HORIZON
NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

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Wylfa Newydd Project

Wylfa Newydd Development Area Groundwater Baseline Report

January 2018

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1 Introduction

1.1 Overview

Horizon Nuclear Power Ltd. (Horizon) is planning to develop a new nuclear power station (the Power Station) on land west of Cemaes on Anglesey, as identified in the *National Policy Statement for Nuclear Power Generation (EN-6)* [RD1]. The Wylfa Newydd Project will require a number of applications to be made under different legislation to different regulators. As a Nationally Significant Infrastructure Project under the *Planning Act 2008*, the construction and operation must be authorised by a Development Consent Order.

Jacobs UK Ltd (Jacobs) was commissioned by Horizon to undertake a groundwater (hydrogeological) assessment to inform the various applications, assessments and permits that will be submitted for approval to construct and operate the Power Station and Associated Development. This report only provides baseline information for the Wylfa Newydd Development Area. Baseline data for the off-site developments, including the Off-Site Power Station Facilities, Park and Ride and Logistics Centre are provided in: chapter E8, Off-Site Power Station Facilities: AECC, ESL and MEEG - Surface water and groundwater (Application Reference Number: 6.5.8); chapter F8, Park and Ride - Surface water and groundwater (Application Reference Number: 6.6.8); and, chapter H8, Logistics Centre - Surface water and groundwater (Application Reference Number: 6.8.8).

The indicative areas of land and sea that would be used for the construction and operation of the Power Station are referred to as the Wylfa Newydd Development Area, and this report details the groundwater baseline within and in the vicinity of the Wylfa Newydd Development Area. This includes a desk study of available information, including data published by regulators such as Natural Resources Wales (NRW), historical groundwater data and data collected on soils and geology. Site works have been undertaken to expand the historical dataset and collect further information on groundwater levels and groundwater quality. A groundwater model has been produced to assess the effects on groundwater receptors during construction and operation of the Power Station. Discussions have been held with NRW and the Isle of Anglesey County Council (IACC) with regards to groundwater monitoring and their expectations.

The groundwater topic has close alignment with the following subject areas, which are subject to separate baseline reports:

- Geology and soils, including land contamination (WNDA Development App D7-1 - Baseline Condition Report - Wylfa Newydd Development Area (Application Reference Number: 6.4.24));
- Surface water (WNDA Development App D8-1 - Surface Water Baseline Report (Application Reference Number: 6.4.26));
- Fluvial geomorphology (WNDA Development App D8-2 - Fluvial Geomorphology Baseline Report (Application Reference Number: 6.4.27));
- The Tre’r Gof Site of Special Scientific Interest (SSSI) (WNDA Development App D8-5 - Tre'r Gof Hydroecological Assessment (Application Reference Number: 6.4.30)); and
- The Cae Gwyn SSSI (WNDA Development App D8-6 - Cae Gwyn Hydroecological Assessment (Application Reference Number: 6.4.31)).

It is not the purpose of this groundwater baseline report to reproduce the data and assessments in these reports although where necessary the reports are referred to.

1.2 Proposed development

The Power Station Site comprises the indicative area of land and sea within which the majority of the permanent Power Station buildings, plant and structures would be situated. It would include the two Reactor Units, steam turbines, the Cooling Water System intake and pumphouse, outfall structures, breakwaters and the Marine Off-Loading Facility, as well as other Ancillary Structures. A Site Campus to house workers during construction would be developed in the north of the Wylfa Newydd Development Area, between the Tre'r Gof SSSI and the coast.

The development within the Wylfa Newydd Development Area will involve several stages, and the first of these will be the Site Preparation and Clearance works, which will involve clearance of vegetation, demolishing a number of buildings and other above ground structures and realignment of a stream (the Nant Caerdegog Isaf, a tributary of the Afon Cafnan). The clearance works will be followed by the Main Construction works, which will include stripping and mounding of topsoil, excavation of deep basements (which will require dewatering), mounding of excavated rock to form landscape mounds and construction of the reactor units and ancillary structures and infrastructure. Following construction, the Operation phase will take place which will involve the operation of the Power Station for approximately 60 years and also the construction of a Spent Fuel Store approximately 10 years after the start of electricity generation. Decommissioning will see controlled hazard removal, demolition of the Power Station and, if considered necessary, land remediation.

1.3 Study Area

When data collection started, design of the construction works and Power Station operations was at an early stage with only limited information available (for example, it hadn't been determined what the dewatering requirements may be for construction or operation) and a detailed groundwater assessment had not been undertaken. Therefore, there were uncertainties regarding the radius of potential impacts to hydrogeological receptors. As a result of this uncertainty regarding the radius of potential effects to hydrogeological receptors, a conservative approach to the assessment was taken by identifying two zones to define the groundwater study area.

- An inner study area with a 1.8km radius from the centre of the Wylfa Newydd Development Area (at National Grid Reference 23512, 39299, see figure 1.1). The boundary was selected as a circular area (albeit truncated by the coast) to reflect the nature of groundwater movement and the potential zones of influence of dewatering activities, which in ideal homogeneous aquifers will be circular in nature. The 1.8km radius incorporates all of the Wylfa Newydd Development Area out to its furthest points from the centre. In addition, the inner study area captures all of the groundwater features considered to have the highest potential of being affected by the Power Station Development. Important ecological sites, which need to be assessed due to their sensitivity (including the Tre'r Gof SSSI, Cae Gwyn SSSI and the eastern extent of Cemlyn Bay SSSI), are also captured by the inner study area.
- An outer study area, which measures 3km in radius, was defined (see figure 1.1) in order to capture residual uncertainty associated with the radius of influence calculations, especially the degree of heterogeneity of the aquifer, and the possibility that potential effects may extend further than 1.8km. The

heterogeneity of the aquifer was confirmed by pumping tests undertaken in late summer 2015. The 3km boundary was set based on professional judgement regarding how low permeability secondary fractured aquifers behave when pumping takes place and the maximum likely distance across which the proposed activities could have an effect. This outer study area allows all relevant features that could be of concern to the public and regulators to be assessed, even where the potential effect is assessed as being extremely low.

Defining two areas allows collection of baseline data to be concentrated in the area of most concern, but does not lose sight of the fact that features further from the Wylfa Newydd Development Area may be of concern to third parties. It should also be noted that the area considered for a groundwater model comprises a larger study area than shown above to ensure that boundary effects in the model do not affect the results of the model.

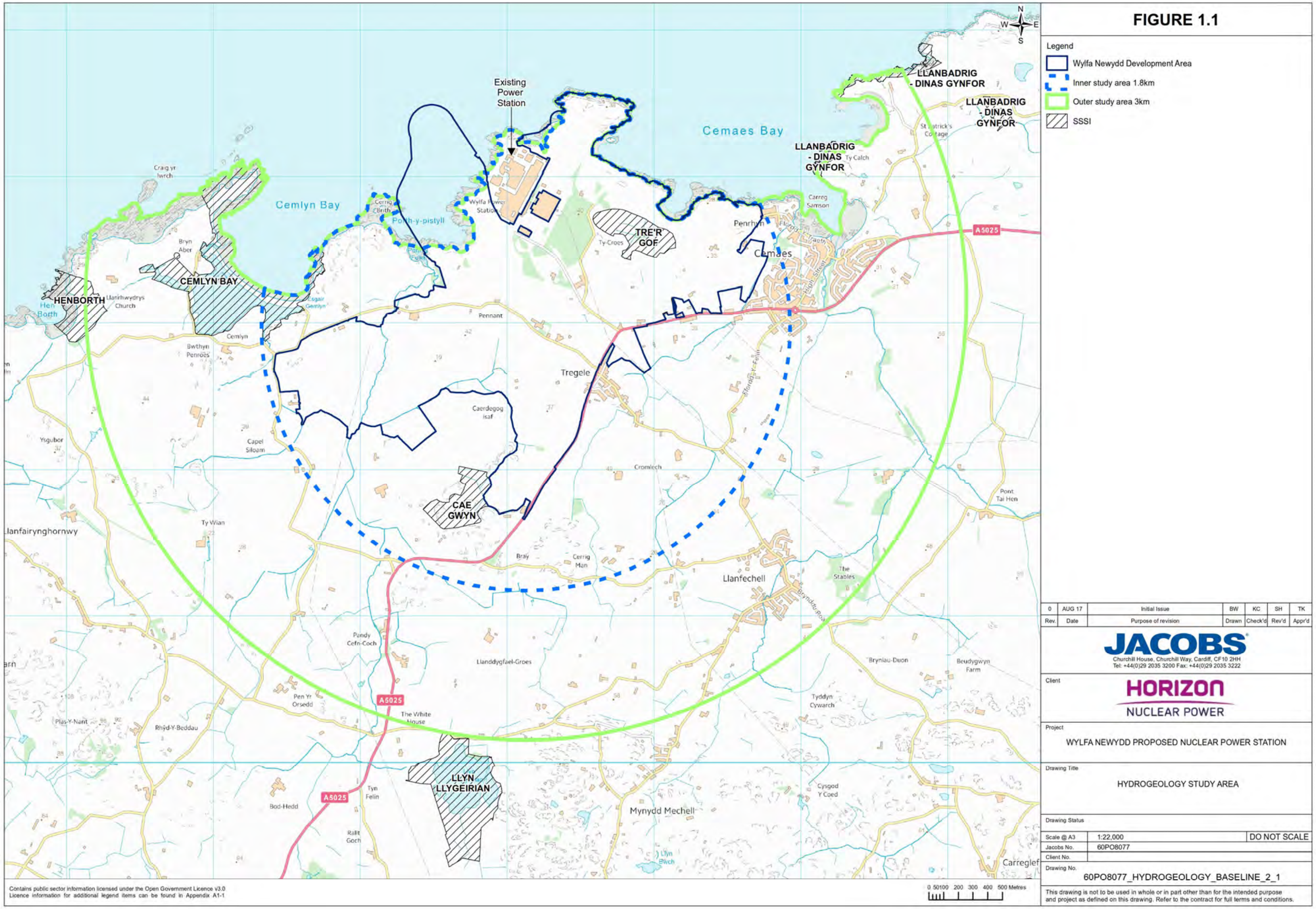

FIGURE 1.1
Legend
Wylfa Newydd Development Area
Inner study area 1.8km
Outer study area 3km
SSSI
Existing
Power
Station
Cemaes Bay
Cemlyn Bay
LLANBADRIG
- DINAS GYNFOR
LLANBADRIG
- DINAS
GYNFOR
TRE'R
GOF
CEMLYN BAY
HENBORTH
CAE
GWYN
LLYN
LLYGEIRIAN
Cemaes
Tregele
Llanfechell
Mynydd Mechell
Llanfairynghornwy
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Drawing Title
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Drawing Status
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1.4 Site description

The Wylfa Newydd Development Area (including the Power Station Site and surrounding area to be used for the construction and operation of the Power Station) covers an area of approximately 380ha. It is bounded to the north by the coast and the Existing Power Station. To the east, the area is separated from Cemaes by a narrow corridor of agricultural land. The A5025 and residential properties define part of the south-east boundary, with a small parcel of land bordering the road to the north-east of Tregele. To the south and west, the Wylfa Newydd Development Area abuts agricultural land, and to the west it adjoins the coastal hinterland.

There is one SSSI within the Wylfa Newydd Development Area: the Tre'r Gof SSSI. It is also within 1km of the Cae Gwyn SSSI, Cemlyn Bay Special Area of Conservation (SAC)/Special Protection Area (SPA)/SSSI. The Anglesey Terns/Morwenoliaid Ynys Môn SPA covers the sea all around the north-western coast of Anglesey. Other SSSIs as shown on figure 1.1 outside of the Inner study area do not have any conceivable hydrogeological connection to the Wylfa Newydd Development Area and are not considered further in this report.

The Tre'r Gof SSSI is a small basin mire adjacent to the Existing Power Station, west of Cemaes (see figure 1.1 for location). The area receives mineral-enriched waters from the surrounding superficial deposits, leading to the development of notable flora. It is primarily the botanical interest that provides the reason for the designation of the site as an SSSI.

The groundwater study area is predominantly agricultural land used for animal grazing. However, it does incorporate the Existing Power Station and also the village of Tregele as shown on figure 1.1.

