstone Group	1040	330	Red Sandstone	Principal Aquifer
Permain	Undifferentiated	1360	580	Mudstones, Anhydrite, Dolmitic Limestones	Non Aquifer Limestones - Principal Aquifer
Carboniferous	Millstone Grit Series	1940	>700	Sandstones, Mudstones and thin Coals	Secondary Aquifer

Depths estimated from BGS Sheet no' 54.

3.4 Hydrogeology

3.4.1 Hydrogeological Units

Corallian Aquifer (Upper Jurassic)

The site is underlain by a Principal Aquifer, known as the Corallian. The outcrop area for the Corallian is presented as Figure 7, while the aquifer classification is presented as Figure 8. This aquifer is highly fractured and extensively used for water supply in the region (especially the urban area of Scarborough).

The northern extent of the aquifer outcrop is defined by the west to east trending scarp slope located close to the site, while the southern extent is defined by the contact with the Kimmeridge Clay at end by the Helmsley-Ebberston-Filey Fault in the Vale of Pickering.

The base of the Corallian aquifer is defined by the underlying Oxford Clay which comprises up to 35m of low permeability clays. The thickness of the Corallian aquifer in the immediate vicinity of the site is estimated at approximately 40m.

Middle Jurassic Secondary Aquifers

Underlying the Oxford Clay a further series of secondary (minor) aquifers associated with the Osgodby Formation, Cornbrash, Ravenscar Group and the Dogger Sandstone. These rocks form a variable series of predominantly mudstones, sandstones and limestones, with the Ravenscar Group generally attaining a thickness of around 210m in the region (Jones *et al* 2000). The full sequence of Middle Jurassic strata beneath the site is estimated at approximately 200m and are likely to be encountered at a depth of approximately 90m below ground level (as estimated from a vertical cross section provided on BGS Sheet 54).

Generally the more permeable sandstones and limestones have some potential to form aquifers of local importance, although groundwater flow is restricted by numerous interbedded thin mudstones which can give rise to numerous springs at their contact at surface. A more detailed description of these aquifers is provided in Jones *et al* (2000).

Deeper Strata

Deeper strata beneath the site (>280m BGL) are summarised in Table 2 along with their generic aquifer classification. In summary:

- The Lias Group, and Mercia Mudstone Group are characteristically low permeability strata and generally form non aquifers.
- Sherwood Sandstone Group: is estimated to be located at a depth of greater than 1km below ground surface and at the near surface forms a principal aquifer of regional importance. Despite its significant depth beneath the site, the sandstone will likely retain a good permeability, however, it is not considered to be economically usable due to its depth and likely saline or mineralised (poor) groundwater quality.
- Permian: Mudstones and Anhydrite form the majority of the Permian Strata are characteristically low permeability strata and generally form non aquifers. The Limestone and Dolomite strata are commonly referred to as the Magnesian Limestone aquifer and at the near surface form a principal aquifer of regional importance. However, these strata are not considered to be economically usable due to their significant depth and likely saline or mineralised (poor) groundwater quality

- Carboniferous Millstone Grit: at near surface this formation can form secondary aquifers of minor or local importance, with variable permeability and water quality. However, these strata are not considered to be economically usable due to their significant depth and likely saline or mineralised (poor) groundwater quality.

These deeper strata will not be discussed in any more detail within this report.

3.4.2 Aquifer Properties

Corallian Aquifer (Upper Jurassic)

The aquifer properties of the Corallian of North Yorkshire are summarised in Allen *et al* 1997. Due to its highly fractured nature, with fracture flow being well developed, transmissivities can be high (up to 3800m^2/d) and large yields possible close to major springs and faults (Allen et al 1997). The highest yielding boreholes are located close to the confined zone (north of the Helmsley-Ebberston-Filey Fault). The Corallian aquifer is underlain by the low permeability Oxford Clay Group and in the Pickering basin overlain by low permeability Ampthill and Kimmeridge Clay Formations.

Due to the fractured nature of the Corallian aquifer, groundwater levels and the springs and streams fed by the aquifer respond rapidly to rainfall events. In summer stream flows are sustained by baseflow from the aquifer.

The bulk of groundwater discharge from the Corallian occurs via a series of major springs located at the Helmsley-Ebberston-Filey Fault (boundary with the overlying clay cover). In summer, the sum of discharges from all the springs exceeds the total discharge from the whole aquifer as all the flow from some rivers crossing the Corallian outcrop disappears down swallow holes to reappear later as spring flow elsewhere. Large volumes of water are therefore transferred via well developed solution enhanced conduit network,

The published transmissivity values range from less than 1 m^2/d to over 10,000 m^2/d as obtained from pumping tests at 29 locations (Allen et al 1997\0. The interquartile range is 38 to 2,249m2/d and the geometric mean is 318m^2/d. Storage coefficients where calculated are low and range between 4 x10-7 and 0.024. Due to the fractured nature of this aquifer, the effective porosity (through which groundwater flows) is likely to be in the order of 1% or less for the bulk of the aquifer and as a result groundwater velocities will be expected to be high.

A regional distribution of transmissivity has been prepared in a groundwater model developed by Aspinwall (1994 reported in Allen et al 1997) for the eastern area of the Corallian aquifer up to the Helmsley-Ebberston-Filey Fault. This distribution is presented as Figure 9.

The hydraulic properties of the aquifer in the vicinity of the site are likely to be predominantly controlled by the distribution and degree of fracturing and fissuring in the Corallian limestone. The zone where fracturing is best developed is likely to be within the zone of water level fluctuation, along the route of valleys (as along Bee Dale), within the zones of former water table fluctuation and close to faults.

Middle Jurassic Secondary Aquifers

The Middle and Lower Jurassic Secondary (minor) aquifers are encountered at depth beneath the site and are confined by the low permeability Oxford Clay formation. As noted above, the properties of these secondary aquifers will be locally variable and limited by interbedded mudstones, for a fuller description of their hydraulic properties the reader is referred to Jones *et al* (2000).

3.4.3 Groundwater Level Elevation, Fluctuations and Flow

According to Environment Agency records (data supplied in July 2012) indicate that no information on groundwater levels within the Corallian Aquifer is available within a 2km radius of the site.

Based on a general hydrogeological understanding of the Corallian aquifer, it is anticipated that groundwater would be expected to be encountered within 5 to 10m of ground surface and groundwater flow would be expected to follow topography. The major flow direction would be expected to be to the south/southeast following the regional dip of the Corallian strata (which follows topography); while a small proportion would be expected to flow northwards towards the major scarp slope. Such flow is evidenced by the presence of numerous springs and small streams that originate on the scarp slope. A natural and localised groundwater divide would be expected which would generally follow the profile of the scarp slope. Such a divide is likely to be coincident with the catchment boundary defined for the West Ayton Water Resource Management Unit presented on Figure 3 (Environment Agency 2006). Given the sites proximity to the scarp slope, this local groundwater divide may be located close to the site. A review of the OS map indicates that to the north west of the site topography rises slightly (by approximately 3-5m) and this may indicate that site is located just to the south flowing side of the divide. However, without site specific groundwater elevation data the depth to groundwater, groundwater flow directions and hydraulic gradients remain uncertain.

Based on the fractured nature (and low effective porosity) of the Corallian aquifer described in Section 3.4.2, annual fluctuations in groundwater levels in response to seasonal rainfall could potentially be large >5m with summer low conditions at the site due to it proximity to the edge of the aquifer resulting in an almost dry conditions within the aquifer.

3.4.4 Groundwater Abstractions

Licensed and private groundwater and surface water abstractions are listed in Table 6 and their locations in relation the site are presented on Figure 10.

Table 6 Licensed and Un-licensed Water Abstractions in the Vicinity of the Site (July 2012)

Figure Reference	number	Designation	Use	Source	Name	Distance From Site	Down Hydraulic Gradient of Site
1	2/27/27/183	Licensed	Private - Amenity	Surface Water	Troutsdale Beck	1170m NW	**Possibly**
2	2/27/26/026	Licensed	Private - Water Supply	Groundwater - Spring	Corallian	1180 NE	**Possibly**
3	2/27/27/091	Licensed	Private - Amenity	Groundwater - Spring	Corallian	1120 E	**Possibly**
4	2/27/27/089	Licensed	Private - Water Supply	Groundwater - Spring	Corallian	1260 E	**Possibly**
5	2/27/27/090	Licensed	Private - Water Supply	Groundwater - Spring	Corallian	1320m E	**Possibly**
6	2/27/26/036	Licensed	Private - Amenity	Groundwater - Spring	Jurassic	1600m NE	No
7	2/27/27/061	Revoked	Water Undertaking	Surface Water	fed by Corallian	1700m S	**Yes**
8	2/27/27/085	Revoked	Water Undertaking	Groundwater - Spring		1810 NE	No
9*	-	Unlicensed	Ox Pasture	Groundwater		4000m E	No
10*	-	Unlicensed	Osborne Lodge	Groundwater		4000m SE	**Possibly**
11*	-	Unlicensed	Yedmandale Farm	Groundwater		3500m SW	No
12*	-	Unlicensed	Basin Hoye	Groundwater		3500m SW	No
13*	-	Unlicensed	Broxa Farm	Groundwater		2800m N	No
14*	-	Unlicensed	Kirkless Supply	Groundwater		4800m NW	No
Closest PWS					Corallian	6000m SE	**Yes**

* Information supplied by Scarborough Borough Council, 4 July 2012

Groundwater abstractions include water wells sunk to abstract water from a given aquifer and also groundwater fed springs.

The closest public water supply operated by Yorkshire Water Services Limited is located approximately 6km to the south east of the site close to West Ayton (no further details on this source were available at the time of this study). Scarborough Borough Council (4 July 2012) held details of six private unlicensed abstraction in the area. Such abstractions can be common in rural areas, are often used for domestic water supply. Any abstraction of less than 20m3/d is not required by law to be licensed. These unlicensed sources are normally registered with the Local Authority, however, they often remain unregistered.

For the current study, a total of fifteen abstractions are known to present within a 6km radius of the site with two of these abstractions identified as being located in areas down hydraulic gradient from the site and six sources that could possibly be in areas where groundwater in the vicinity of the site could potently migrate to.

3.4.5 Water Framework Directive Status

Groundwater

The Water Framework Directive (WFD) sets a target of achieving overall 'Good status' in all water bodies (including rivers, streams, lakes, transitional and coastal water bodies, and groundwater) by 2027. For groundwaters, Good status has a quantitative and a chemical component; status is measured on the scale High, Good, Moderate, Poor and Bad.

The WFD status of groundwater bodies of interest to the current study is provided in Table 7 (EA website accessed July 2012).

Table 7 WFD assessment of Groundwater bodies in proximity to the site

Waterbody Name / ID	Current Quantitative Quality	Current Chemical Quality	2015 Predictive Quantitative Quality	2015 Predicted Chemical Quality
Derwent Vale of Pickering Corallian Limestone GB40401G701200	Poor	Poor	Poor	Poor
Derwent North Yorkshire Moors Ravenscar GB40402G700800	Good	Good	Good	Good

Although not noted on the EA website, the poor designation for quantity is likely to reflect that the aquifer unit has been designated as over licensed (for Groundwater Abstractions).

Under the WFD classification the Corallian aquifer has been designated as poor quality. Although not noted on the EA website, the poor designation for quantity is likely to reflect impact from pollution from agricultural chemical such as nitrates. This will be particularly of concern in the study area since the Corallian aquifer is unconfined.

The Corallian aquifer has been assigned an "At Risk" designation, while a "Probably At Risk" designation has been assigned to the Ravenscar aquifer (EA website, accessed July 2012).

Surface Water

The WFD status of surface water bodies of interest to the current study is provided in Table 8 and Figure 11 (EA website accessed July 2012).

Table 8 WFD assessment of Surface Water bodies in proximity to the site

Waterbody Name / ID	Current Ecological Quality	Current Chemical Quality	2015 Predictive Ecological Quality	2015 Predicted Chemical Quality
Troutsdale Beck from Source to River Derwent GB104027067910	Poor	Not assessed	Poor	Not assessed
River Derwent from Troutsdale Beck to River Rye GB104027067930	Moderate Potential	Good	Moderate Potential	Good

The reasons for the poor ecological quality are not stated on the EA website, however, URS consider that this may be due to peat erosion and downstream sediment transport which affects water colour and decreases biodiversity (measures are proposed to reduce Peat erosion within the National Park).

Both the have been assigned an “At Risk” designation by the EA (EA website July 2012)

3.5 Land Designations

3.5.1 Source Protection Zones and Aquifer Vulnerability

Source Protection Zones (SPZ) are areas that have been designated by the EA. There are three zones; an inner or Zone 1, outer or Zone 2 and total catchment or Zone 3. The zones have been determined to represent a 50 day travel time, a 400 day travel time, and the whole groundwater catchment for public water supply groundwater sources, respectively. These zones highlight the increasing vulnerability of the groundwater abstractions to contaminant inputs. The closer the polluting activity to the groundwater source, then the greater the potential risk will be.