1.5 Key issues

The Wylfa Newydd Project will involve several stages of construction, and the key issues in relation to potential impacts on groundwater from construction and operation within and around the Wylfa Newydd Development Area include the following:

- changes to groundwater flow direction caused by temporary groundwater dewatering activities during construction;
- changes to groundwater flow direction caused by control of groundwater levels around deep basements during operation of the Power Station;
- changes to groundwater recharge patterns due to the presence of landscape mounds and associated drainage ditches;
- changes to groundwater quality from the disturbance of ground during operation and leaching of contaminants;
- changes to groundwater recharge rates and groundwater flow direction due to the presence of buildings and hardstanding at the operational site;
- changes to groundwater flow direction due to below ground structures following construction;
- changes to groundwater quality from leaks and spills from chemicals, fuels and oils from construction plant or operational plant; and
- changes to groundwater recharge rates from the removal of vegetation which may impact on groundwater levels and in turn may lead to changes in the groundwater flow direction and associated groundwater discharge points.

Changes in groundwater levels from the construction or operation of the Power Station could then lead to impacts on secondary receptors including groundwater abstractions, flows within watercourses which are in continuity with groundwater, and discharge to groundwater dependent terrestrial ecosystems (GWDTEs). Changes in groundwater levels could also lead to subsidence in buildings outside of the Wylfa Newydd Development Area, depending upon their construction and foundations.

1.6 Study aims and objectives

The objective of the groundwater baseline report is to characterise the groundwater environment and collect baseline data to inform the various applications, assessments and permits required to construct and operate the Power Station, with an emphasis on the key issues identified in Section 1.4.

As part of the Environmental Impact Assessment (EIA), a Habitats Regulations Assessment and a Water Framework Directive (WFD) Assessment is required, both of which require detailed temporal and spatial data on watercourses and WFD water bodies. This report presents the findings of groundwater surveys undertaken in 2014, 2015, 2016 and up to August 2017 by hydrogeologists as well as desk study and review of earlier site investigation data collected for the study area. Ongoing data collection will continue into 2018.

The specific aims of this work are to:

- provide an understanding of the baseline groundwater conditions within the Wylfa Newydd Development Area and its vicinity;
- identify the key receptors for groundwater;
- provide a report that can be referred to throughout the EIA process for key groundwater information for the Wylfa Newydd Project;
- inform a WFD Compliance Assessment (Application Reference Number: 8.26);
- inform the relevant EIA (Scoping and Environmental Statement) chapters;
- inform the Site Nuclear Licensing, and
- inform Environmental Permitting (where applicable).

The methodology is detailed in Section 2 of this report and then this baseline report is divided into the following chapters presenting the available data:

- Section 3: Geology and ground investigation data;
- Section 4: Aquifer recharge;
- Section 5: Regulator data and groundwater resources;
- Section 6: Groundwater levels and flow; and
- Section 7: Groundwater quality.

Some of these data are common with other study topics, and where data are more relevant to the other disciplines, the baseline data are not presented in this report. However, these relevant reports and data are referred to.

A preliminary hydrogeological conceptual model is presented in Section 8 setting out the key hydrogeological concepts, and Section 9 identifies how the groundwater regime may change over time. Appendices are presented at the end of this report.

2 Methodology

2.1 Introduction

The baseline report is based on a combination of a desk study, which reviews the existing information from the study area, and hydrogeological surveys to further develop the key baseline observations. The following steps were undertaken:

- collation and review of baseline, desk-based information on the Wylfa Newydd Project study area, including data held by Horizon and NRW; and
- groundwater reconnaissance surveys to measure groundwater levels and collect groundwater samples for chemical analysis.

A groundwater model has also been set up for the Wylfa Newydd Development Area and surrounding land so that potential effects of the construction and operation of the Power Station can be assessed (see Section 2.4 for further details). The model details are provided in full in appendix D8-7 (Application Reference Number: 6.4.32).

2.2 Desk study

The desk study comprised the analysis of available information, including maps, geology, soils, data collected from previous phases of investigation and publicly available data provided by NRW and the IACC. The following is a list of the key documentation/data utilised to inform the desk study:

- Environment Agency 'What's in Your Backyard?' online tool[1] accessed March 2015 [RD2].
- Ordnance Survey (OS) 1:10,000, 1:25,000 and 1:50,000 maps [RD3].
- geological maps including on-line "Geology of Britain Viewer" and 1:50,000 Special Map for Anglesey (solid geology) [RD4].
- data collected as part of ongoing ground investigations as follows.
  - Preliminary Site Investigation (PSI) undertaken in 2009 [RD5].
  - Intermediate Onshore Ground Investigation (IOnGI) undertaken in 2011 [RD6].
  - Detailed Onshore Ground Investigation[2] (DOnGI) undertaken in 2014 [RD7], [RD8]. This investigation was split into two sections defined as the 'high priority' (HP) and 'low priority' (LP) boreholes.
  - Site Preparation and Clearance (SPC)1 2015 Ground Investigation [RD9].
- the following consultancy reports:
  - Surface water baseline report (Application Reference Number: 6.4.26) which sets out the findings of surface water investigations in the Wylfa Newydd Development Area.

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[1] The Environment Agency used to be the regulator for groundwater in England and Wales, but in April 2013 the Environment Agency's functions passed to NRW for Wales. However, data relating to the groundwater conditions in Wales which were on the Environment Agency's "What's in Your Backyard?" website have now been removed and as of February 2017 the equivalent information is not published on the NRW website. Data shown in this report refer to data that were on the EA's website accessed in March 2015.

[2] It should be noted that the DOnGI factual data have been reported in two separate phases, the high priority (HP) and low priority (LP) reports. Where relevant, the two phases are referred to as the "DOnGI (HP)" and "DOnGI (LP)".

- Geomorphology baseline report (Application Reference Number: 6.4.27) which sets out the fluvial geomorphological assessment of the Wylfa Newydd Development Area.
- Tre'r Gof hydroecological assessment (Application Reference Number: 6.4.30) which provides an assessment of the functioning of the Tre'r Gof SSSI.
- Cae Gwyn hydroecological assessment (Application Reference Number: 6.4.31) which provides an assessment of the functioning of the Cae Gwyn SSSI.
- Interpretation of geological data [RD5], [RD6], [RD10]. These reports interpret the data collected in the PSI, IOnGI and DOnGI investigations. The reports also summarise historical investigations undertaken in relation to the proposed construction of a second nuclear reactor at Wylfa in the 1980s (the original reports for these investigations have not been accessed).
- Geology Baseline Report (Application Reference Number: 6.4.24). This report provides a summary of the geological data and assesses contaminated land issues associated with the Wylfa Newydd Development Area.
- Wylfa Newydd: Groundwater and Stream Flow Impact Modelling: Technical Note for DCO (Application Reference Number: 6.4.32) which presents the set up, calibration and results of groundwater modelling.

- Environment Agency report into groundwater quality and supply for the Gwna Group on Anglesey [RD11].

Relevant data from these sources are summarised within this report.

2.3 Hydrogeological surveys

A hydrogeological reconnaissance survey was undertaken by two hydrogeologists on 17 September 2014. The reconnaissance survey assessed the condition of a number of boreholes within the Wylfa Newydd Development Area, identified locations for the installation of 'sentinel' boreholes around the periphery of the study area, and allowed an appreciation of the statutory designated sites and how these may be controlled by groundwater inputs (although access to the majority of the Cae Gwyn SSSI was not possible at that time and remains restricted at the time of writing). The reconnaissance survey also provided an understanding of the existing topographic conditions.

Following the initial reconnaissance survey, further surveys have been undertaken as outlined in table 2.1. A list of monitoring boreholes is shown in appendix B.

Table 2.1 – Surveys undertaken

Date	Nature of survey
24 to 29 November 2014	Groundwater sampling from eight boreholes and measurement of groundwater levels in 77 boreholes.
9 to 11 February 2015	A walkover survey of the Tre'r Gof SSSI to determine potential groundwater inflows and outflows.
2 to 6 March 2015	Groundwater sampling and measurement of groundwater levels from 33 boreholes and assessment of private water supplies which may be affected by the development.
25 and 26 March 2015	Downloading groundwater level data loggers that were installed in 101 boreholes in late February/ March 2015.

Date	Nature of survey
22 April 2015	Collection of a groundwater sample from a private water supply (PWS) at Foel Fawr.
8 to 12 June 2015	Groundwater sampling from 33 boreholes and the PWS at Foel Fawr. Also, downloading groundwater logger data from 101 boreholes and checking water levels at each logger location with a manual measurement.
July 2015	Resetting of groundwater level data loggers in 101 boreholes (undertaken twice, at start and end of month). Data for the period mid-June to the end of July are missing. Also installation of a logger in borehole RGMBH1S.
August to November 2015	Pumping tests: drilling of two groundwater abstraction boreholes, associated observation boreholes and pumping tests at two locations (see section 3.1 for further details).
14 to 18 September 2015	Groundwater sampling from 33 boreholes and one PWS (Foel Fawr). Also, downloading groundwater logger data from 102 boreholes and checking water levels at each logger location with a manual measurement.
4 November 2015	Hydrogeological investigation of the Tre'r Gof SSSI including the installation of nine shallow piezometers with groundwater level data loggers.
14 to 18 December 2015	Groundwater sampling from 33 boreholes and one PWS (Foel Fawr). Also, downloading groundwater logger data from 102 boreholes and checking water levels at each logger location with a manual measurement.
12 January 2016	Installation of four shallow piezometers within the Cae Gwyn SSSI.
25 to 29 April 2016	Groundwater sampling from 33 boreholes and one PWS (Foel Fawr). Also, downloading groundwater logger data from 99 boreholes and checking water levels at each logger location with a manual measurement.
1 to 5 August 2016	Groundwater sampling from 33 boreholes and one PWS (Foel Fawr). Also, downloading groundwater logger data from 99 boreholes and checking water levels at each logger location with a manual measurement.
24 to 28 October 2016	Groundwater sampling from 33 boreholes and one PWS. Also, downloading groundwater logger data from 99 boreholes and checking water levels at each logger location with a manual measurement.
1 December 2015 to 25 August 2017	Collection of monthly level and quarterly quality data from the Tre'r Gof SSSI piezometers. These data are presented in a separate report for Tre'r Gof (Application Reference Number: 6.4.30)
10 February 2016 to May 2017	Collection of monthly level and quarterly quality data from the Cae-Gwyn piezometers. These data are presented in a separate report for Cae Gwyn (Application Reference Number: 6.4.31)

Date	Nature of survey
30 January to 3 February 2017 and 6 March 2017	Groundwater sampling from 30 boreholes and one PWS (Foel Fawr). Also, downloading groundwater logger data from 92 boreholes and checking water levels at each logger location with a manual measurement. Due to access issues during this monitoring round, three groundwater samples had to be collected on 6 March 2017, data from which are included in this report.
8 May to 12 May 2017	Groundwater sampling from 26 boreholes and one PWS. Also, downloading groundwater logger data from 91 boreholes and checking water levels at each logger location with a manual measurement.
21 August to 25 August 2017	Groundwater sampling from 33 boreholes and one PWS. Also, downloading groundwater logger data from 86 boreholes and checking water levels at each logger location with a manual measurement.

Further surveys are planned for 2018 with groundwater sampling, downloading of groundwater level data loggers and manual measurement of water levels planned to be undertaken on a quarterly basis. Other works would be undertaken as required.

2.4 Groundwater modelling

In order to provide a quantification of impacts on groundwater levels from the construction works, a groundwater model has been constructed by Amec Foster Wheeler (now Wood). The model set up, calibration and results are provided in a separate report (Application Reference Number: 6.4.32).

This modelling used two software packages. The first was the 4Rs Model (4R) which was used to estimate the recharge that will occur to groundwater in the bedrock and that which will discharge to surface water. The recharge data from the 4R model was then used in a groundwater flow model for the bedrock using the MODFLOW modelling package. The 4Rs and MODFLOW bedrock groundwater model utilised rainfall data from the period 1960 to 2016 and was calibrated against groundwater level data collected from the data loggers installed in the bedrock, and surface water flow gauging points. Calibration was achieved through a process of iterative review and refinement, constrained within the simple conceptualisation and parameter ranges for the bedrock aquifer. The final calibrated model runs incorporated the two pumping tests carried out during autumn 2015 so that monitored and simulated responses could be compared. However, it is important to note that as there is no clearly defined areal patterns in bedrock hydraulic conductivity, local parameter adjustments for hydraulic conductivity were avoided. The main focus for the MODFLOW refinement and parameter exploration was to consider the effects of altering the vertical profile of the hydraulic conductivity and how it varies with depth due to changes in fracture density.

Once a calibration had been achieved (subsequently called the “Central” model), the sensitivity of the model was assessed by creating two variant models, a “High” model which had a four times increase in recharge to the bedrock aquifer and hydraulic conductivity, and a “Low” model which had a four times reduction in recharge to the bedrock aquifer and hydraulic conductivity.

Once the model was calibrated against the baseline data, the Central model was used to model the effects on water levels in the bedrock aquifer during the construction of the Power Station (including dewatering for the excavation of deep basements) and operation of the Power Station (including the use of a passive drainage system around deep basements).

Simulated bedrock groundwater levels from the predictive baseline scenario model were post-processed into grids and coloured raster maps. in order to understand seasonal variations, maps and output data were prepared for a representative dry period (30 September 1991) and a wet period (31 December 2000) to illustrate potential changes in groundwater levels during construction and operation compared to the baseline conditions.

The results from the model have been used to:

- assess the potential for dewatering to cause saline intrusion to the bedrock aquifer;
- estimate the drawdown in groundwater levels at sensitive receptors including the Tre’r Gof, Cae Gwyn and Cemlyn Bay SSSIs and at PWSs;
- estimate the drawdown in water levels and changes to groundwater flow direction at any point within the model area;
- assess groundwater/surface water interactions;
- estimate the drawdown in groundwater levels beneath buildings outside of the Wylfa Newydd Development Area; and
- estimate the potential groundwater abstraction rate required for dewatering.

3 Geology and ground investigation data

3.1 Ground investigations

The first ground investigations in the vicinity of the Wylfa Newydd Development Area were undertaken in the 1950/60s in relation to the construction of the Existing Power Station. Further investigation was undertaken in the 1980s and 1990s in response to the proposed Wylfa B power station and a proposed Combined Cycle Gas Turbine development. The DOnGI Interpretative Report [RD10] provides a summary of these earlier investigations with borehole locations shown in figures 5130177-ATK-XX-ZZ-DR-C-0003A and B in appendix C.

In relation to the Wylfa Newydd Project, three principal ground investigations have now been undertaken (PSI, IOnGI and DOnGI) in or immediately adjacent to the Wylfa Newydd Development Area. Over time the investigations have become more detailed with a larger number of boreholes and testing and these investigations, rather than the older assessments, and the greater datasets provide the focus of this baseline report, although considering the earlier data where relevant. For each investigation, factual and interpretative reports have been produced. A smaller ground investigation was undertaken in 2015 [RD9], principally to aid the contaminated land assessment but including the installation of two groundwater monitoring boreholes to assess ground conditions in relation to a stream realignment of the Nant Caerdegog Isaf. Selected borehole logs from all ground investigation phases are contained in appendix D.

3.1.1 Preliminary Site Investigation

The PSI was undertaken in 2009 and 2010 [RD5]. The investigation involved the drilling of 11 rotary boreholes and 10 cable percussive boreholes and excavation of nine trial pits. The maximum depth of the boreholes was 120m with boreholes labelled as the “300 series” boreholes. Geophysical logging was undertaken in 10 of the rotary boreholes and 123 (single and double) packer tests were carried out in selected boreholes. Standpipes and piezometers from previous investigations were re-commissioned where these could be located. Variable head commissioning tests were undertaken on 18 piezometers.

3.1.2 Intermediate Onshore Ground Investigation

The IOnGI was undertaken in 2011 [RD6]. The investigation comprised the drilling of 57 rotary cored boreholes, 23 cable percussive boreholes and five hand augered boreholes (the latter being in the area of the Tre’r Gof SSSI). It also included the excavation of 10 trial pits and 28 trial trenches. The maximum depth of the boreholes was 100m.

In situ testing involved surface geophysics, downhole seismic tests in 15 boreholes, downhole geophysical logging in all boreholes (80) and hydraulic conductivity (permeability) tests in 5 boreholes (variable head in 3 boreholes and packer testing using double packers in 2 boreholes, referred to by the contractor as “hydrotests”). An assessment of soil contamination was also undertaken.

The boreholes were labelled as the “500 series” and “600 series” and 27 standpipe piezometers were installed in the boreholes.

3.1.3 Detailed Onshore Ground Investigation

The DOnGI was undertaken in 2014 and was reported as two separate phases (High Priority, Volume 1 [RD7] and Low Priority, Volume 2 [RD8]). The total investigation comprised the drilling of 344 rotary cored boreholes and 96 cable percussive boreholes to a maximum depth of 188m. It also included the excavation of 85 trial pits.

In situ testing involved surface geophysics, downhole seismic testing in 21 boreholes, downhole geophysical logging in 278 rotary cored holes and hydraulic conductivity variable head tests in superficial boreholes, 195 packer tests and 76 hydrotests. An assessment of soil contamination was also undertaken.

The boreholes were labelled as the "RGM" borehole series (these being 'sentinel' boreholes installed around the edge or just outside of the Wylfa Newydd Development Area), "700 series", "800 series", "900 Series" and "1000 series" and 61 standpipe piezometers were installed in the boreholes.

3.1.4 2015 and 2016 ground investigation

In the summer of 2015, a ground investigation was undertaken, principally in relation to contaminated land and geotechnical assessments. This work principally involved the construction of shallow trial pits which did not reach groundwater. However, the work did also include the drilling of five boreholes towards the south of the Wylfa Newydd Development Area at Caerdegog Isaf (in relation to the realignment of a stream in this area). Two of these boreholes were completed as groundwater monitoring boreholes (BH2201A and BH2203). However, no groundwater samples were taken from these two boreholes. Two further monitoring installations were installed in two deeper trial pits to the east of Porth-y-pistyll, but groundwater has not been encountered in these boreholes.

In addition, groundwater was sampled from six boreholes in January 2016 near to Porth-y-pistyll in response to an oil leak from a below-ground electricity cable and other historical contamination.

3.1.5 Pumping tests

In order to assess the aquifer's hydrogeological properties over a wider area than is possible in individual boreholes, two pumping tests were undertaken in the autumn of 2015. Details of the work undertaken are provided in factual reports [RD12], [RD13] but in summary the work comprised the following.

- Drilling abstraction boreholes at two locations, with the boreholes being labelled as PW1 and PW2. Both boreholes were drilled to approximately -30mAOD (metres above Ordnance Datum).
- Drilling four observation boreholes around each abstraction borehole with completion as groundwater monitoring points for bedrock and superficial groundwater (the latter only being where there was significant thickness of superficial deposits).
- Undertaking yield tests, step tests, seven or eight day constant rate tests and recovery tests in each of the boreholes.
- Monitoring groundwater levels in the pumped and observation boreholes and other monitoring boreholes during the tests.
- Collecting samples of the pumped groundwater for chemical analysis.

Interpretative reports were produced for each location [RD14], [RD15] and these data are considered in the discussion of the hydrogeology presented later in this report.

The locations of boreholes PW1 and PW2 were based on the original Power Station Site layout design as reported in Pre Application Consultation (PAC) Stage1 (PAC 1) and PAC 2 such that the boreholes were centred on the two proposed generating buildings where deep basements would have been excavated. However, following the reappraisal of the Power Station Site layout at the end of 2016, only abstraction borehole PW1 now coincides with a deep basement, although this basement does include both of the proposed Generating Units. Borehole PW2 is at a location that is now outside of excavations. This notwithstanding, the results of the pumping test at PW2 are of significant value. The very different responses to pumping from PW1 and PW2 demonstrate the heterogeneity of the aquifer and importance of fractures in controlling groundwater movement.

3.1.6 Investigations at the Tre'r Gof and Cae Gwyn SSSIs

The Tre'r Gof SSSI is a GWDTE (wetland) feature within the Wylfa Newydd Development Area. To understand the hydrogeology of this feature, and in particular to assess whether there are significant inputs of shallow and deep groundwater to the SSSI, monitoring of the wetland has been undertaken. The works have included the installation of nine shallow piezometers into the wetland and installation of groundwater level loggers into these piezometers. Further details of the investigation works are provided in the Tre'r Gof hydroecological assessment (Application Reference Number: 6.4.30) which includes the data sets.

With respect to the Cae Gwyn SSSI, which is situated outside and to the south-west of the Wylfa Newydd Development Area and also defined as a GWDTE, four shallow piezometers were installed in January 2016 with groundwater level data loggers installed in each piezometer. Further details of the assessment investigation works are provided in the Cae Gwyn hydroecological assessment (Application Reference Number: 6.4.31) which includes the monitoring information (for the period when access was permitted: November 2015 to May 2017).

3.1.7 Groundwater monitoring boreholes

The boreholes and piezometers that have been completed as groundwater monitoring points are shown in appendix B with all locations shown on figure 3.1 and more detail provided on figures 3.1A, B, C and D. It should be noted, however, that boreholes BH875 and BH878 were decommissioned in December 2015 to allow a new cable to be installed through the area.

3.2 Regional and site geology

3.2.1 Regional summary

The geology of Anglesey and in the vicinity of the Wylfa Newydd Development Area is complex with the bedrock comprising a mixture of igneous, sedimentary and metamorphic rocks that were mostly formed between 300 and 650 million years ago. Superimposed on to these bedrock strata, are much more recent glacial deposits, including glacial landforms such as half-egg-shaped drumlins. The regional geology is shown in figure 3.2. More details are provided in chapter D7, WNDA Development - Soils and geology (Application Reference Number: 6.4.7).