The SPZ map for the catchment in which the proposed drilling site lies is presented as Figure 12, which indicates that the site is located within Zone 2. The SPZ maps for the Corallian aquifer have recently been updated (June 2012). Zone 1 of the SPZ map covers a wide expanse of the Corallian aquifer and also the river Derwent and tributaries close to the site.

The river Derwent and tributaries have been included within the new EA SPZ maps to highlight that the Corallian is a highly sensitive and vulnerable aquifer due to rapid migration via extensive fractures and karst features. The River Derwent and other surface water features are known to loose water and recharge the Corallian Aquifer. As a result, the surface water features have been combined with the aquifer as contamination could impact rivers and then discharge into the underlying aquifer. In effect, the new SPZ map links both groundwater and surface water.

The site is situated above a portion of the Corallian aquifer that has been designated as Zone 2 (representing an area within a calculated 400 day travel zone). Immediately to the south of the site the Corallian aquifer has been designated as Zone 3, whereas, to the north the surface water features that emanate from the scarp slope are designated as Zone 1. Thus, URS consider that this pattern may indicate that groundwater beneath the site is more likely to flow to the north & feed the surface water features rather than to the south. Such surface water features would then flow quickly to the Derwent and then subsequently to the south where they can potentially recharge the Corallian aquifer at distance from the site.

Should groundwater in fact flow with geological dip to the south-southeast, then the closest designated Zone 1 areas relate to the various surface water features located approximately 1300m from the site (refer to Section 3.2). These then merge with the broader Zone 1 area designated for the bulk of the Corallian aquifer to the south of the site.

Please note that the actual locations of the public water sources are not shown on the maps and their location cannot be given in documents that may be in the public domain.

Aquifer Vulnerability: The designated vulnerability of the Corallian aquifer to surface infiltration of pollutants, as assessed by the EA is presented as Figure 13. The site is underlain by a highly vulnerable Principal (major) aquifer, however, in the vicinity of the site the vulnerability for the Principal aquifer is designated as low due to the presence of low leachable soil (low permeability). It should be noted, that the soils with low leachable characteristics may be thin, or where they are excavated would allow direct entry into the highly vulnerable aquifer.

3.5.2 Nitrate Vulnerable Zones

The site is located within a Nitrate Vulnerable Zone (NVZ) designated for the Jurassic Aquifers in the region (refer to Figure 14). The designation is an indirect indicator for high aquifer vulnerability to leachable pollutants and also indicates that management practices are employed by local farmers to limit nitrate usage.

3.5.3 Historic Land Use and Pollution Incidents

A review of historic 1:2,200 and 1:10,000 scale Ordnance Survey Maps supplied by Landmark Information Group (4 July 2012) for land use changes and evidence of mining or quarrying (quarries & pits often used in past as landfills) indicated the following:

- 1854: site located in area of rough grass/heath land known as Hutton Bushel Moor. Two small quarries (although noted as sandstone on the OS map, they are in fact considered to be within the Corallian limestone) are located approximately 350m to the north and 700m to the northwest of the site. The quarries were located on the scarp slope and are not considered to be an issue to the site due to a combination of their small size, distance from the site, age and the fact that groundwater at the locations of the former quarries is likely to flow northwards with topographic decline. The map also shows an ancient earthwork/embankment is located approximately 150m to the west of the site.
- 1894, 1913-1914, 1930: Same land use at the site as identified in the map from 1854. Land use in the vicinity progressively becoming more wooded from plantations in the area. The Quarries are no longer labelled or where noted on the maps, are labelled as old/disused quarries.
- 1952, 1958, 1977: site is located within Wykeham Forest, which appears to be dense coniferous woodland covering the 2km radius surrounding the site.
- 2006, 2012: Similar land use as recorded in 1977. Development of access routes in the vicinity and Lang Gate road apparent 250m to the north of the site.

According to the EA website (July 2012) no historic or active waste tips or landfills are noted within a 2km radius of the site.

According to environmental database information (Envirocheck) supplied by Landmark Information Group (4 July 2012) the following activities are noted within a 1km radius of the site (please note that provided locations are to within 100m and are presented on Figure 15):

1. Discharge Consent (NGR 496100, 489100) approximately 930m east from site: Sewage discharge of final/treated effluent into freshwater stream/river (not water company) operated privately by B M Drew at Derwent Dale, Consent authorised by the Environment Agency – current status active.
2. Three BGS registered mineral sites located 370m to the northwest, 440m to the northeast and 710m to the northeast which operated the Jurassic Sandstone. All of the mineral sites are now ceased.

A key feature of the available data set is that no pollution incidents to controlled waters are noted within a 1km radius of the site.

3.5.4 Protected Areas

There are no Sites of Special Scientific Interest (SSSI) within 2 km of the site while the location of the closest SSSI's to the site are indicated on Figure 3.

The site lies within a forest park within the North Yorkshire National Park.

4 Hydrogeological Risk Assessment

4.1 Review of Activities Proposed and the Potential Impacts

4.1.1 Site Operations

The identification of the potential sources of impact to groundwater and surface waters in the vicinity of the site has been undertaken by a review of the details of the scheme as provided by Viking UK Gas Ltd (via Petroleum Safety Services Limited). This information included the size, nature, time scale, construction methods and post extraction land use.

The proposal comprises four phases; the details of the activities that are pertinent to the HRA in each phase are;

1. **Site Construction.** The construction of a temporary access track and exploration site. The works are estimated to take about six weeks and comprise removal of topsoil & vegetation, levelling, formation of earth bund screens, a perimeter drainage system and the creation of a high density polyethylene (HDPE) impermeable membrane over the entire area of the site (approx. 90 x 120m). The impermeable membrane will also underlie the perimeter drains. The membrane will be sandwiched between two layers of 300g/m^2 needle punch non woven geotextile to provide protection from puncturing by the underlying Corallian Limestone. The HDPE impermeable membrane will be covered with MOT Type 1 hardcore to create the site working surface. Two cellars will be constructed roughly in the centre of the site. The cellars comprise 2.4m diameter concrete rings which are integrated into the impermeable membrane. The integrity of the cellars is to be tested to ensure that they are sealed.

2. **Drilling.** The drilling of up to two appraisal wells each to a total depth of approximately 1980 m below seal level (approx. 2190m below ground level). The proposed well design and anticipated stratigraphy is shown in Figure 16. The drilling will be undertaken by two different rigs. The top section though the Corallian, Oxford Clay Formation and Middle Jurassic Ravenscar Group sediments to the top of the Lias Group at an anticipated depth of 97m below sea level would be undertaken by a 'Waterwell Rig' while the rest of the depth would be undertaken with an oilfield drilling rig. The duration of the drilling activities are estimated at six to twelve weeks per well with additional two weeks mobilisation and one week of demobilisation. With regards the first drilling run to seal the Upper and Middle Jurassic strata to a depth of approximately 97m below sea level, the diameter of the casing will be 18$^5/_8$" (473mm). The drilling method for the waterwell rig will use water based bentonite drilling fluids. Once the first casing run has been installed and the Upper and Middle Jurassic strata isolated from the borehole, the oilfield drilling rig used to continue the borehole to depth will deploy a range of water based fluids in the remaining 13$^3/_8$" (340mm), 9$^5/_8$" (245mm) and 7" (178mm) holes to depth. These deeper drilling fluids are isolated from the Corallian principal aquifer and Ravenscar secondary aquifer by steel casing and cement grouting which will completely seal the external annulus of the 18$^5/_8$", 13$^3/_8$" and 9$^5/_8$" casings. A deeper cement seal will be placed in the annulus for the final 7" casing which will isolate the Triassic Sandstone and overlap the 9$^5/_8$" casing by approximately 100m. The proposed method for cementing of casing below the first two strings, will ensure any cement goes 100ft above any permeable or hydrocarbon bearing zones. This is the standard used by Oil and Gas UK for the abandonment of wells; however, this is incorporated into the design of the well in order to minimise potential environmental issues and also to make it easier for well abandonments at a later date.

3. **Testing**. It is planned to undertake evaluative drill stem tests and extended well tests. The extended well test could be for a period of up to 90 days when the gas reservoirs are evaluated. During this period the wells are pumped and are anticipated to produce a mixture of gas and water. The anticipated gas and water mixture will be separated and collected in tanks before removal from site for disposal or further processing. The water will likely be saline and must be disposed at a specialist facility. Whilst on site the water poses a potential source of contamination and is held in tanks in bunded areas prior to disposal. Any gas produced during the well test will be flared to establish whether it is commercial.

4. **Restoration**. Site restoration and aftercare or further planning application. If the prospect is not commercial the site will be restored over a five week period to its original condition. The decision to abandon and plug the well(s) may be made by the applicant at any phase of the development. Another planning application would be made to the Mineral Planning Authority should the applicant wish to develop the site into a production gas well. The site restoration would in such an instance be delayed pending the subsequent planning application. The well if abandoned will be sealed with mechanical and cement plugs within the steel casing. The casing strings will be cut off 1.5m below ground level and finished with a welded steel plate. Restoration will remove all materials brought to make the site work area, replace the soil stored in the perimeter bunds. Five years of aftercare will ensure that the land is restored to its previous condition.

4.1.2 Potential sources of impact on groundwater

The potential sources of impact on the water environment for evaluation may include:

1. Incidents that result in the spillage of pollutants to the ground prior to the creation of an effectively sealed site surface;
2. Loss of foul or contaminated drainage from the site via surface water flow or to nearby surface water features or more likely due to permeable soils underground strata and hence to the groundwater;
3. Leakage from the perimeter drainage system due to faults with its construction, particularly if the drains contain pollutants;
4. Loss of chemicals or fuel stored on site to the perimeter drainage or elsewhere that exceeds the storage capacity in the drains;
5. Loss of drilling fluids and associated cuttings into fractures within the underground strata during the construction of wells though the Corallian and Ravenscar aquifers;
6. Loss of cement and other grouting materials into fractures within the underground strata during the grouting procedures of the 18 $^{5}/_{8}$” casing;
7. Loss of drilling fluids while constructing the wells below the top of the Lias Group by leakage through or around the casing and grout seal.
8. Loss of drilling fluids or produced water (brine) that may collect in the wellhead cellars into the ground through failure in the wellhead cellar construction;
9. Incidents that result in loss of contaminants to ground or surface water from vehicles transporting construction materials or product or waste materials to and from the site;

10. Flushing of contaminated surface retained pollutants into the ground during the site decommissioning process;

The list of potential sources of impact includes those that the proposed activities include embedded mitigation measures within the design.

4.1.3 Water Quality

The risk to groundwater quality can arise from the introduction of pollutants to the ground or by the mobilisation of existing contamination (current conditions). At the site and study area there is neither evidence nor expectation of groundwater contamination. This risk factor is, therefore, not carried forward into the risk assessment matrix. The more significant risk to groundwater arises from the introduction of pollutants from the surface or at depth from the construction of the site facility, storage of chemicals on the new site and the drilling of the appraisal wells. The potential losses from the site of polluting chemicals will result in an impact upon the groundwater that underlies the site. The extent of any pollution plume that is created under the site will depend upon the quantity lost and its properties (attenuation rates, density etc). The groundwater level and distribution of major fractures within the Corallian will all play a role in the transport of pollutants underground.

4.2 Receptor Importance

The assessment of Baseline Conditions, as identified in Section 3, has identified the following key groundwater and surface water receptors:

Corallian Aquifer: The most significant and sensitive receptor for the current HRA is deemed to be the Upper Jurassic Corallian strata that underlies the site to a depth of about 40m and extends laterally over the Tabular Hills of the North Yorkshire Moors National Park. The importance of the receptor is assessed as being **very high**. The reasons for the classification of the receptor are in accordance with the factors set out in the method in Table 1, namely that the Corallian is a regionally important principal aquifer which supports public water supply abstraction for Scarborough and the surrounding areas. Moreover, Corallian groundwater is the source of baseflow into surrounding springs and the River Derwent and its tributaries. Groundwater flow within the Corallian aquifer is characterised by rapid migration via extensive fractures and karst features.

Ravenscar Group: of secondary importance will be the underlying minor aquifers of the Ravenscar Group, which in the area of interest to the current site are not currently used for water supply. However, this formation is exposed along the base of Troutsdale Beck to the north of the site and as such may provide base flow to springs and the beck within this valley.