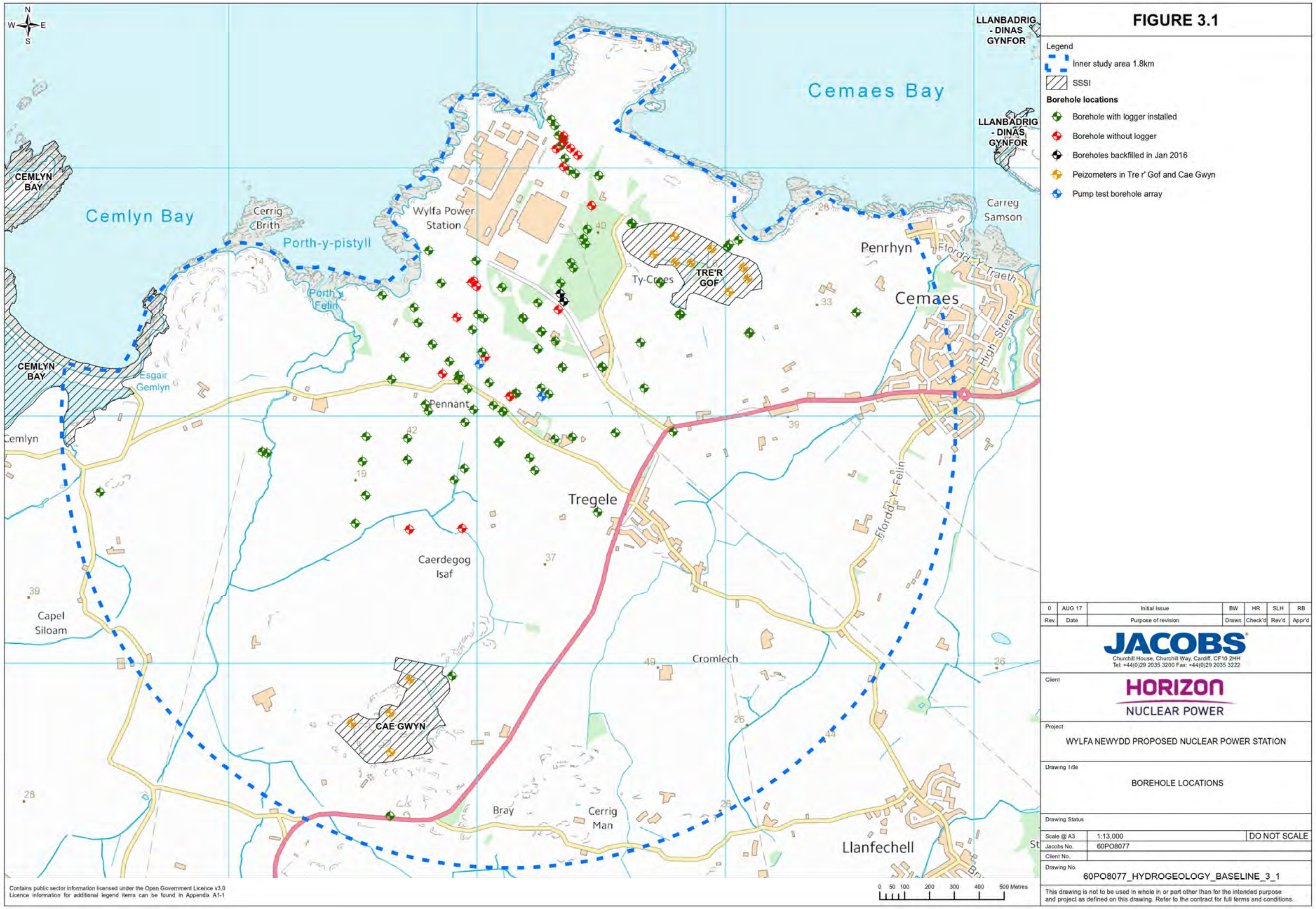
FIGURE 3.1
Legend
Inner study area 1.8km
SSSI
Borehole locations
Borehole with logger installed
Borehole without logger
Boreholes backfilled in Jan 2016
Peizometers in Tre r' Gof and Cae Gwyn
Pump test borehole array
Cemaes Bay
Cemlyn Bay
CEMLYN BAY
LLANBADRIG - DINAS GYNFOR
Wylfa Power Station
Cerrig Brith
Porth-y-pistyll
Porth y Felin
Esgair Gemlyn
Cemlyn
Pennant
Ty-Croes
TRE'R GOF
Penrhyn
Carreg Samson
Cemaes
Ffordd-Y-Traeth
High Street
Tregele
Ffordd-Y-Felin
Caerdegog Isaf
Capel Siloam
Cromlech
CAE GWYN
Bray
Cerrig Man
Llanfechell
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Project
WYLFA NEWYDD PROPOSED NUCLEAR POWER STATION
Drawing Title
BOREHOLE LOCATIONS
Drawing Status
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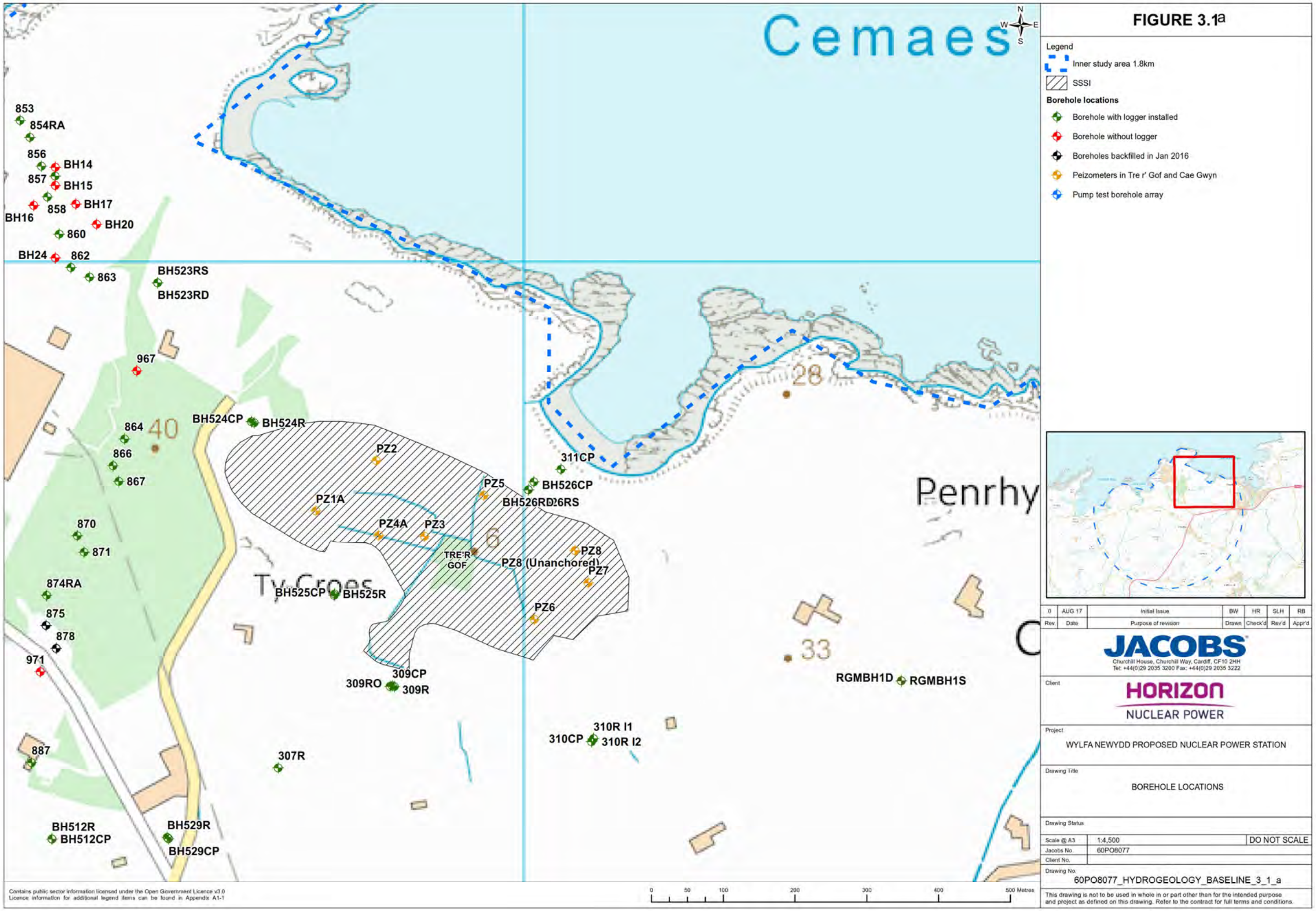

FIGURE 3.1a
Legend
Inner study area 1.8km
SSSI
Borehole locations
Borehole with logger installed
Borehole without logger
Boreholes backfilled in Jan 2016
Peizometers in Tre r' Gof and Cae Gwyn
Pump test borehole array
Cemaes
Penrhy
Ty Croes
TRE'R GOF
853
854RA
856
857
858
860
862
863
864
866
867
870
871
874RA
875
878
887
967
971
BH14
BH15
BH16
BH17
BH20
BH24
BH523RS
BH523RD
BH524CP
BH524R
BH525CP
BH525R
BH526CP
BH526RD
26RS
BH512R
BH512CP
BH529R
BH529CP
PZ1A
PZ2
PZ3
PZ4A
PZ5
PZ6
PZ7
PZ8
PZ8 (Unanchored)
307R
309CP
309RO
309R
310CP
310R I1
310R I2
311CP
RGMBH1D
RGMBH1S
40
28
33
6
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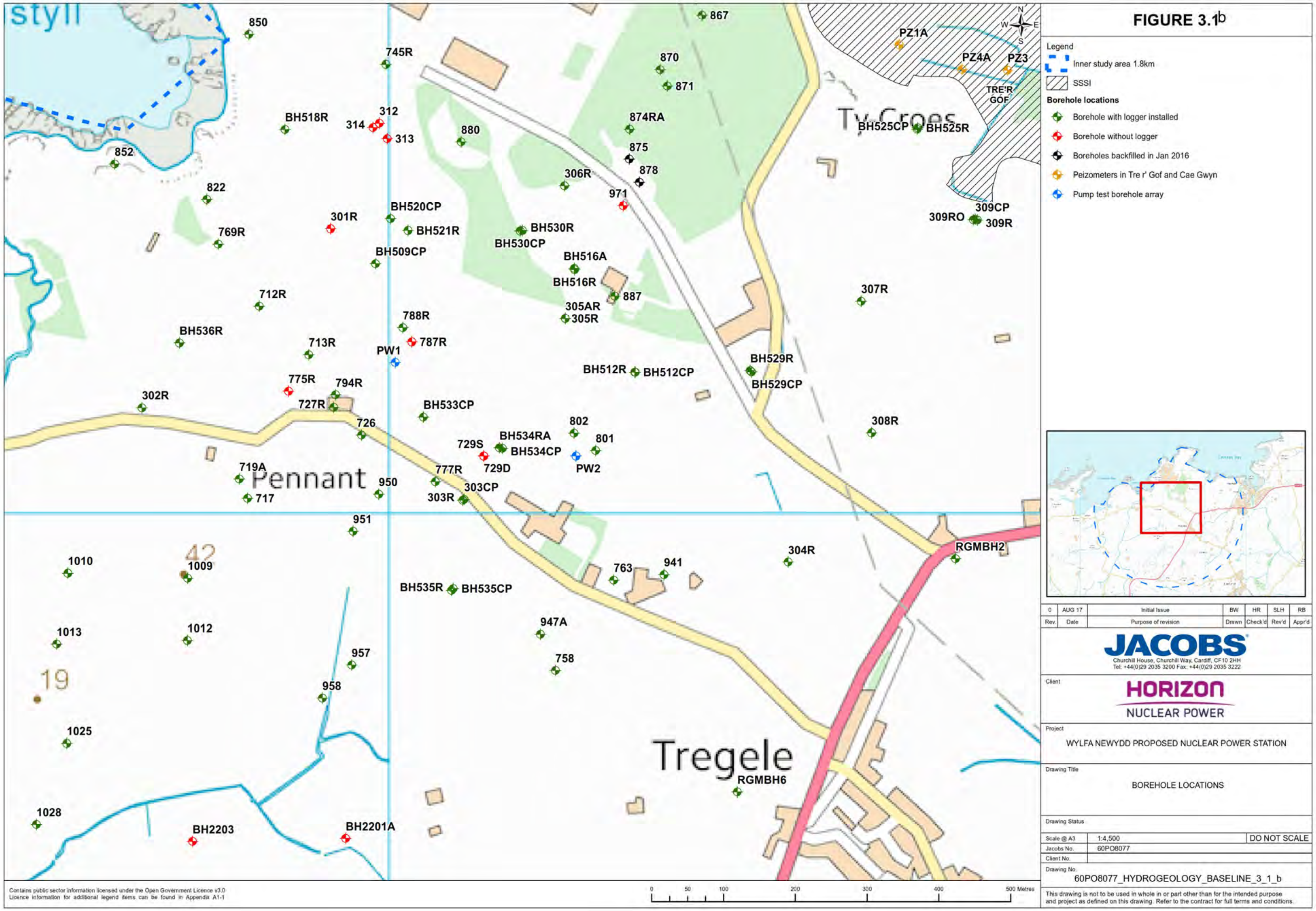