Surface Water Features: Loss of foul or contaminated drainage from the site via surface water flow or to nearby surface water features is considered a relatively minor risk in comparison to the potential impacts to the underlying Corallian aquifer due to permeable soils underground strata. Such losses and initial migration via surface flow would rapidly infiltrate and impact the Corallian aquifer rather than continue later migration across the surface. Surface water features would still remain at potential risk due to their flows being sustained by baseflow derived from groundwater within the Corallian. As such, URS propose that any potential risks to surface water features would firstly be addressed by the assessment of risks to the Corallian aquifer and that any mitigation measures recommended for the Corallian would, by default, be protective of nearby surface waters.

The much deeper Triassic Sandstone (>800m below sea level) and Permian aquifers (>1000m below sea level) are not considered to be important receptors due to their depth and likely high salinity or mineralised groundwater quality. At shallow depths these aquifers are highly productive aquifer of national importance, however, at the depths beneath the current site they are likely not to be exploited for water supply or provide base flow to surface water features. As such these aquifer are not considered to represent viable sensitive receptors for pollution from the proposed drilling operations and are not considered further.

4.3 Identification of Pathways

The pathway provides a route or a method by which potential source or sources of contamination could impact on receptors.

The assessment of baseline conditions described in Section 3 indicates that the unsaturated and saturated Corallian strata under the site are likely to be highly fractured, particularly in the zone of water table fluctuation.

The pathways that are considered in this HRA are;

1. From the ground surface, the pathways for liquid contaminants would be expected to follow the fractures and smaller fissures present withinthe Corallian. Such feature could provide a rapid route for liquid contaminants to reach the groundwater. Within the unsaturated zone of the aquifer, liquid contaminants would be expected to predominantly move vertically, but would also spread laterally by dispersion along sub-horizontal bedding plane fractures over a broader area. Upon reaching the water table, the contaminants would move in the direction of groundwater flow. The permeability of Corallian strata is likely to be high due to its highly fractured nature with good connectivity between fracture networks which will rest in potentially rapid movement of contaminants laterally away from the site. This pathway exists prior to the sealing of the site surface with an impermeable membrane.
2. Through failures in the impermeable membrane where it may become damaged. This pathway could originate under the site or from beneath the perimeter drains. Once in the unsaturated zone the pathway would be the same as that in Pathway 1 above.
3. Through faults in the cellars as a result of unidentified construction issues that provide a route through the cellar wall or around the junction between the cellar floor and the 18 $^{5}/_{8}$" (473mm) casing. The pathway through the unsaturated zone would be the same as that in Pathway 1 above.
4. A vertical pathway through the unsaturated zone could be created in the annulus of the well between the 18$^{5}/_{8}$" (473mm) casing and the borehole wall. This void will be completely filled with grout to the surface.
5. Movement of fluids during the drilling of the 18 $^{5}/_{8}$" (473mm) hole through the borehole walls that intercept fractures could provide a rapid pathway to depth for the short period when the drilling operations through the Corallian and Ravenscar strata take place.
6. Movement from depth below the casing shoe of the 18 $^{5}/_{8}$" (473mm) casing when drilling the 13$^{3}/_{8}$" (340mm) hole. This would only provide a pathway if the base of the cement job were to be unsatisfactory or that the casing shoe is set at too shallow a depth and within strata that is permeable. The casing depth is proposed to be at approximately 97m below sea level which is anticipated to be approximately 3m below the prognosis depth for the base of the Middle Jurassic Ravenscar Group. To reduce

the possibility of this pathway the setting of the conductor pipe 10 m into the Lower Jurassic Lias Formation is recommended.

4.4 Appraisal of Magnitude of Impact on Receptors

The proposed development has the potential to impact water resource features within the area. The significance of any effect will depend on the sensitivity of the water resource and the current conditions of the resources, the magnitude of any impact and the implementation of any mitigation measures during construction and operation.

The magnitude of the potential impact on the receptor has also qualitatively assessed the anticipated likelihood of an of the risk elements. Those events that are considered very unlikely are given a lower magnitude than those that are more likely to occur. The likelihood of the particular event that could present a risk to the receptors has also been assessed with the embedded mitigation within the proposed planning application.

4.5 Assessment of Significance of Effects

As described in Section 2.1, the significance of effects is a product of the magnitude of the impact and the importance of the receptor. The estimated significance of the potential impacts on the identified receptors are presented in Table 9. The significance of the effect is assessed shown with the embedded mitigation measures, which are stated, and with the additional mitigation measures recommended. Where it is considered that the embedded and or the additional mitigation are likely to completely remove the risk then the magnitude of potential impact is marked as ‘Scoped Out’ and the significance marked as ‘No Impact’

Table 9 Hydrogeological Risk Assessment Summary

Activity or Phase	Potential Source of Impact	Pathway	Receptor Name	Receptor Importance/ Sensitivity	Likelihood	Magnitude of Potential Impact	Significance of effect with embedded mitigation	Embedded Mitigation within proposed application	Additional Mitigation	Magnitude of potential impact with additional mitigation	Significance after additional mitigation
Site Construction	Existing contamination under site	fractures in unsaturated zone	Unsaturated Corallian	Medium	Very Unlikely	Very Low	Negligible		Geotechnical boreholes to establish baseline conditions	Scoped Out	No Impact
			Saturated Corallian	Very High	Very Unlikely	Very Low	Moderate/Minor			Scoped Out	No Impact
All Construction Phases	Fuel Oil spillage on ground	fractures in unsaturated zone	Unsaturated Corallian	Medium	Likely	Medium	Moderate/Minor	Use of double walled fuel tanks and bunded areas		Scoped Out	No Impact
			Saturated Corallian	Very High	Likely	Medium	Major/Moderate	Use of site impermeable membrane		Scoped Out	No Impact
Construction of Wells	Drilling Fluid - Bentonite, Caustic Soda, Sodium Carbonate	From 18 $^{5}/_{8}$" (473mm) borehole walls into fractures	Unsaturated Corallian	Medium	Unlikely	Medium	Moderate/Minor	Use of drilling fluid loss materials to plug the fractures	a. Clean drilling equipment prior to use at the site. b. Water well drilling techniques - Reverse circulation and use of potable water as the drilling fluid	Scoped Out	No Impact
			Saturated Corallian	Very High	Unlikely	Medium	Major/Moderate			Scoped Out	No Impact
	Contaminants inadvertently introduced as a result of failures of drilling equipment		Unsaturated Corallian	Medium	Very Unlikely	Very Low	Negligible	Standard good practice for rig & equipment maintenance		Very Low	Negligible
			Saturated Corallian	Very High	Very Unlikely	Very Low	Moderate/Minor			Very Low	Moderate/ Minor Likely to be Minor due to low likelihood of occurrence
			Saturated Ravenscar Group								
	Cement Grout during sealing of the 18 $^{5}/_{8}$" (473mm) casing	Directly via fractures & fissures intercepted by the borehole	Unsaturated Corallian	Very High	Likely	Medium	Moderate	Continuous monitoring of cementation process to identify excessive losses		Medium	Moderate
			Saturated Corallian	Medium	Likely	Low	Minor			Low	Minor
			Saturated Ravenscar Group								
	Water based drilling fluids while drilling of the deeper hole sections from 97m below sea level to base of well 1980m below seal level.	In annulus behind the casing strings if the cement grout is incomplete	Saturated Corallian	Very High	Very Unlikely	Very Low	Moderate/Minor	a. Pressure testing of casing following cementation b. Top casing to be set within the Lias Group strata. Monitoring drilling fluid losses	Ensure casing set 10m into Lias Clay	Scoped Out	No Impact
			Saturated Ravenscar Group								

Activity or Phase	Potential Source of Impact	Pathway	Receptor Name	Receptor Importance/ Sensitivity	Likelihood	Magnitude of Potential Impact	Significance of effect with embedded mitigation	Embedded Mitigation within proposed application	Additional Mitigation	Magnitude of potential impact with additional mitigation	Significance after additional mitigation
Well Construction & Testing	Site Chemical and drilling fluids lost at surface	Spillage onto site surface, to site drainage then via leaks in impermeable membrane or overtopping drainage system capacity	Unsaturated Corallian Saturated Corallian	Medium	Unlikely	Medium	Moderate/Minor	a. Bunding of chemicals stored on site b. Heat sealing of impermeable membrane c. Drain capacity to be sufficient to retain storm event site runoff d. Site runoff to be tankered offsite for appropriate disposal	a. Regular visual inspection of perimeter drain b. Monitor daily the water level in perimeter drain c. Contingency plan to empty drain and repair should leakage be suspected	Scoped Out	No Impact
Testing	Produced water (brine) that is lost from the well head and collects in the wellhead cellar	Leakage from the wellhead cellar through faults in the impermeable seal or via faults in the wellhead	Unsaturated Corallian Saturated Corallian	Medium	Unlikely	Medium	Moderate/Minor	a. well cellar sealed with impermeable membrane b. annulus of 17 1/2" hole grouted to surface with cement c. integrity of cement seals demonstrated with leak off tests	a. routine regular inspection of cellars b. pump out and dispose using a licensed waste carrier of fluids collected in the cellar.	Scoped Out	No Impact
	Produced water (brine) that is lost from subsurface	Leakage through unidentified faults in the well casing	Saturated Corallian Saturated Ravenscar Group	Very High	Very Unlikely	Very Low	Moderate	a. Well integrity testing b. Detail monitoring of pressures during production testing. Should these indicate loss of fluids underground then remedial action will be taken		Very Low	Moderate/ Minor Likely to be Minor due to low likelihood of occurrence
Site Restoration	Contaminants within site surface hardcore accumulated during drilling and testing phases	Leached from hardcore onto areas of site following removal of impermeable membrane, thence directly into the subsurface	Unsaturated Corallian Saturated Corallian	Medium	Very Unlikely	Low	Minor	Removal of all potentially contaminated material from site prior to removal of the impermeable membrane		Scoped Out	No Impact
Construction & Testing	Loss of pollutants during road transportation as a result of accident or misadventure. Produced hydrocarbons, brines, drilling arisings, drilling fluids	Various	Various	Un assessed	Unlikely	Very Low	Un assessed	Selection of contractors with experience in petroleum products and high level of HSE		On-site Risks Scoped out Off-site Risks Un assessed	On-site No Impact Off-site Risks Un assessed

5 Conclusions

A hydrogeological risk assessment (HRA) has been undertaken for the proposed gas appraisal borehole drilling at Ebbertson Moor 4 site to identify whether the development is likely to have significant residual effects upon water features.

The water features that could be potentially adversely impacted by a development are the Corallian and Ravenscar aquifers.

Based upon the information supplied to URS for this assessment, the following conclusions are drawn:

- It is considered that the greatest potential impact to the Corallian and Ravenscar aquifers posed by the proposed appraisal site is likely to result from drilling activities, namely the release of turbid waters and/or associated contaminants to groundwater. Although due to the proposed drilling methods the likelihood of impact is considered low, it is greatest during the first stage of drilling through the Corallian aquifer. The proposed drilling method is designed to completely isolate the Corallian and the underlying Ravenscar Group aquifers from the deeper drilling activities by the sealing of the first (outer) casing run. In addition, the use of water based drilling muds during all drilling phases will act to seal the borehole wall and limit any loss of fluid to the wider Corallian and Ravenscar aquifers .
- Following completion of the full borehole, the Corallian and Ravenscar aquifers are considered to be protected from very deep fluids by the presence of four separate well casings, all of which cover the full length of the Corallian and Ravenscar aquifers. In addition, the annuluses for all the casings are to be fully cemented. It should be noted, however, that this protection is reliant on adequate cement grout seals to fill the small voids between individual well casings and also the borehole wall. These seals are due to be pressure tested as part of the installation works.
- The potential risks to groundwater posed by above ground activities, is considered to be low, provided the following are maintained:
  - the integrity of the impermeable membrane is maintained throughout the lifespan of the site operations, Where new services or structures are planned then trenching or foundation excavations should be prohibited unless suitable mitigation measures and appropriate below ground trench/foundation designs to achieve fluid containment are adopted.
  - continual integrity testing of wells, wellhead chambers and above ground pipes, tanks/bunded areas etc
  - continual operation throughout the lifespan of the site in line with the most up to date management, health & safety and environmental standards in operation at the time.

Mitigation measures, most of which are embedded into the design of the development, have significantly reduced the risk of contamination associated with the construction and operation of the site for gas appraisal via the drilling and testing of a ca. 2000m deep borehole from entering the aquifer in either the unsaturated or saturated zones. The significance of the effect of this risk is assessed to be no impact or negligible for most categories assessed, including the completed borehole. However, during the drilling phase of works, minor to moderate potential risks are indicated for the loss of cement grout to the aquifer (as the first well casing is sealed) and also for the unlikely event that a drill rig breakdown results in the loss of fluids to the aquifer. Although categorised as “Moderate” at worse, under the adopted risk assessment methodology, this is only one graduation above the lowest possible effect that can be assessed for activities on the Corallian and Ravenscar aquifers which is “Moderate/Minor”. Given the low likelihood of such events occurring, the moderate designation is not considered to be significant.