FIGURE 3.1b
Legend
Inner study area 1.8km
SSSI
Borehole locations
Borehole with logger installed
Borehole without logger
Boreholes backfilled in Jan 2016
Peizometers in Tre r' Gof and Cae Gwyn
Pump test borehole array
850
745R
867
870
871
PZ1A
PZ4A
PZ3
TRE'R GOF
BH518R
314
312
313
880
874RA
875
878
852
306R
971
822
BH525CP
BH525R
301R
BH520CP
BH521R
BH530R
BH530CP
309CP
309RO
309R
769R
BH509CP
BH516A
BH516R
887
712R
305AR
305R
307R
788R
787R
BH536R
713R
PW1
BH512R
BH512CP
BH529R
BH529CP
775R
794R
302R
727R
BH533CP
726
802
308R
729S
BH534RA
BH534CP
801
729D
PW2
719A
777R
950
303CP
717
303R
951
RGMBH2
304R
1010
1009
763
941
BH535R
BH535CP
1013
1012
947A
957
758
958
1025
1028
BH2203
BH2201A
RGMBH6
Pennant
Tregele
Ty-Croes
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Drawing Status
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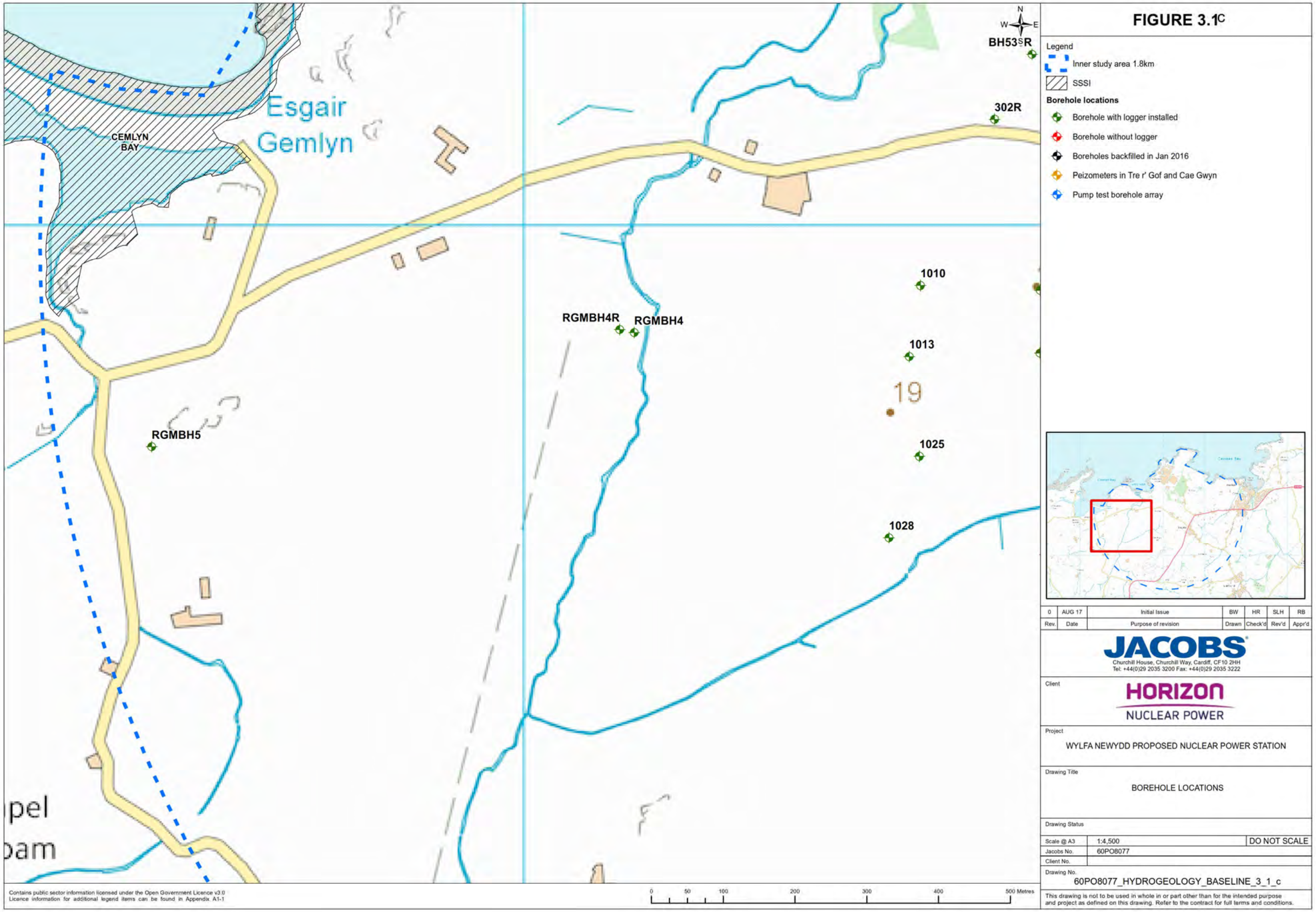
FIGURE 3.1C
Legend
Inner study area 1.8km
SSSI
Borehole locations
Borehole with logger installed
Borehole without logger
Boreholes backfilled in Jan 2016
Peizometers in Tre r' Gof and Cae Gwyn
Pump test borehole array
Esgair
Gemlyn
CEMLYN
BAY
BH53SR
302R
1010
1013
1025
1028
19
RGMBH4R
RGMBH4
RGMBH5
pel
bam
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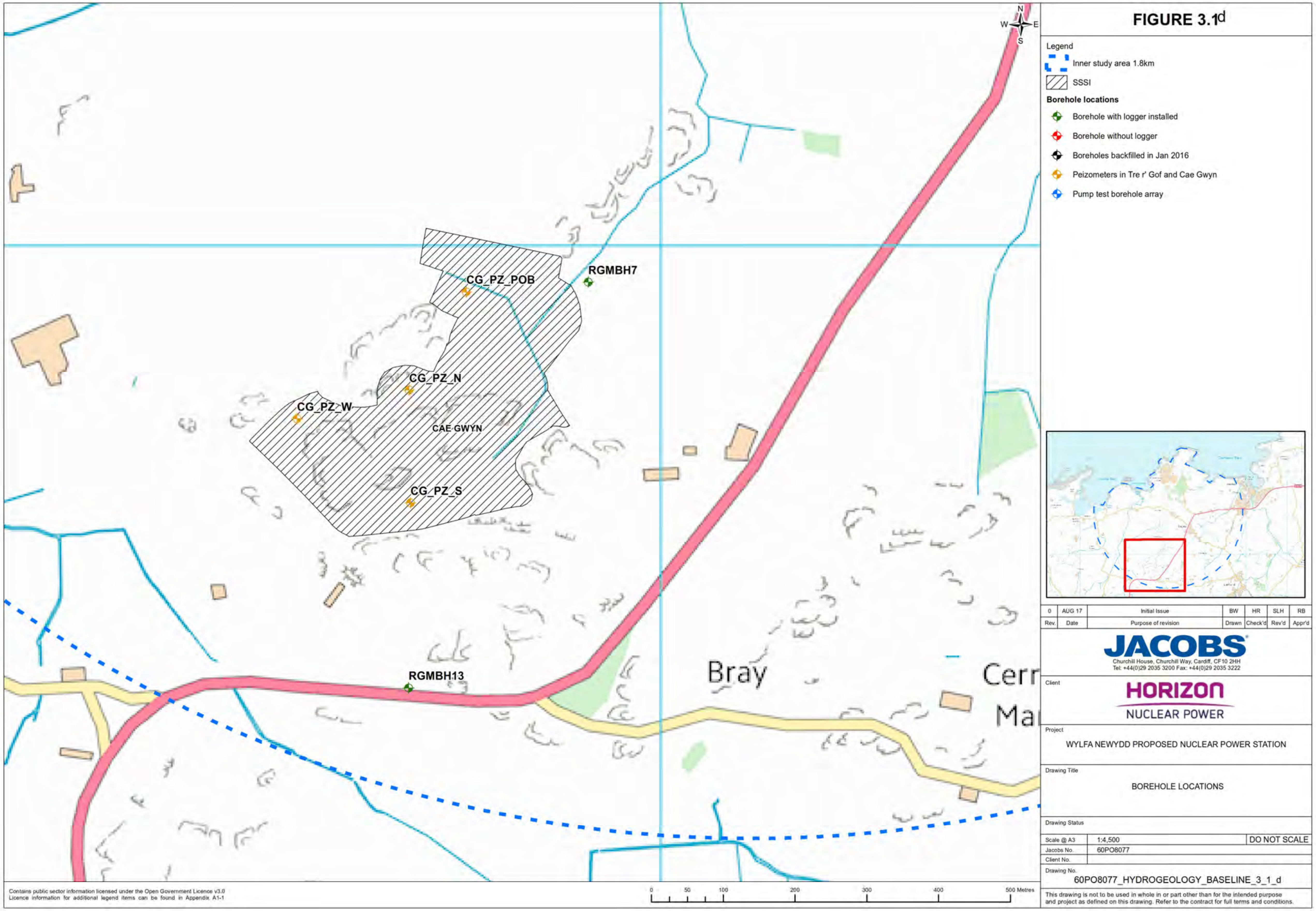
FIGURE 3.1d
Legend
Inner study area 1.8km
SSSI
Borehole locations
Borehole with logger installed
Borehole without logger
Boreholes backfilled in Jan 2016
Peizometers in Tre r' Gof and Cae Gwyn
Pump test borehole array
CG_PZ_POB
RGMBH7
CG_PZ_N
CG_PZ_W
CAE GWYN
CG_PZ_S
RGMBH13
Bray
Cerr
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Drawing Title
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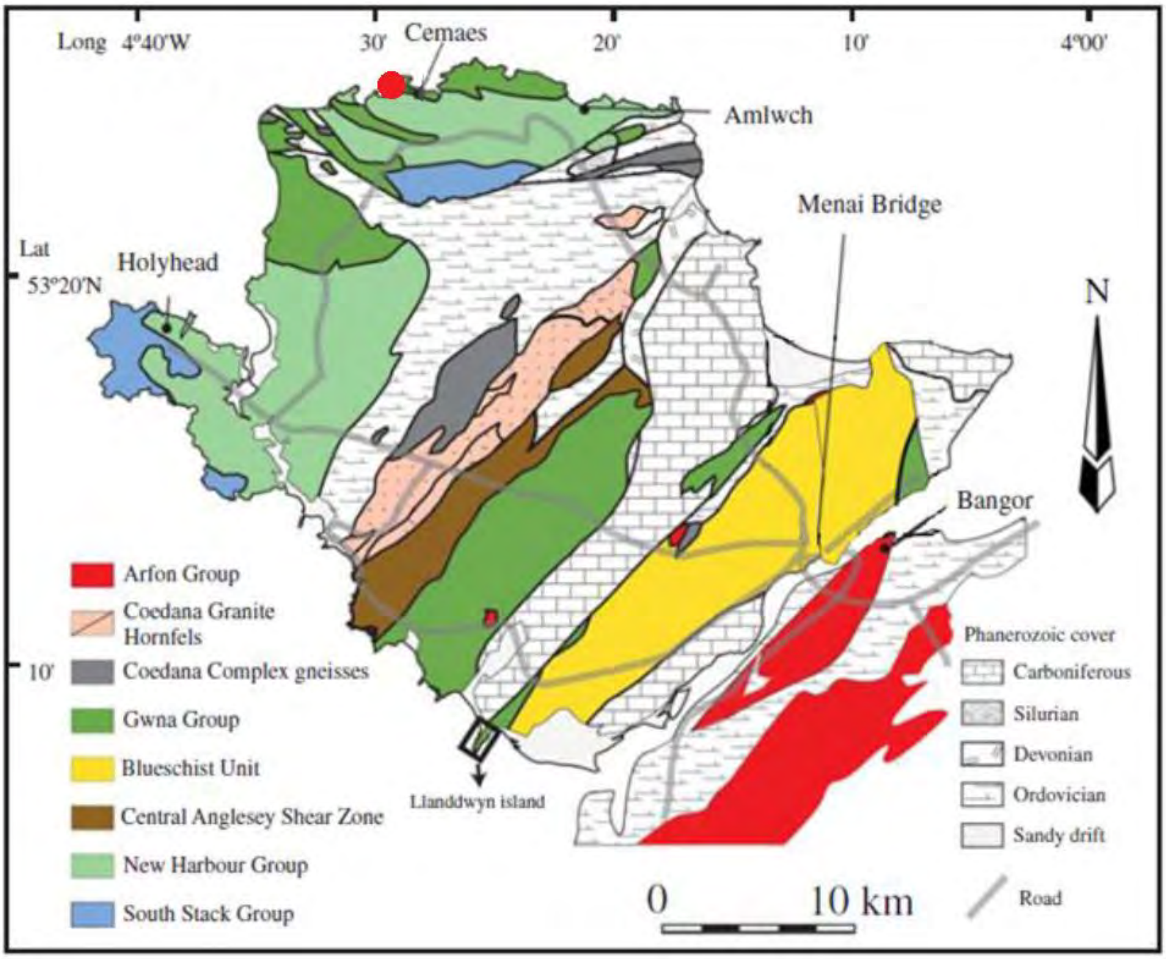
0 50 100 200 300 400 500 Metres

Figure 3.2: Bedrock geology map of Anglesey and the Menai Strait (Location of the Wylfa Newydd Development Area is shown as a red dot (from [RD10] and adapted from Maruyama *et al*., 2010)



3.2.2 Site geology summary

The Wylfa Newydd Development Area is located in a geologically complex area, which has been the subject of a number of investigations over many years. In summary, the area around the Wylfa Newydd Development Area is underlain by superficial deposits, predominantly of glacial origin, which overlie metamorphic bedrock of Cambrian age with some minor igneous intrusions of Palaeozoic and Tertiary age. The thickness of made ground and superficial deposits and rock head elevation contours that have been recorded in the site investigations were compiled in the DOnGI report and the figures from the report are reproduced in appendix C (5130177-ATK-XX-ZZ-DR-C-0005A and B; and 5130177-ATK-XX-ZZ-DR-C-0006A and B).

3.2.3 Site geology – made ground

The made ground on the Wylfa Newydd Development Area is generally related to the construction of the Existing Power Station to the north of the Wylfa Newydd Development Area. The arisings that have been deposited on the Wylfa Newydd Development Area are mainly from excavations to form the platform and excavations for the foundations of the Existing Power Station. They are mainly derived from naturally occurring materials and were used to form screening bunds. These bunds were investigated as part of the IOnGI. However, parts of the Power Station Site have been identified as areas where wastes have been deposited and where contaminated land may be present a number of 'Areas of Potential Concern' (APCs) have been identified as shown in table 3.1 (the figure from the geology baseline report showing these areas is reproduced in appendix C as Figure 7). These are areas where the likelihood of made ground is anticipated to be highest, or where made ground is known to be present (see the Land Contamination Risk Assessment and Remediation Strategy (Application Reference Number: 6.4.25) for further details of made ground conditions).

Table 3.1 – Areas of Potential Concern identified

Ref.	Description
APC6	Non-radiological contaminants may be present within fill material (which may have included railway ballast) used to landscape area to the north of the gas turbine fuel oil tanks, in the north of the Existing Power Station site. Ballast may contain some hydrocarbon contamination relating to leaks of fuel and hydraulic liquid from rolling stock.
APC7	Located to the south of the Existing Power Station and included a contractor's laydown area, car park and workshop during construction of the Existing Power Station. Redundant site vehicles and abandoned cars were present in the area in the early 1970s. Chlorinated solvents (primarily trichloroethene) were observed within water samples obtained from a sump and surface water course during historical investigations. Asbestos and hydrocarbon contamination was identified in made ground in the area to the southwest of the Existing Power Station.
APC7a	Located adjacent to the north of APC7 and currently populated by a car park associated with the Existing Power Station. Aerial photography dated to 1968, 1971 and 1972 shows the construction compound and storage area identified within APC7 to have extended across into the area, thus similar ground conditions may persist.
APC9	Located to the north of the 400kV switch house at the Existing Power Station and included offices, parking, site plant, stores, workshops and a cement mixing plant during the construction of the Existing Power Station. APC9 also includes part of a former contractor's site disposal area.
APC10	Former topsoil storage area.
APC11	Existing Power Station construction works spoil heap (later removed to an area north of 400kV switch house, APC9). Former contractor's site disposal area.
APC12	Spoil heap area (including Dame Sylvia Crowe's Mound). Anecdotal evidence that the heap contains buried heavy machinery and site vehicles. The mound covers the areas of two old quarries identified during the review of historical mapping.
APC15	Area identified from historical map review in [RD6] as potentially containing made ground relating to the Existing Power Station construction works.
APC16	Tregele petrol station located within the Wylfa Newydd Development Area, on the south-eastern boundary.
APC17	A localised area of made ground including a spoil heap containing general waste (plastic, rubber, etc.) but also recorded as containing asbestos located to the east of the Tai Hirion farmstead.
APC18	Made ground associated with former properties along Cemlyn Road (identified following the DOnGI).
APC19	Made ground associated with Wylfa Sports and Social Club area (identified following 2015 GI).

Ref.	Description
APC20	Area of the Existing Power Station within the Wylfa Newydd Development Area, including a 132kV switch house, car parks and offices. Historical mapping/aerial photography shows the land use to have remained relatively consistent since the Existing Power Station was first shown in 1968, with the occasional addition and removal of buildings/structures.

There are likely to be other smaller areas of made ground in the areas of buildings and roads. Made ground, where encountered, is generally less than 2m thick but deposits over 4m thick have been encountered with the thickest areas being identified as being areas of re-worked natural material. The thickest deposit of waste material has been identified in APC7 where up to 2.4m of made ground was identified and mixed waste and natural material has been identified at up to 5m in APC18. Waste material encountered has been described as containing a mixture of metal, wire, plastic sheeting, fibreglass, whole bricks, asphalt, slag, ash, plastic pipe, plastic tape, glass, wood, masonry, corrugated board/metal and possible asbestos board/cement.

3.2.4 Site geology – superficial deposits

Superficial materials (formerly known as drift by BGS) are the youngest geological deposits and are generally unconsolidated and overlie bedrock. Superficial geological materials occur across the Wylfa Newydd Development Area in varying thicknesses and are locally overlain by made ground. The following superficial deposits have been encountered on the Wylfa Newydd Development Area:

- locally derived coarse basal till;
- locally derived lodgement till;
- Irish Sea lodgement till;
- melt-out till;
- silty sand loess deposit; and
- lacustrine and alluvial deposits (Tre'r Gof Catchment).

The region has experienced repeated advances of glaciers during the Quaternary Period with the last major glaciation being approximately 12,000 years ago when the area was covered by an ice sheet. This last glaciation period destroyed many of the effects and evidence of earlier glaciation.

Anglesey was located on the eastern margin of the Irish Sea ice stream during the Devensian glaciation. The formation and recession of the Devensian ice sheet (together with previous ice sheets) formed the rounded topography of Anglesey. The principal glacial features observed on the Wylfa Newydd Development Area and surrounding land are north-east to south-west trending “drumlins” (elongated, half-egg-shaped hills), glacial outwash sand and gravel plains, striations and plucking of bedrock surfaces.

The thickness of superficial deposits at the Wylfa Newydd Development Area varies widely with over 30m of deposits being present beneath the high points of the drumlins, but with less than 2m present in other areas. However, typically the superficial deposits are less than 5m thick over much of the area as shown in Drawing TQHOWA406 (from [RD6]) and Drawing 5130177-ATK-XX-ZZ-DR-C-0005A (from [RD10]) and reproduced in appendix C.

An assessment of the logs for boreholes drilled across the site (see appendix D for a selection of logs) suggests that the glacial till dominantly has a clay matrix and is typically a sandy gravelly clay, although there is a range in the proportion of sand and gravel in the deposits. Granular superficial deposits, expected to be more permeable and consisting of variably clayey, silty sand and gravel, are present across the south-western part of the Power Station Site (figure 3.3). These include examples where significant layers of both low permeability and granular materials are present. The ground investigation information suggests that granular materials become the predominant superficial deposits broadly to the south-west of a line between Tregele village and Porth-y-pistyll. Low permeability, clay dominated deposits are still present in this area and are observed further to the south-west in the vicinity of Cae Gwyn.

Within the Tre'r Gof Catchment which covers an area of 1km^2, the typical thickness of superficial deposits is between 3m and 8m. The SSSI itself has formed over a kettle hole or buried valley feature which was infilled with over 25m of silts, sands and clays (proven in BH311, appendix D). In the basin these silts, sands and clays are overlain by peats, which as shown in appendix D8-5 (Application Reference Number: 6.4.30), have been proven to be over 3m thick in the central basin area during the current investigations. The maximum thickness of the peat is not known. The surrounding superficial deposits are largely of Irish Sea Lodgement Till.

This assessment therefore indicates significant variations in the nature and thickness of superficial deposits across the site, but concludes that they dominantly have a clay matrix and where this is the case, are likely to be of relatively low permeability.

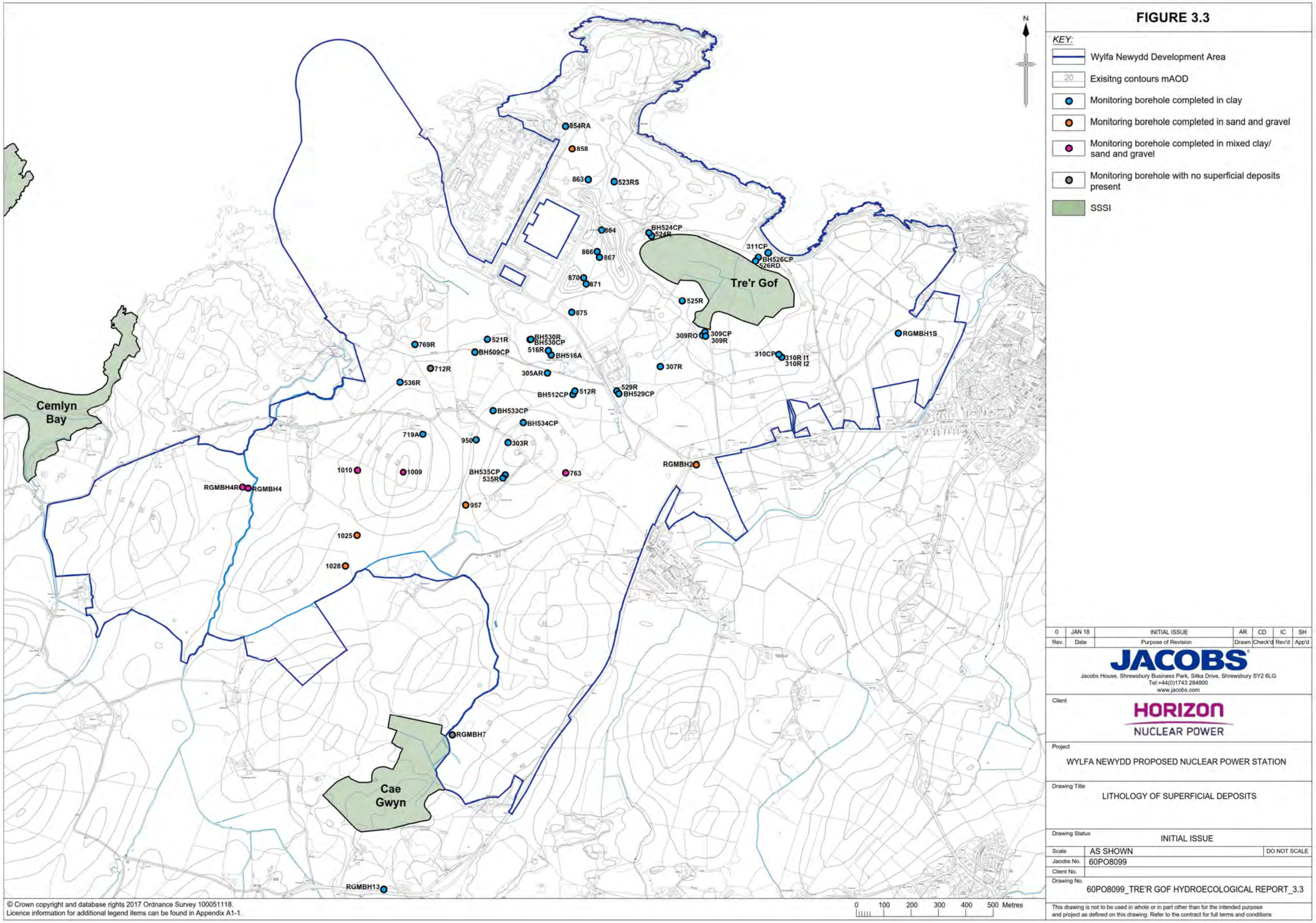


FIGURE 3.3
KEY:
Wylfa Newydd Development Area
Exisitng contours mAOD
Monitoring borehole completed in clay
Monitoring borehole completed in sand and gravel
Monitoring borehole completed in mixed clay/ sand and gravel
Monitoring borehole with no superficial deposits present
SSSI
Cemlyn Bay
Tre'r Gof
Cae Gwyn
854RA
858
863
523RS
864
866
867
870
871
875
BH524CP
524R
311CP
BH526CP
526RD
525R
309RO
309CP
309R
310CP
310R I1
310R I2
RGMBH1S
307R
529R
BH529CP
769R
521R
BH530R
BH530CP
516R
BH516A
BH509CP
712R
305AR
536R
BH512CP
512R
BH533CP
BH534CP
719A
950
303R
1010
1009
BH535CP
535R
763
RGMBH2
RGMBH4R
RGMBH4
957
1025
1028
RGMBH7
RGMBH13
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Project
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Drawing Title
LITHOLOGY OF SUPERFICIAL DEPOSITS
Drawing Status
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Scale AS SHOWN
DO NOT SCALE
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Drawing No.
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3.2.5 Site geology – bedrock

The bedrock of the Wylfa Newydd Development Area comprises metamorphic rocks of late Precambrian and early Cambrian age with igneous intrusions of both Paleogene (Tertiary) and undefined much older Palaeozoic age. Table 3.2 provides a summary of the bedrock beneath the Wylfa Newydd Development Area. The majority of the Wylfa Newydd Development Area is underlain by rocks belonging to the New Harbour Group which also incorporates the Skerries Group, with the Gwna Group being at the northern extent of the Wylfa Newydd Development Area only (in the vicinity of Wylfa Head and the proposed outfall at Porth Wnal). The elevation of the rock head in the Wylfa Newydd Development Area is typically 10mAOD to 20mAOD, although it is lower than this in the west and north (see appendix C for Drawing 5130177-ATK-XX-ZZ-DR-C-0006A taken from [RD10] showing the rock head elevation contours).