Based upon the available information supplied to URS, the proposed drilling method, along with continued operation of the site and associated maintenance to ‘up to date’ regulatory standards, we consider that site represents a low to minor risk to the Corallian aquifer, primarily due to the mitigation measures implemented by the site. However, such mitigation measures should be continually reviewed and revised, especially where site conditions vary from currently expected. It should also be noted that although likely risks are deemed at this stage to be ‘low to minor’, these could potentially increase to ‘moderate’ as a result of unforeseen situations or where failures of the mitigation measures arise.

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Scarborough Borough Council (2012) Details of private abstractions close to site. Information sent by e-mail to Mr Philip Silk of Petroleum Safety Services Limited

Yorkshire Water Services (2012) Wykeham 2 Well Site, Sawdon, Scarborough - Drilling Operations on behalf of Viking UK Gas Limited. Letter response by e-mail from Stephanie Walden (YWS) to Mr Philip Silk (reference N000767, dated 16 February 2012).

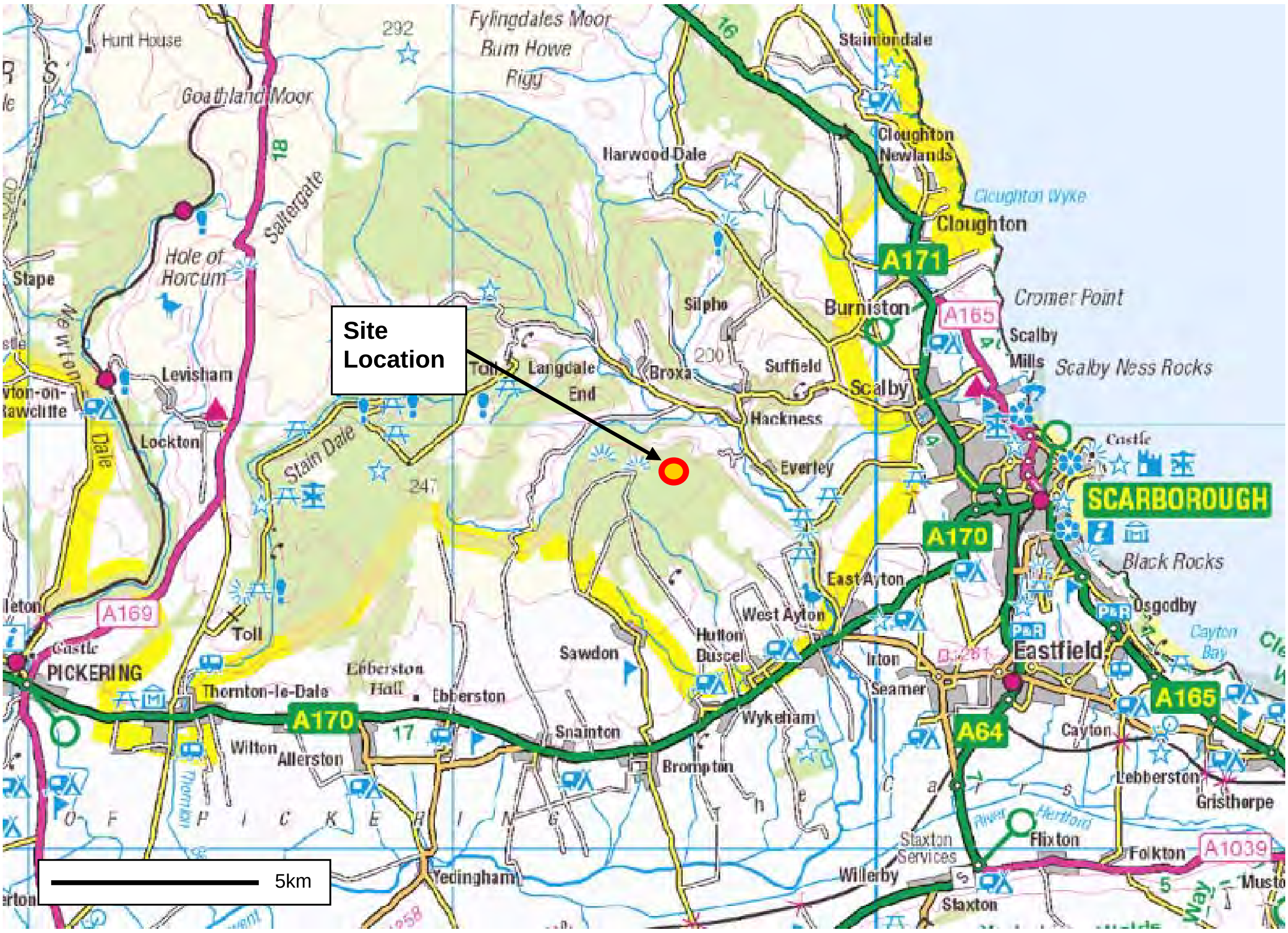


Figure 1: General Location Map (1:250,000 Scale Ordnance Survey)

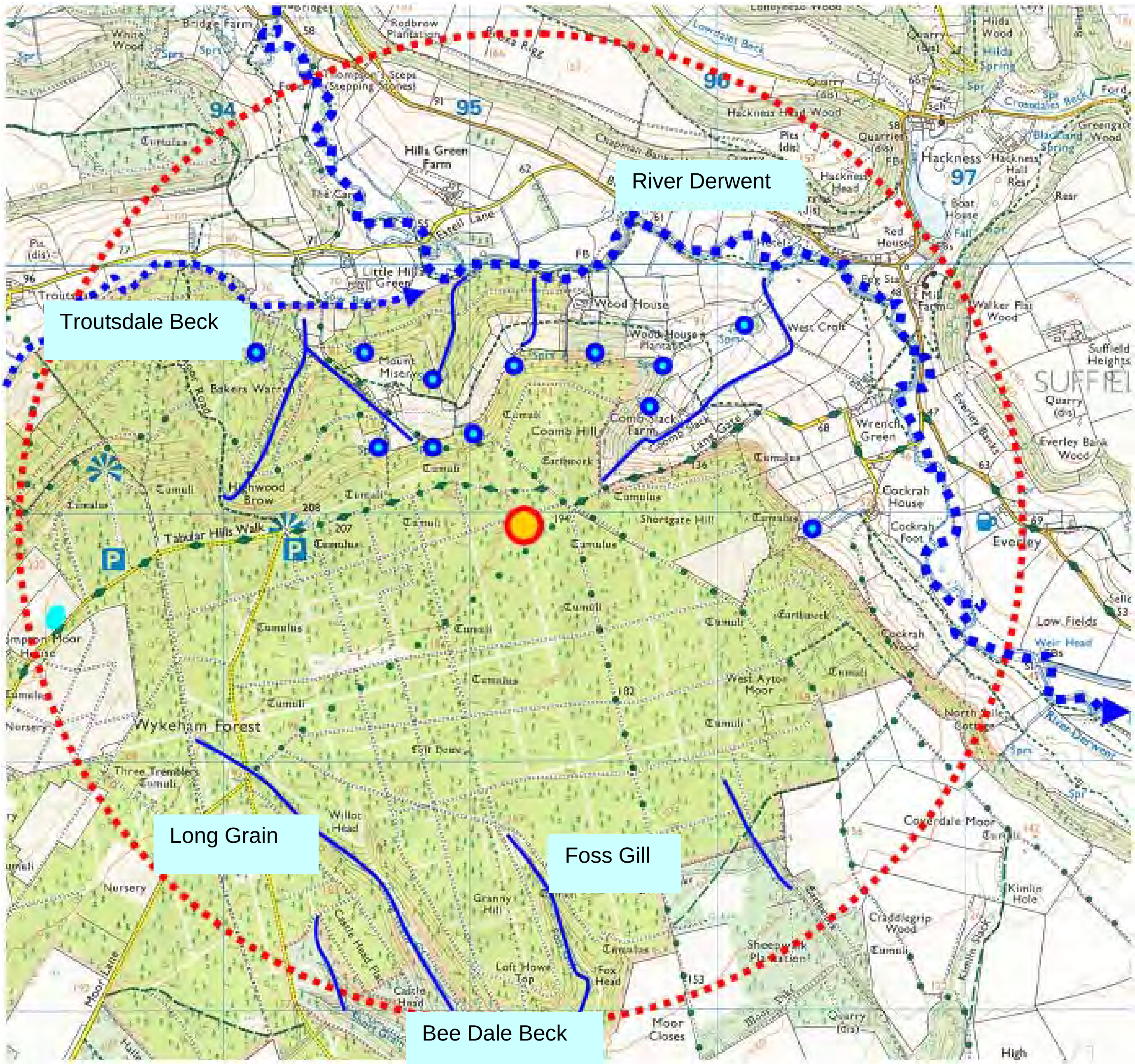


Figure 2: Detailed Site Location Map Highlighting Key Surface Water Features and Spring Locations

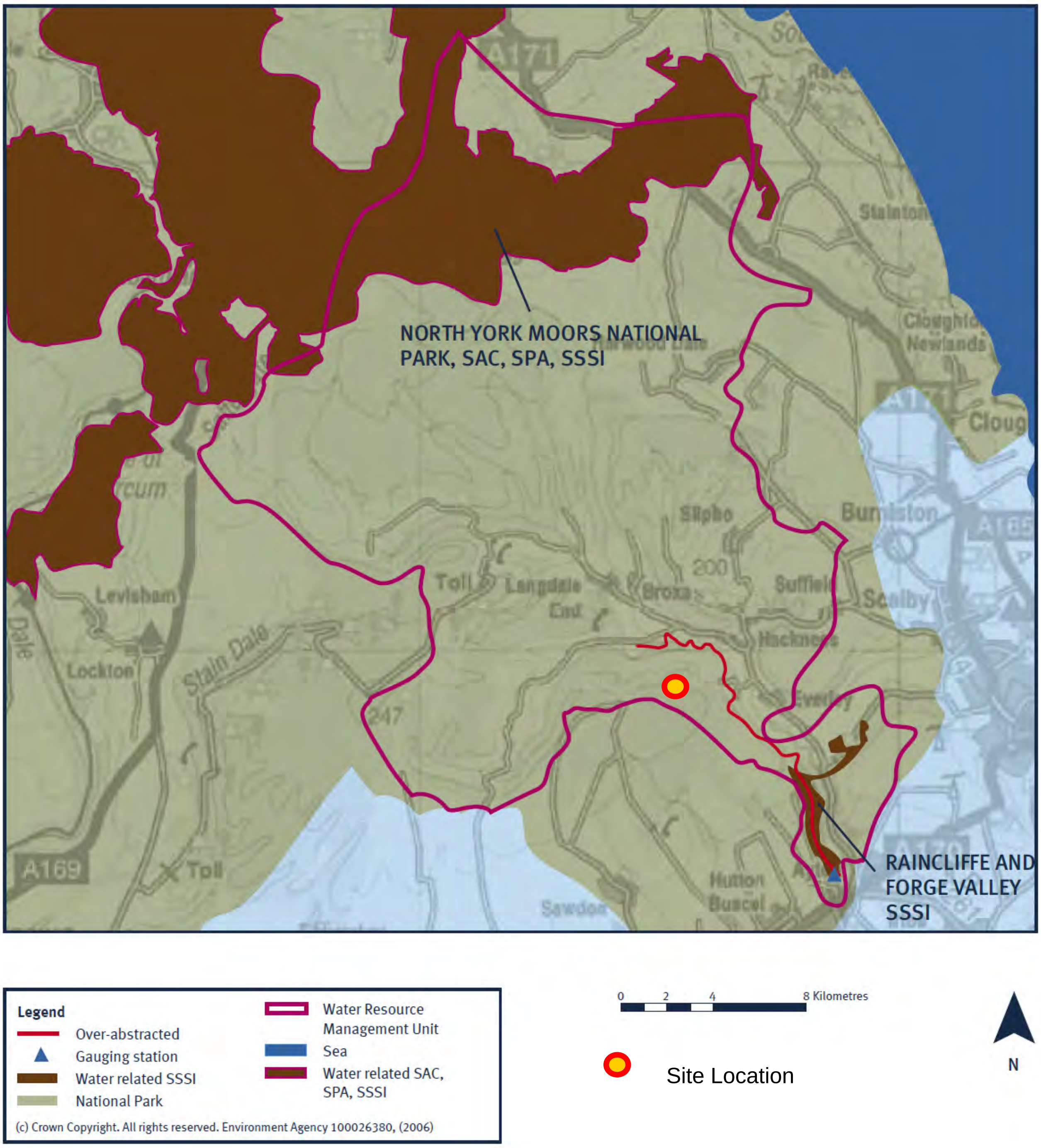
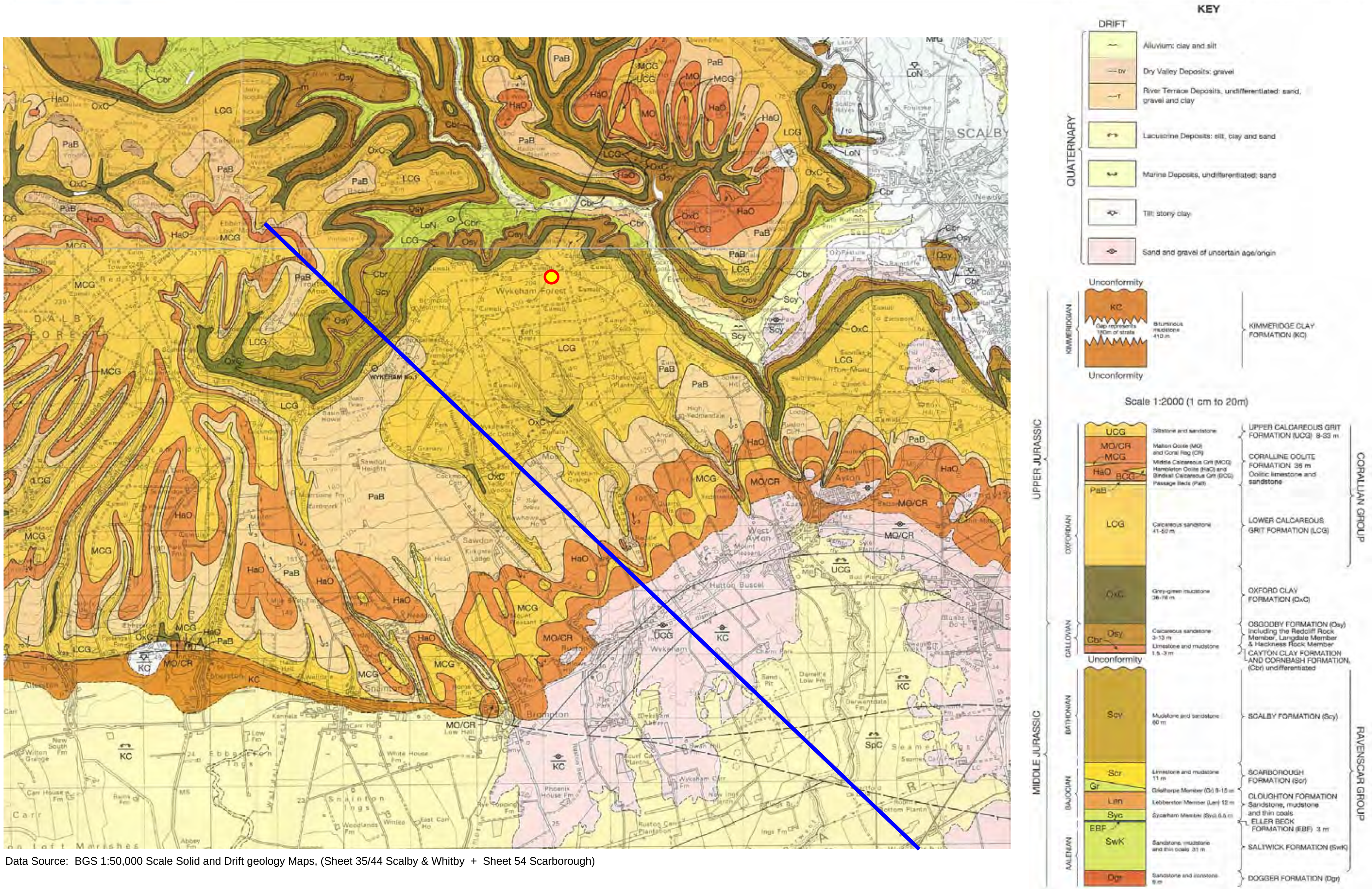


Figure 3: Location of Designated SSSI's and over abstracted reaches of the River Derwent within the West Ayton Water Resource Management Unit (Environment Agency 2006)



Data Source: BGS 1:50,000 Scale Solid and Drift geology Maps, (Sheet 35/44 Scalby & Whitby + Sheet 54 Scarborough)

Figure 4 Solid and Drift Geology in Area Around Site

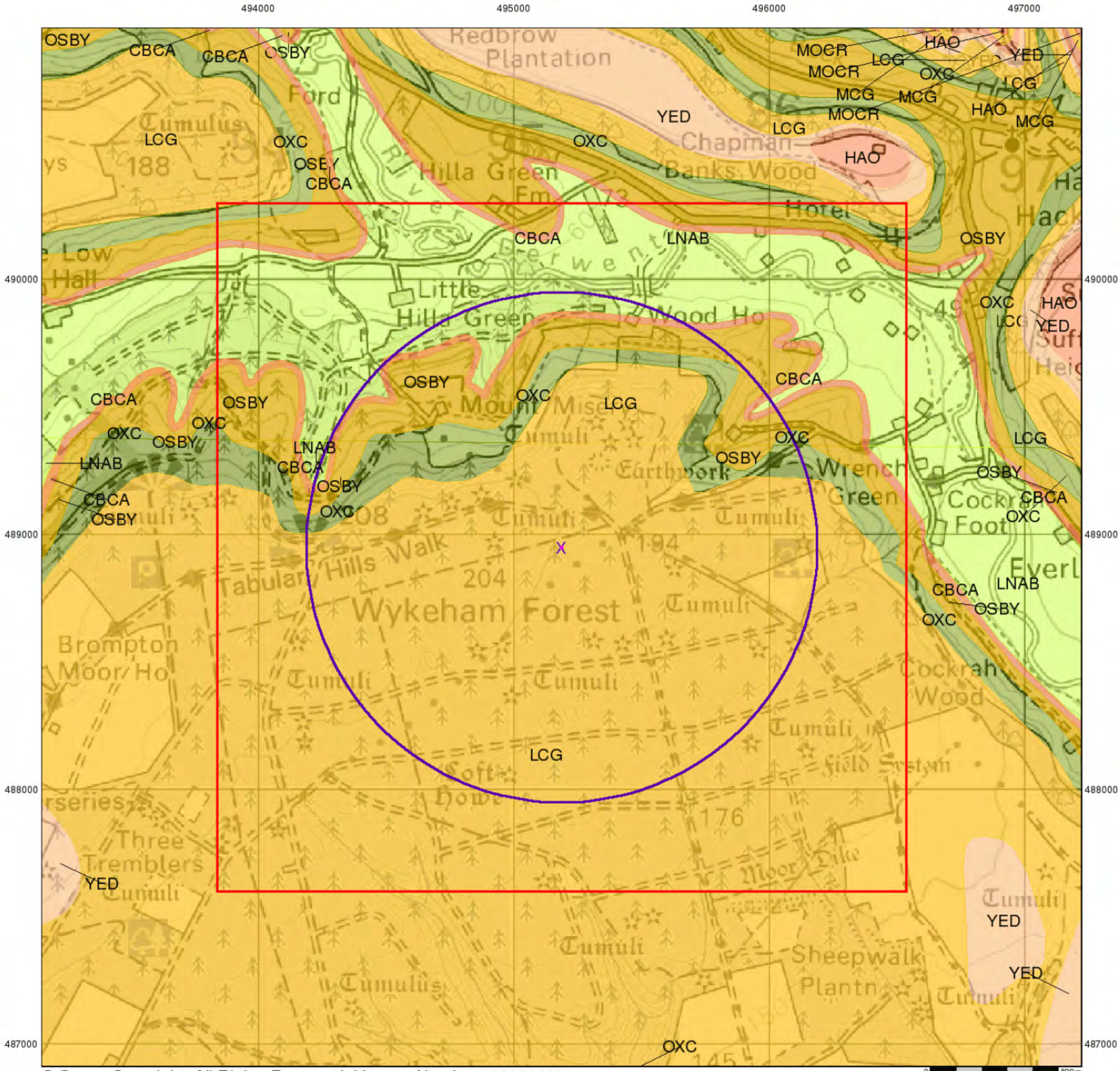


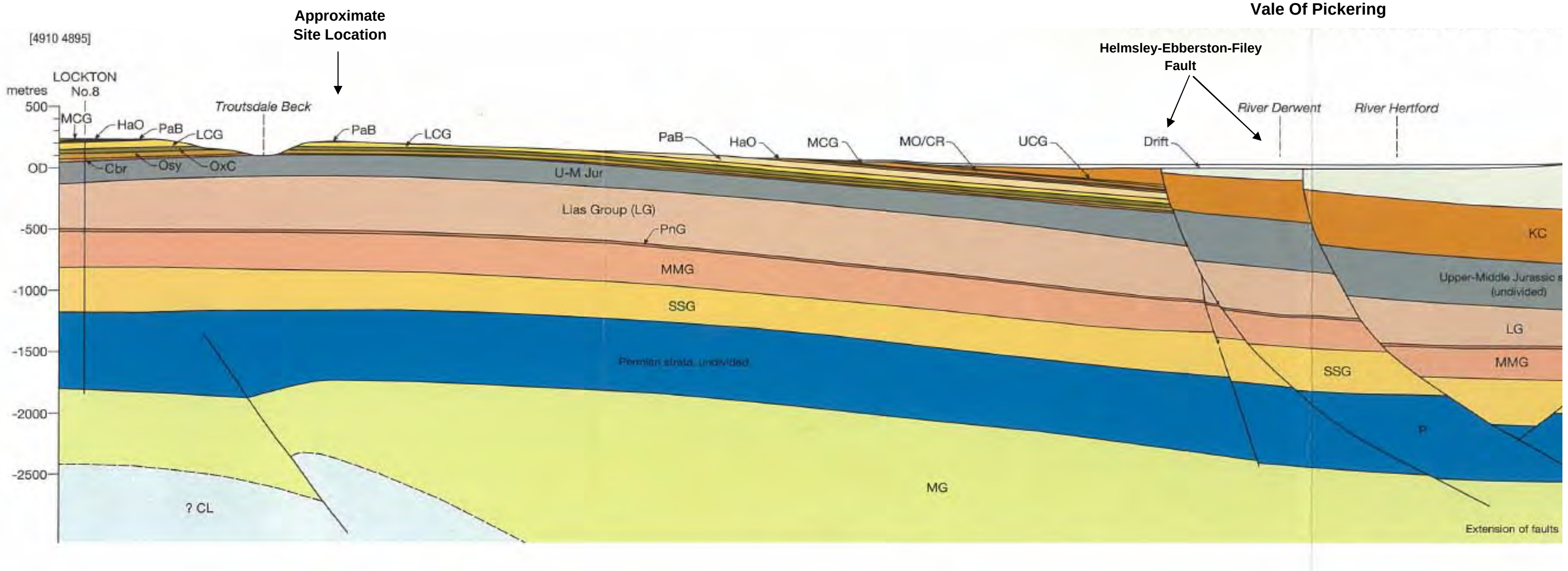
Image provided by Envirocheck report Ref: 40039059_1_1, dated 16 February 2012

Map Colour	Lex Code	Rock Name
	ALV	Alluvium
	RTDU	River Terrace Deposits (Undifferentiated)
	RTDU	River Terrace Deposits (Undifferentiated)

Map Colour	Lex Code	Rock Name
	LCG	Lower Calcareous Grit Formation
	YED	Yedmandale Member
	YED	Yedmandale Member
	HAO	Hambleton Oolite Member