Table 3.2: Bedrock geology beneath the study area

Geological Unit/Group	Lithologies	Description*	Wylfa Newydd Development Area Distribution
Paleogene Intrusions	Dolerite/Gabbro/ Basalt	These rocks were formed from silica-rich magma intruded into the Earth's crust.	Northern part of the area, close to the proposed outfall tunnels.
Palaeozoic Intrusions	Dolerite/Gabbro/ Basalt	These rocks were formed from silica-rich magma intruded into the Earth's crust.	Predominantly central portion of the area, i.e. the proposed Power Block and Intake Structures.
Gwna Group	Grit, phyllite, quartzite, limestone, jasper, graphitic phyllite, spilitic pillow lavas and tuffs	Schist. Metamorphic bedrock formed approximately 508 to 635 million years ago in the Cambrian and Ediacaran Periods. Originally sedimentary rocks formed in deep seas by chaotic deposition from underwater gravity slide. Later altered by low-grade metamorphism.	Northern part of the study area, close to outfall tunnels.
New Harbour Group (including Church Bay Tuffs and Skerries Grits)	Psammite, Phyllite, Metaconglomerate, Metabreccia	Mica schist and psammite. Metamorphic bedrock formed approximately 542 to 635 million years ago. Originally sedimentary rocks formed in deep seas. Later altered by low-grade metamorphism.	Area-wide. The Church Bay Tuffs and Skerries Grit occurs to the south of the Wylfa Newydd Development Area

Geological Unit/Group	Lithologies	Description*	Wylfa Newydd Development Area Distribution
		The Church Bay Tuffs and Skerries Grits are a sub unit of the New Harbour Group and comprise tuff and sandstone sedimentary and igneous bedrock.	

* From BGS website (BGS, 2015)

Tectonic activity has resulted in the formation of a series of faults within the bedrock. Faults occur across the Wylfa Newydd Development Area as either open or infilled which may provide preferential pathways (for open faults) or provide a barrier for groundwater flow where they are infilled with clay deposits. A total of 28 major (persistent) faults have been mapped across the Wylfa Newydd Development Area, with generally either an east to west or north-west to south-east trend. These faults generally have an inclination between 30° and 80° and have typical thicknesses of 0.1m to 5.0m. Numerous smaller faults are also present. A map showing the faults is included as Drawing 5130177-ATK-XX-ZZ-DR-C-0007 in [RD10] which is included in appendix C.

In terms of the igneous intrusions, these generally strike north-west to south-east (the same as the faults) and are typically sub-vertical or steeply inclined, and are typically between 0.1m and 5.0m wide [RD10] (with the identified intrusions shown in Drawing 5130177-ATK-XX-ZZ-DR-C-0007 in appendix C). The intrusions have the potential to form a barrier to groundwater flow. A preliminary study of the intrusions was undertaken during the DOnGI to correlate the igneous intrusions identified from the IOnGI with the intrusions identified by the DOnGI. Intrusions identified in the DOnGI generally dip to the northeast, which is consistent with previous investigations. However, a detailed intrusion model of the Wylfa Newydd Development Area was not possible due to the large number of intersections, variable thickness, dip and orientation of the intrusions from the DOnGI.

A more detailed description of the geology can be found in Chapter 4 of the IOnGI interpretative report [RD5] and Chapter 4 of the DOnGI interpretative report [RD10] and the geology and soils Baseline condition report (Application Reference Number: 6.4.24).

4 Aquifer recharge

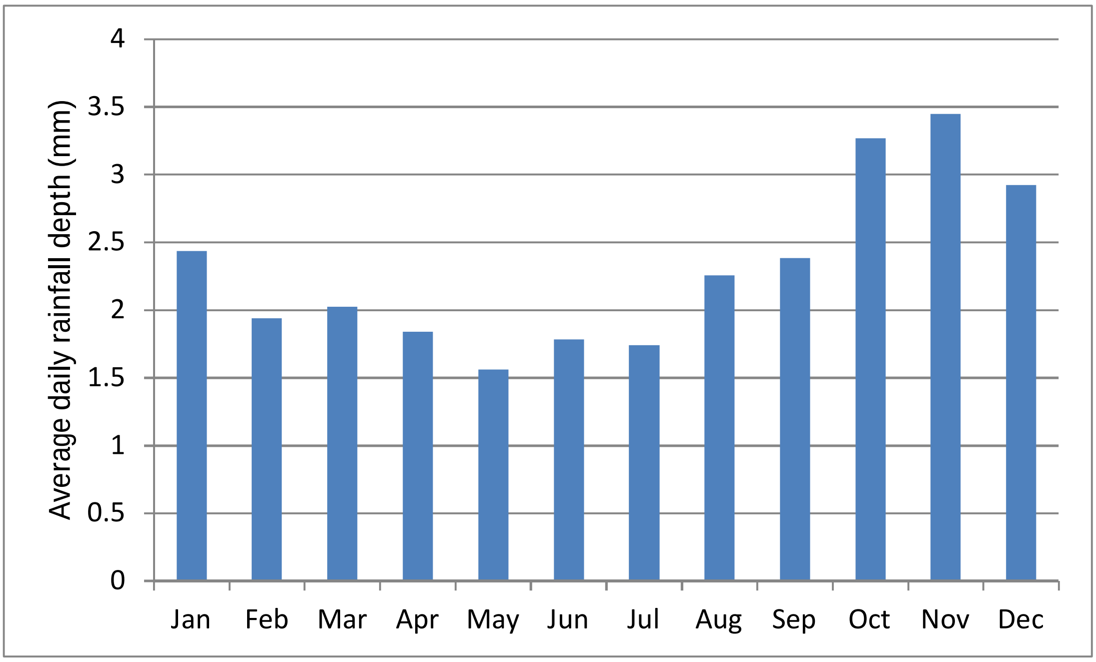
4.1 Meteorological data

Twenty years of rainfall data are available from the nearby NRW operated Llyn Alaw rain gauge (Met Office Gauge No. 532550, located at NGR SH 376 853). The RAF Valley gauge (approximately 19km south-south-west of the Wylfa Newydd Development Area at NGR SH 3097 7577) comprises more than 50 years of digitised hourly data (1960 to 2014). Data from before 1960 are only available in analogue form. Data from these rain gauges have been used to establish the baseline rainfall data.

The UK Meteorological Office average annual rainfall data available online [RD16] for the period 1981 to 2010, shows an average annual rainfall at RAF Valley of 841mm/yr. This is below the UK average of 1154mm/yr.

As can be seen in figure 4.1, the long term data indicate that rainfall is typically higher in the late autumn/early winter and lowest in late spring/early summer.

Figure 4.1: Average daily rainfall depths for each month at RAF Valley (1981 to 2010)



A meteorological station was installed by Magnox at the Existing Power Station in May 2010. Rainfall depths, humidity, temperature and wind speed (all required for assessing potential evaporation) are collected at this station although due to technical problems, significant gaps exist in this data record. In addition, it is understood that this meteorological station is located in proximity to the 400kV overhead lines and the presence of a physical structure close to the meteorological station may have an influence on the readings obtained.

In March 2015, Horizon installed an additional meteorological station in the Wylfa Newydd Development Area (the Salt Survey Weather Station). Rainfall depths, humidity, temperature, pressure and wind speed are all collected at this station.

The data collected on site from both the Existing Power Station and Horizon meteorological stations are supplemented by data held and supplied by the Met Office. This includes the Numerical Weather Prediction dataset which is based on modelling of meteorological conditions at any chosen location and provides hourly data for various parameters including rainfall depth.

As such, in addition to the four years of hourly data available from the local meteorological stations (2010 to 2015), there is a 20 year record available from Llyn Alaw and long-term data are available from RAF Valley. These provide a robust basis for assessing the long-term hydrogeological conditions at the Wylfa Newydd Development Area.

In addition to the actual monitoring data, the Met Office also provides estimates of potential evaporation and actual evaporation specific to a given type of land cover. This dataset, referred to as MOSES (Met Office Surface Exchange Scheme), can be provided at a 2km grid across the UK at one hour intervals and is driven by analyses of precipitation, cloud and near-surface temperature, humidity and wind.

A summary of the meteorological data considered in the assessment is provided in table 4.1.

Table 4.1: Summary of meteorological data

Provider	Location	Data type	Frequency	Record Length Available
Horizon	Wylfa Newydd Development Area	Air temperature, relative humidity, pressure, wind speed and direction and rainfall depth	10 minutes	March 2015 to December 2016 (data collection is ongoing, but unavailable at time of writing)
Magnox	Existing Power Station	Air temperature, relative humidity, pressure, wind speed and direction and rainfall depth	Hourly	2010 to present
NRW	Llyn Alaw gauge	Rainfall depths	Hourly	1990s to present
Met Office	On site modelled Numerical Weather Prediction dataset	Wind speed, wind direction, temperature, rainfall, cloud cover, relative humidity, sensible heat flux, and boundary layer depth	Hourly	Not determined
	On site modelled (MOSES)	Potential and actual evaporation for different land cover types	Hourly	Not determined
	RAF Valley met station	Rainfall depths	Hourly	1960 to present

4.2 Groundwater recharge

Groundwater recharge refers to the flux of water which moves from the ground surface or a surface water body into an underlying aquifer. Rainfall is often the most significant source of recharge although only a proportion of total annual rainfall actually enters the groundwater system; runoff, evaporation and transpiration from plants all reduce the total annual flux.

Average annual effective rainfall rates have been estimated to be approximately 500mm/a. This is based on the mean annual catchment rainfall and the mean annual catchment runoff data reported for the Cefni flow gauging station (station number 102001, Anglesey at NGR SH 429 769 [RD17]). It is acknowledged that a degree of uncertainty attaches to this figure due to the need to use averaged data and complexity of the systems involved. The effective rainfall rate of 500mm/a in part reflects the flux which recharges shallow groundwater located in the superficial deposits or the shallow bedrock where overburden is very thin or absent.

Recharge to bedrock in areas where the superficial overburden is very thick (such as beneath drumlins) and with a clay matrix is likely to be significantly lower than where bedrock or permeable superficial deposits are at or near the surface. Studies from other parts of the UK indicate recharge rates through glacial till with a clay matrix are typically around 20% of the total annual effective rainfall [RD18]. Where the glacial till in the Wylfa Newydd Development Area is of a similar composition to that in [RD18] recharge would be approximately 100mm/a.

Recharge to the bedrock aquifer has been modelled from rainfall and evapotranspiration data and stream flow hydrographs as part of Amec Foster Wheeler's 4R modelling, details of which are provided in appendix D8-7 (Application Reference Number: 6.4.32). Within the Wylfa Newydd Development Area, the Central model shows a recharge to the bedrock of between 30mm/a and 100mm/a. A degree of uncertainty attaches to these figures due to the complexity of the system being modelled, however they are in line with the assessment of recharge through glacial till by BGS [RD18], albeit for a different part of the UK. The highest recharge rates in the model occur where bedrock is at or near the ground surface (such as near the coast and at Cae Gwyn SSSI) with the lowest rates occurring where there are the thicker drift deposits such as where drumlins are present.

5 Regulator data and groundwater resources

5.1 Aquifer designations and vulnerability

The EA (prior to the formation of NRW) defined geological units across England and Wales according to their hydrogeological characteristics. The designations below have been prepared by the EA and are provided on their website [RD2] which was accessed in March 2015 as part of this study.

> *"Principal Aquifers*
> *These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifers.*
>
> *Secondary Aquifers*
> *These include a wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into two types:*
>
> *Secondary A - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers;*
>
> *Secondary B - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.*
>
> *Secondary Undifferentiated - has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.*
>
> *Unproductive Strata*
> *These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow."*

It should be noted that these data are no longer shown on the EA website for Wales and to date NRW has not published the data (or similar data) on their website or elsewhere. Designations as of April 2015 are still applicable to the aquifer bedrock designations for Wales.

The EA groundwater designation map for the superficial deposits located across the vast majority of the Wylfa Newydd Development Area showed that the superficial deposits were generally designated as Unproductive Strata. However, in relation to the superficial deposits, the EA and NRW have reclassified the Devensian glacial till deposits since the maps were produced and now classify this till as a Secondary (Undifferentiated) aquifer [RD19]. However, based on observations and measurement of permeability (see Section 6), it is unlikely that there will be significant groundwater flow within these deposits across the majority of the Wylfa Newydd Development Area.

In the vicinity of the Tre'r Gof SSSI the superficial deposits associated with this feature were designated as a Secondary A aquifer (figure 5.1). If present, these deposits would be important in the hydrology of the SSSI, although ground investigations around the Tre'r Goff SSSI and reported in appendix D8-5 (Application Reference Number: 6.4.30) do not indicate the presence of a Secondary A aquifer.