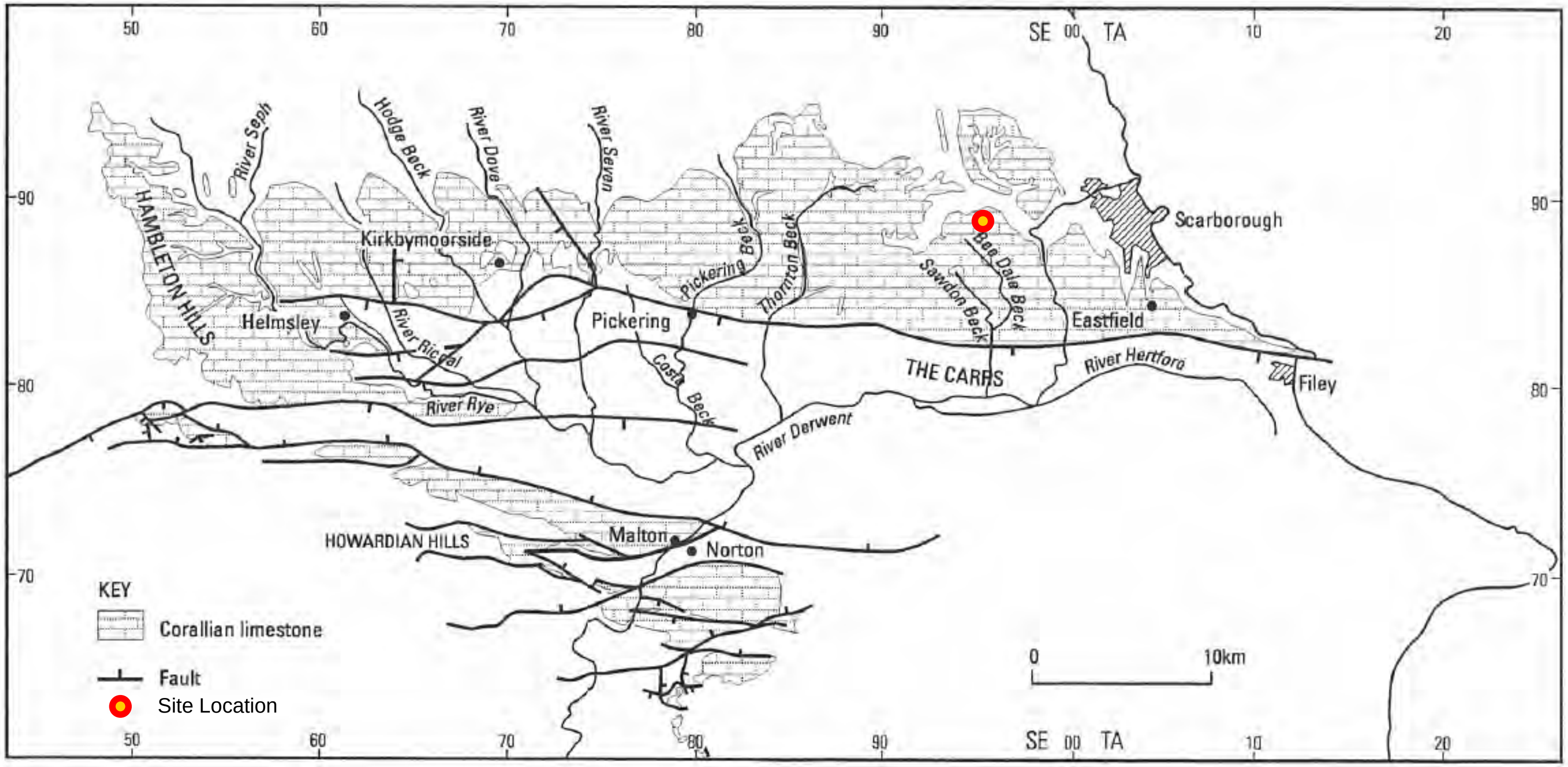
Map Colour	Lex Code	Rock Name
	OXC	Oxford Clay Formation
	OSBY	Osgodby Formation
	CBCA	Cornbrash Formation and Cayton Clay Formation (Undifferentiated)
	LNAB	Long Nab Member

Figure 5: Detailed Geology Map for the Immediate Area of the Site



Source: BGS Geological Sheet #54 Scarborough 1:50,000 Scale (Solid and Drift Geology)

Figure 6 Regional Geological Cross-Section



Adapted from Allen *et al* 1997

Figure 7: Outcrop Area For the Corallian Limestone Aquifer

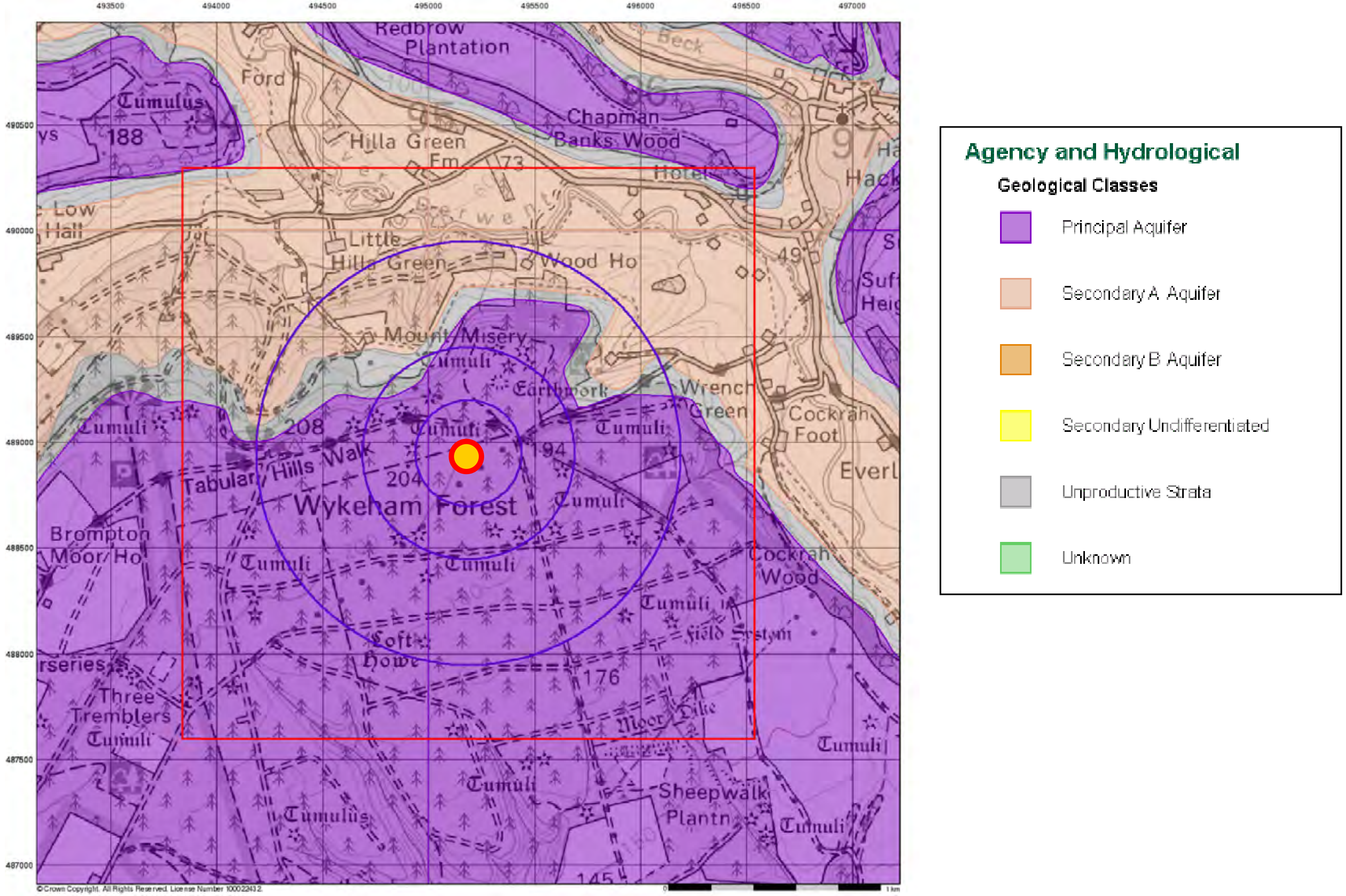
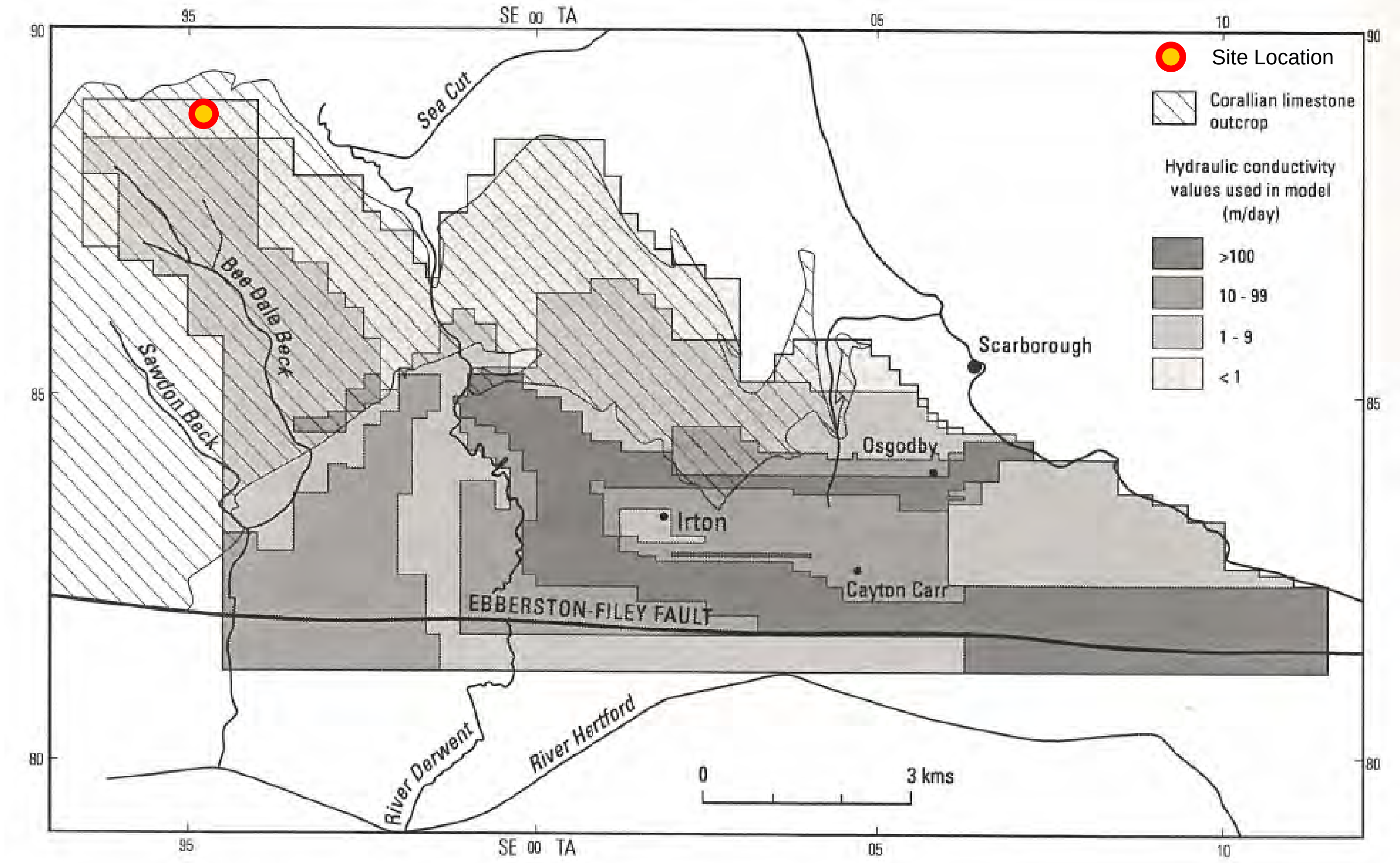


Figure 8: EA Aquifer Classification (Adapted from Landmark Survey Report, July 2012)



Source: Aspinwall (1996) in Allen et al (1997)

Figure 9: Distribution of Modelled Bulk Hydraulic Conductivity for the Corallian Limestone Aquifer

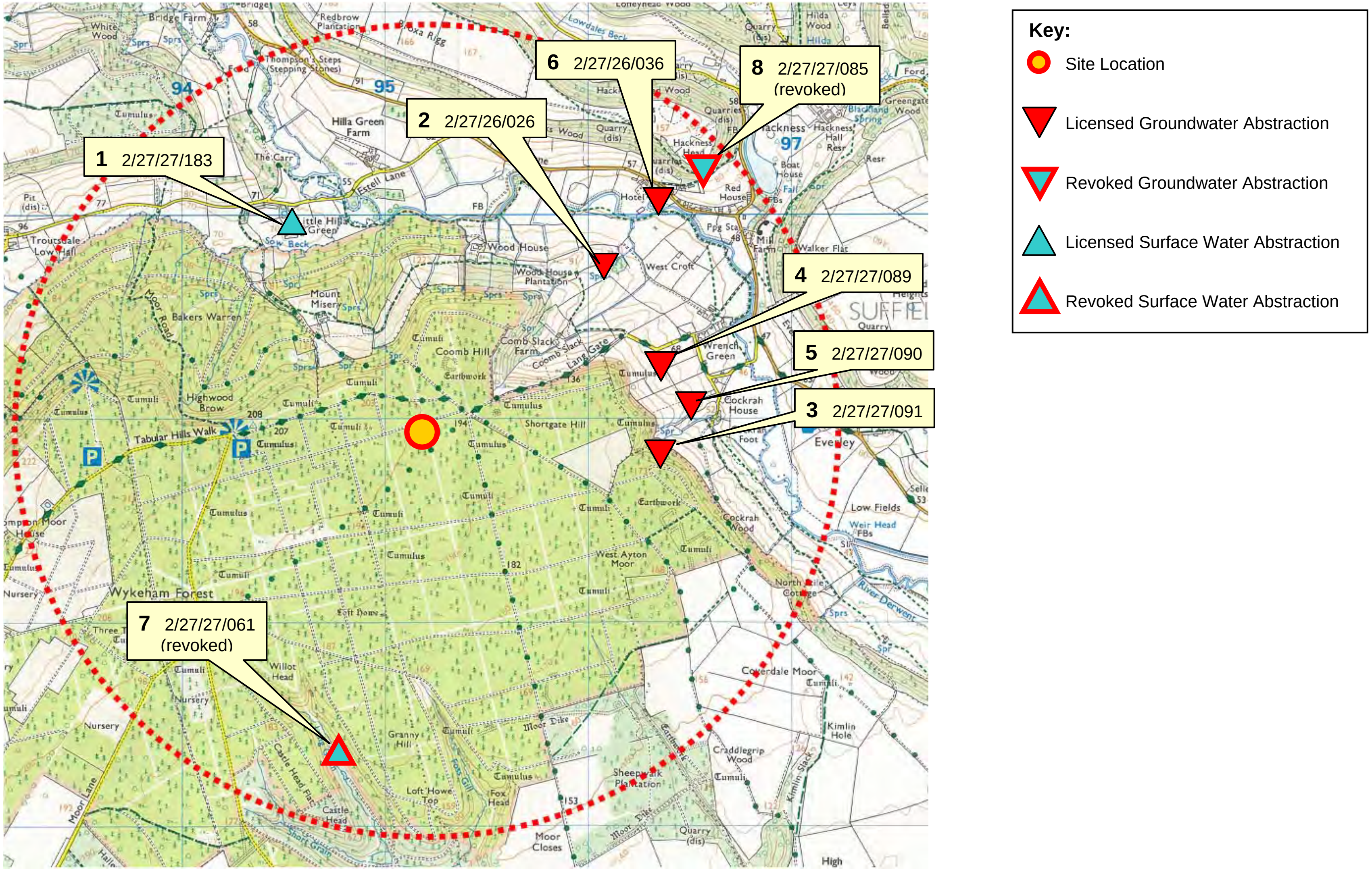


Figure 10: Location of Licensed and Private Water Abstractions within a 2km radius of site (adapted from information supplied by Landmark Survey Report 2012 and EA Supplied Information July 2012)

Current Ecology Quality | **Current Chemical Quality**

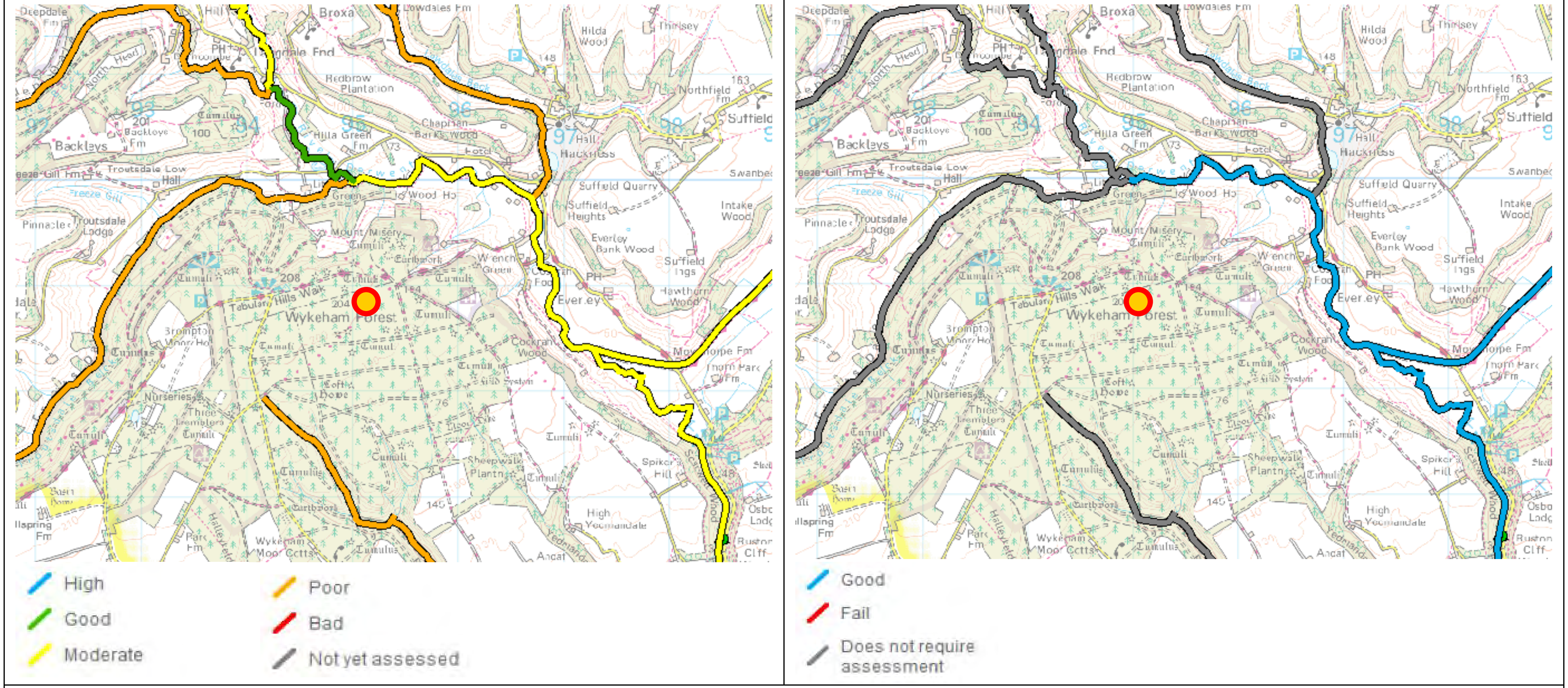


Figure 11: WFD Designation for Surface Waters in the vicinity of the site (EA website July 2012)

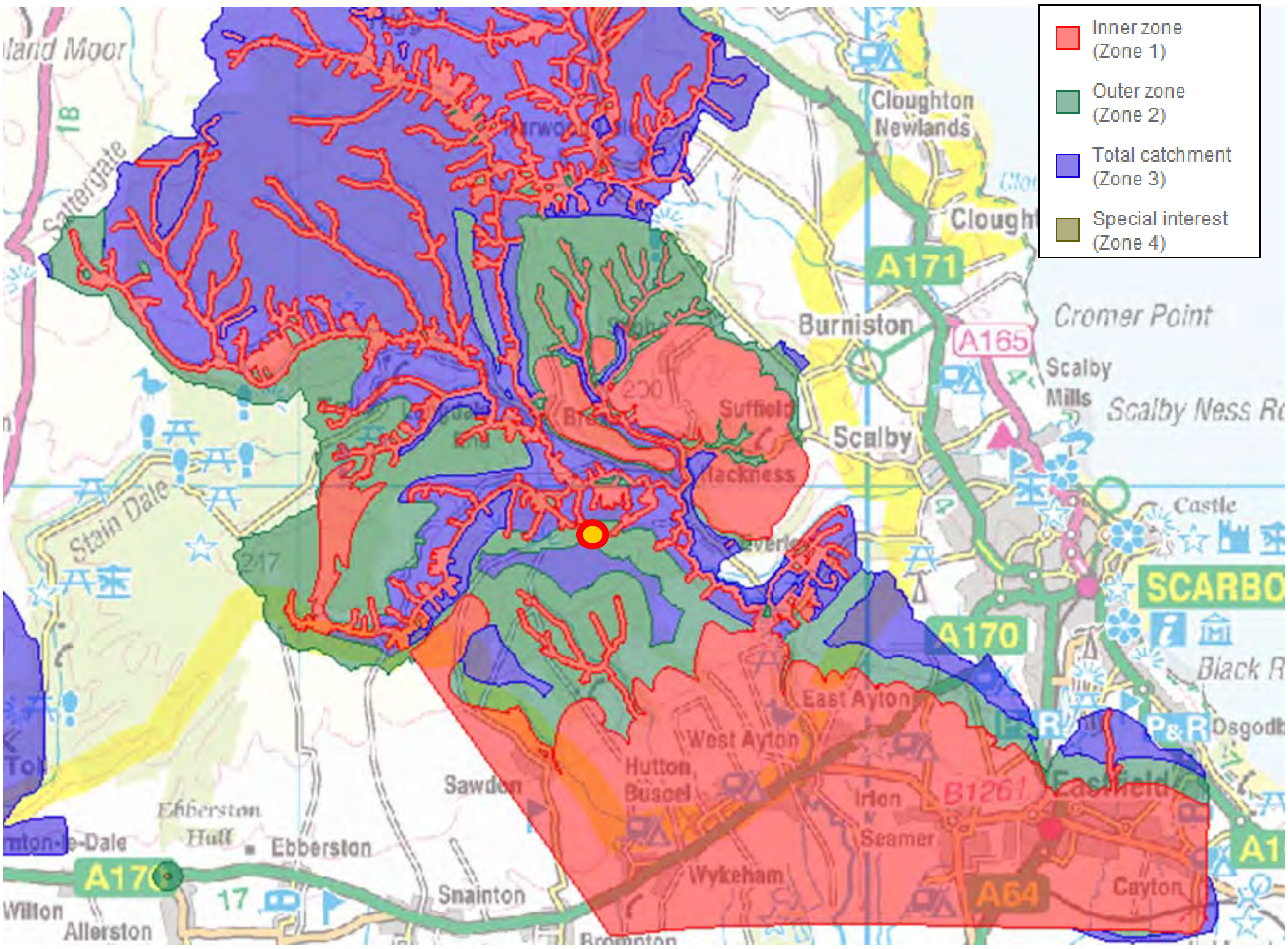


Figure 12: Designated Source Protection Zones (Environment Agency Website 2012)

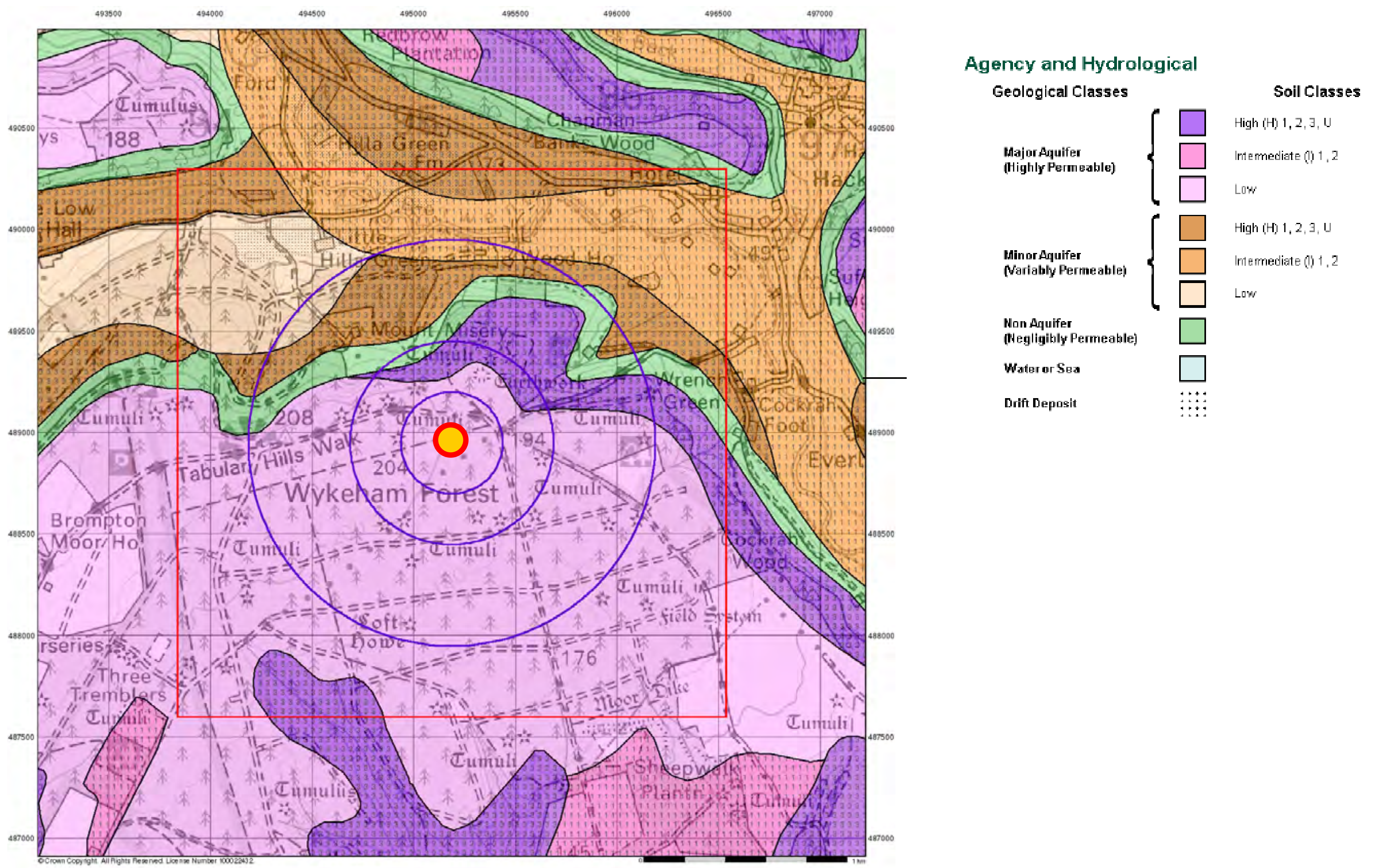


Figure 13: EA Groundwater Vulnerability Classification (Adapted from Landmark Survey Report, July 2012)

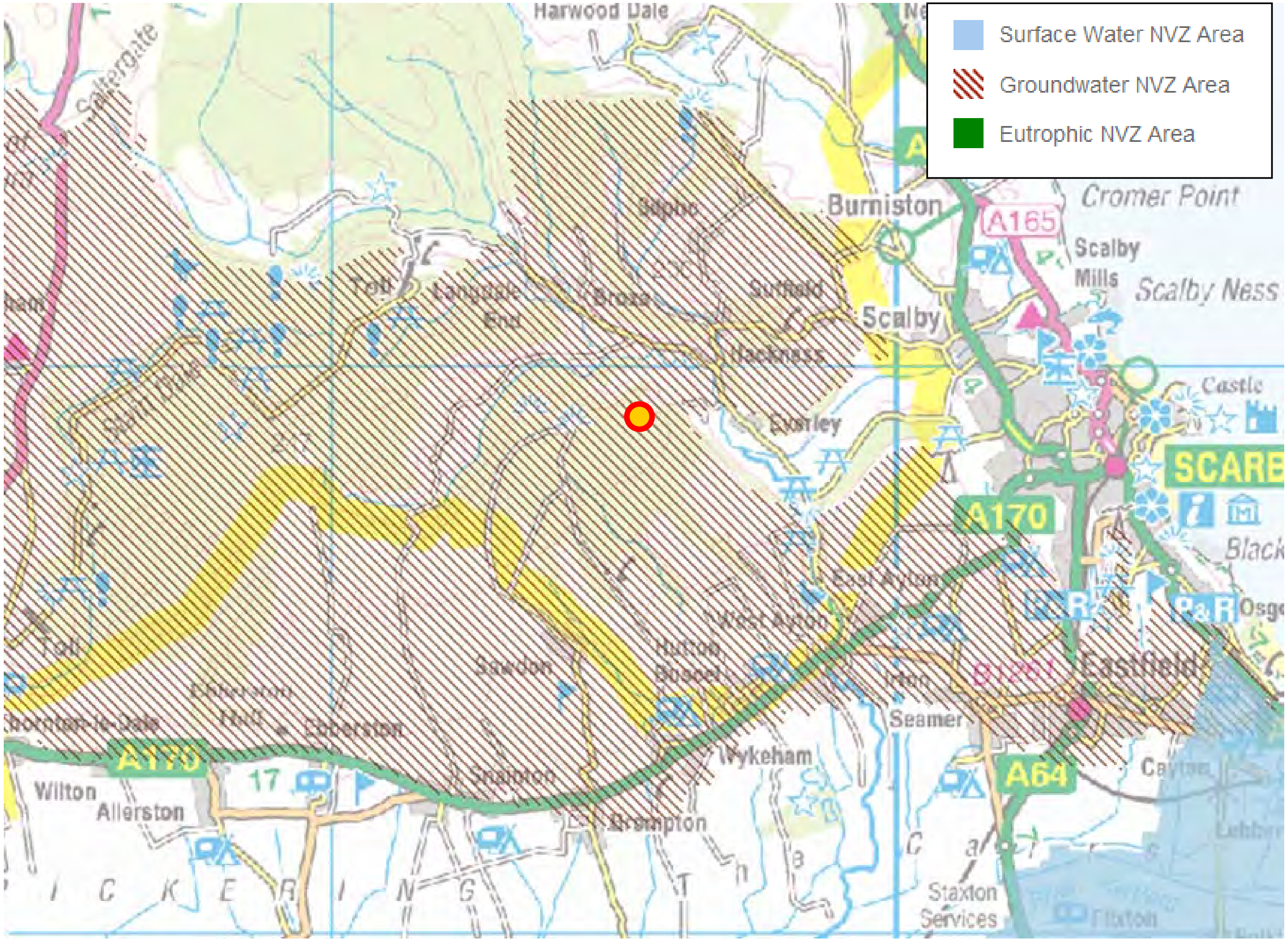


Figure 14: EA Designated Nitrate Vulnerable Zone (EA website, July 2012)

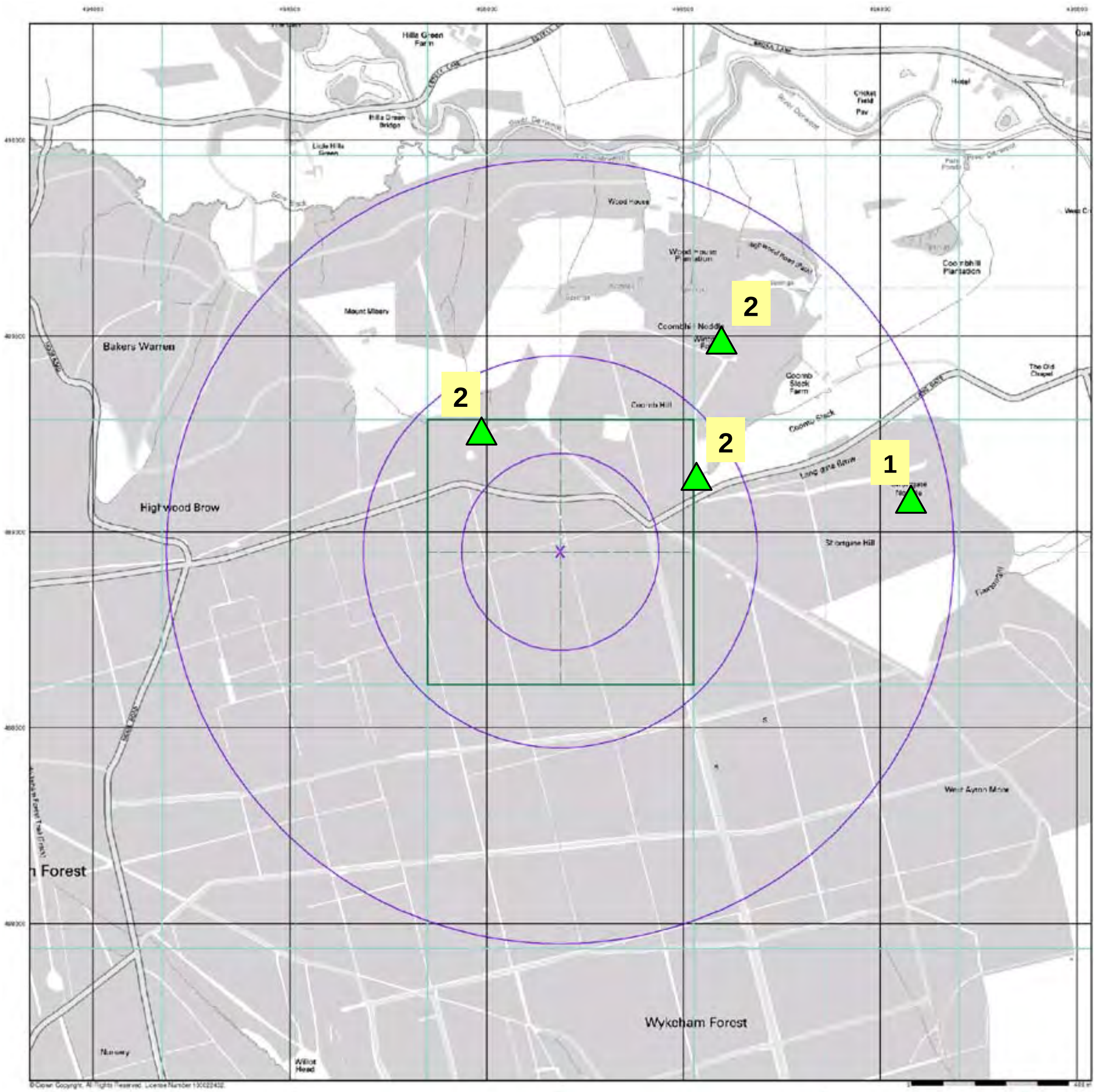


Figure 15: Recorded Activities within a 1km radius of the Site

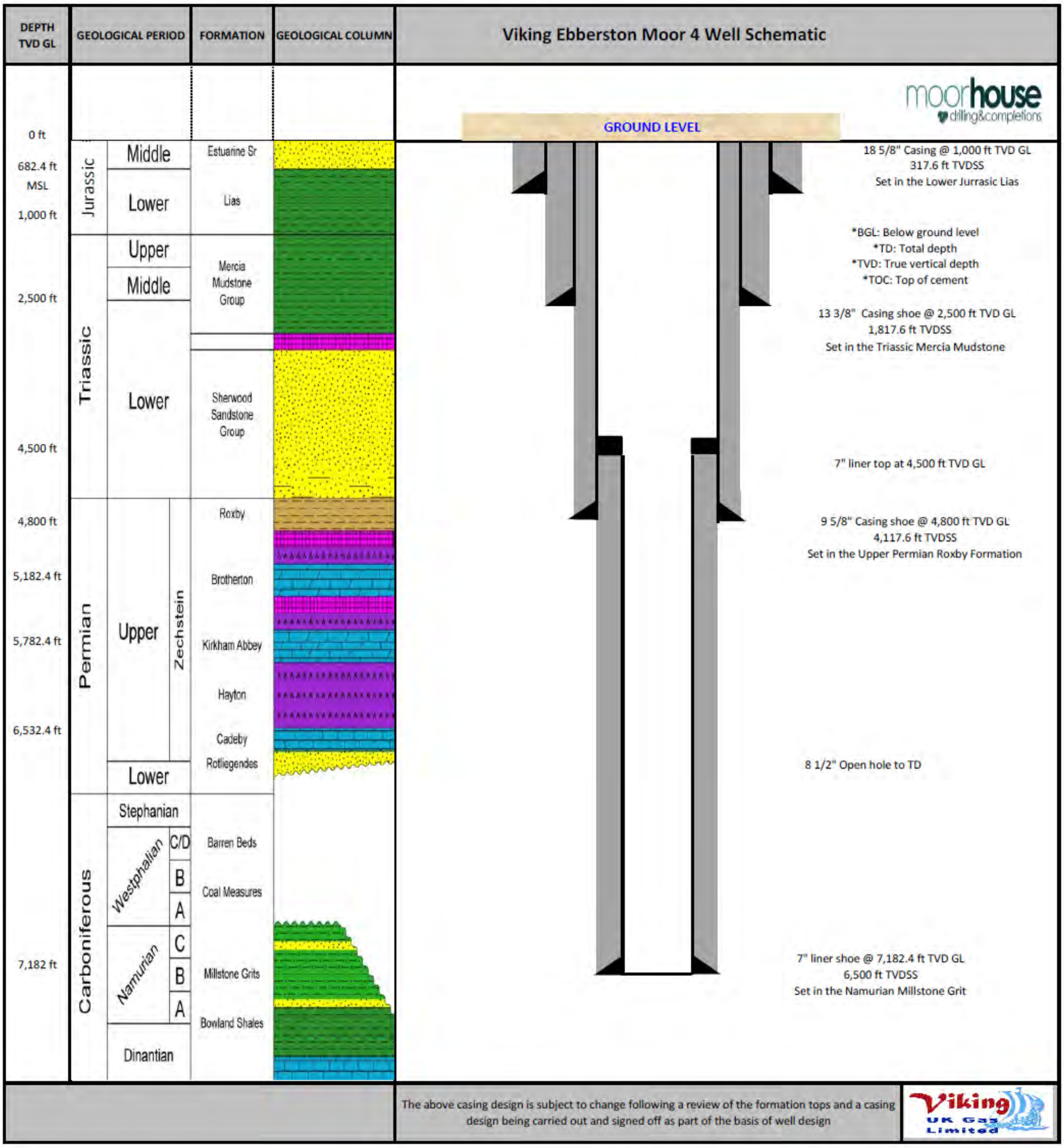


Figure 16: Indicative Stratigraphy and Well Casing Schematic for Appraisal Well