With respect to the bedrock, the EA groundwater designation map showed the Wylfa Newydd Development Area, and indeed all of north-west Anglesey, to be situated on Secondary B aquifers.

Figure 5.1: Designated Secondary A Aquifers for superficial deposits (light red areas show Secondary A aquifers). From [RD2].

In terms of aquifer 'vulnerability', the EA maps showed that the area of the Tre'r Gof Catchment designated as a Secondary A Aquifer is described as being of high vulnerability. This means that the soils readily transmit liquid discharges because they are either shallow or susceptible to rapid flow directly to rock, gravel or groundwater. The bedrock is not designated a vulnerability as it was previously classified by the EA as being a non-aquifer for which vulnerability was not defined.

5.2 WFD groundwater designations

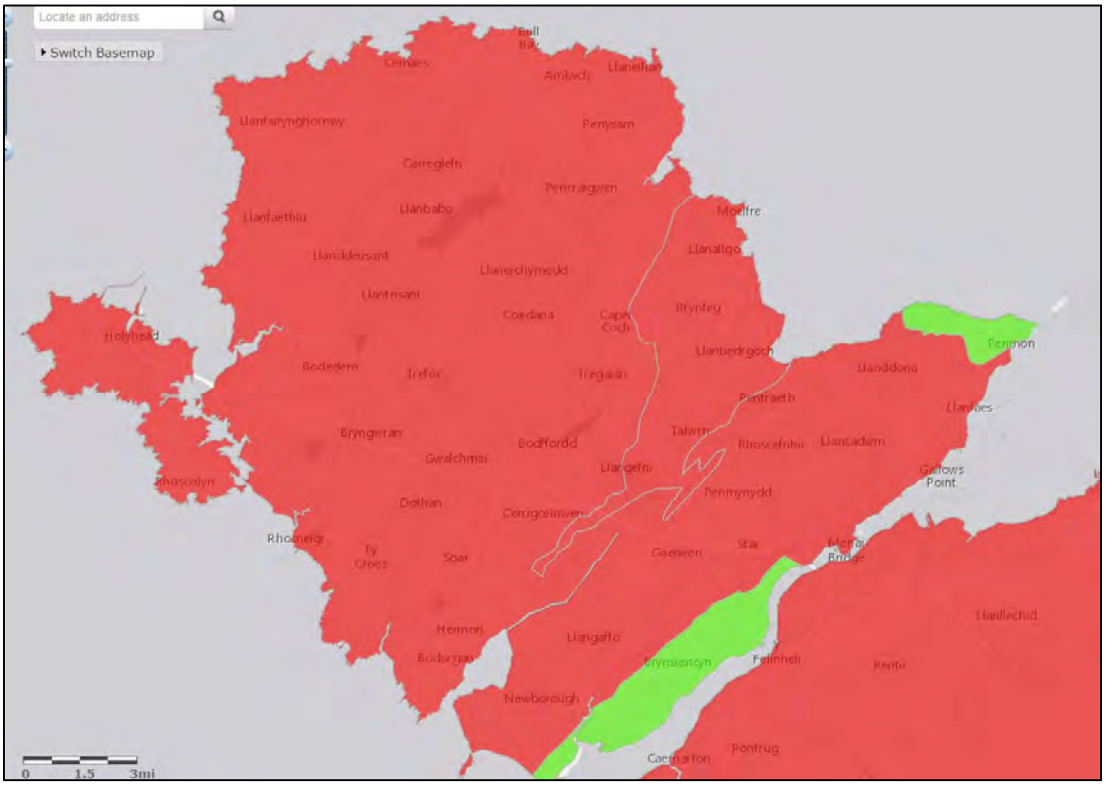
The WFD[3] establishes an integrated approach for the protection and sustainable use of the water environment. This requires a holistic approach to managing waters, looking at the water within the wider ecosystem and taking into account the movement of water through the hydrological cycle. The WFD is implemented through river basin management and planning that involves setting environmental objectives for all groundwater and surface water and devising and implementing programmes of measures to meet those objectives.

The NRW Water Watch Wales website [RD20] shows that the Wylfa Newydd Development Area lies within the Ynys Môn Secondary groundwater body unit (GB41002G204400) which covers a large part of Anglesey (figure 5.2). This area was

[3] The WFD is regulated in Wales by the *Water Environment (Water Framework Directive) (England and Wales) Regulations 2003* (as amended).

designated in 2015 as being of “Good” quantitative status (that is, there are no significant pressures on groundwater resources with, for example, sufficient water to support stream flows and groundwater inputs to terrestrial ecosystems) and “Poor” quality status [RD20] (see appendix E for the NRW designation).

Figure 5.2: WFD Groundwater Bodies showing current chemical status (red shows poor status, green shows good status). From NRW’s Water Watch Wales website, 2016



The “Poor” status in relation to quality is shown on the Water Watch Wales website [RD20] as due to pollution associated with abandoned mines (particularly at Parys Mountain, approximately 9km to the east of the Wylfa Newydd Development Area). As the groundwater body covers much of Anglesey, the chemical water quality will vary throughout and is likely to be much better in many areas than the classification for the whole water body would indicate. Groundwater from the Parys Mountain area would not affect groundwater quality in the Wylfa Newydd Development Area. As NRW does not have any groundwater monitoring boreholes in relation to the WFD in the vicinity of the Wylfa Newydd Development Area, the quality closer to the development area, in relation to the WFD criteria, is currently uncertain.

In Wales, all WFD designated groundwater bodies, including the Ynys Môn Secondary groundwater body, are designated as Groundwater Drinking Water Protected Areas. Under the WFD, these areas have to be protected with the aim of avoiding deterioration in their water quality which would compromise a relevant abstraction of groundwater intended for human consumption.

A WFD Compliance Assessment (Application Reference Number: 8.26) has been prepared as part of the Environmental Impact Assessment for the Wylfa Newydd Project to assess the effects of the Wylfa Newydd Project on the relevant water bodies and to determine whether the Wylfa Newydd Project is compliant with the objectives of the WFD including the effects to the Ynys Môn Secondary groundwater body.

5.3 Groundwater dependent terrestrial ecosystems

There are three sites within the Groundwater Study area which are ecological statutory designated sites and their locations are shown on figure 1.1. Aspects of these sites relevant to groundwater are outlined below.

5.3.1 Tre'r Gof SSSI

The NRW citation [RD21] states that the Tre'r Gof SSSI is lime-rich wetland, dependent on a steady water supply through springs, groundwater seepages, ditches and surface runoff. It is sensitive to changes in water flow, water level and water quality. Studies undertaken in the period 2015 to August 2017 as part of the Wylfa Newydd Project, and reported in appendix D8-5 (Application Reference Number: 6.4.30) have shown that the Tre'r Gof SSSI is a seasonal GWDTE. It is dependent on winter recharge by direct rainfall and shallow groundwater flows which bring in mineral-enriched water (in comparison with rainwater) vital to the maintenance of the ecological interest in the SSSI.

The essential lime content of the water supplying the wetland is believed to derive from contact of infiltrating water with the calcareous Irish Sea Lodgement Till, and potentially from other sources that may include bedrock groundwater. Streams that flow into the system of ditches that run through the SSSI are not thought to flow into or across the peat surface within the SSSI, but maintaining a high water level in the ditches is essential to prevent localised draining of the fen.

The low permeability and low hydraulic gradient in the peat soils within the fen play an important role in preventing water from being flushed rapidly through the soils. The retention time of water in the peat allows ion exchange to occur resulting in the build-up of calcium and bicarbonate/carbonate ions which lime-loving plant species require.

During the summer months, the water level in the peat drops below the surface of the SSSI, although it remains high and relatively close to the surface. Spring flow, seepage and baseflow in drains largely ceases. The presence of a deep peat soil across the wetland is crucial in maintaining high water levels throughout the summer months by storing winter recharge.

The majority of groundwater inputs are thought to be derived from the shallow superficial deposits. Due to the thick layer of low permeability superficial deposits underlying Tre'r Gof (reaching over 25m at the north-eastern side of the SSSI in BH311) there is not expected to be significant upward discharge into the SSSI basin from groundwater in the bedrock, although there is potential for lateral inflow. The shallow groundwater system has a low storage capacity and baseflow contribution to the SSSI is of the order of weeks; groundwater inputs cease quickly in the spring with the SSSI experiencing 'dry' conditions in the summer. The recharge radius for critical winter-borne springs and seeps has been estimated to be of the order of 50 to 150m, although these areas will be semi-circular rather than circular in shape.

Further details of the Tre'r Gof SSSI and monitoring undertaken in and around this wetland feature are provided in appendix D8-5 (Application Reference Number: 6.4.30) and as such further information is not provided within this baseline report.

5.3.2 Cae Gwyn SSSI

The NRW citation [RD22] indicates that Cae Gwyn SSSI is groundwater fed in part and that a high groundwater table is essential for the survival of wetland plants and animals. The citation also indicates that it is important not to lower water levels at the site and that the water supply to the site is maintained by springs and groundwater seepage.

Studies undertaken from November 2015 to May 2017 as part of the Wylfa Newydd Project (Application Reference Number: 6.4.31) have shown that The Cae Gwyn SSSI comprises a system of basin mires separated by dry heathland habitat.

Since November 2015, water quality data have been collected from in and around Cae Gwyn SSSI and from January 2016 to May 2017, shallow groundwater level data have been collected from piezometers installed into the basin mires. The water level data indicate that water levels in the piezometers are at or close to ground level all year round and show a reduction in level relative to Ordnance Datum from south to north across the SSSI. All water samples collected in and around Cae Gwyn SSSI are characterised by a neutral to acidic pH, as well as low concentrations of total dissolved solids and nutrients.

Cae Gwyn SSSI is not a single uniform site; instead, it comprises four basins and a central rocky outcrop. These basins are the Southern Basin, the Northern Basin, the Western Basin and the Primary Outflow Basin (POB). The four basins display different ecological qualities, have a distinctly different hydrochemistry and function hydrologically in different ways as follows.

- **The Southern Basin** is a fen underlain by peat that is up to 7m thick in places. It appears that the majority of inflows to the basin are due to surface water inputs, mostly from incident rainfall. The groundwater levels, water quality and ecology indicate that potentially there is some groundwater enrichment of the basin, possibly from seepages around the edge of the basin, or from a deeper groundwater source. However, based upon all of the lines of evidence it is concluded that this basin is generally surface water fed, with limited groundwater inflows.

- **The Northern Basin** is an acid fen with thin mineral soils, a fluctuating water level and includes a small pond. The basin receives input from direct rainfall and from flows from the small surrounding surface water catchment, but with no formal inflow channel. There is no formal outflow channel from the basin. The Northern Basin is separated from the POB by a shallow rocky outcrop therefore any rise in water above this elevation would result in discharge informally towards the POB. Available data suggest that rainfall discharges from the basin via an overland flow route and through seepage to bedrock, indicating that this basin recharges groundwater below the site and recharges the POB by overland flow (although the actual volume of water is small due to the small size of this basin).

- **The Western Basin**, although different in ecological character to the Northern Basin, appears to have a similar hydrological function and is underlain by thin mineral soils with no peat. The Western Basin appears to receive water input purely from rainfall to the surface water catchment and the basin with no groundwater input. Available data suggest that rainfall discharges to the Western Drain by informal overland flow and through seepage to bedrock.

- **The POB** is a large and flat basin, underlain by peat and which generally slopes down to the north-east towards the outfall channel. The basin is characterised by herbaceous plants dominated by grasses and rushes that are supported by moderately base-rich conditions and are tolerant of waterlogging, but their soils tend to dry out in summer. Available data suggest that the majority of the water within the basin is from surface water sources with no evidence of any significant groundwater recharge to this basin.

Further details of the Cae Gwyn SSSI and monitoring undertaken in and around this wetland feature are provided appendix D8-6 (Application Reference Number: 6.4.31) and as such further information is not provided within this baseline report.

5.4 Cemlyn Bay SAC, SPA, SSSI

This is designated as it is considered by NRW to be the best example of a saline coastal lagoon in Wales. The lagoon is separated from the sea by a shingle bank with a narrow channel at the western end. Surface waters flow into the lagoon, along with sea water and these are the primary controls on the lagoon quality. Direct groundwater inputs are likely via diffuse seepage, but this is thought to be of much lower importance than the surface water inputs. As such, this SSSI is not designated as being dependent on groundwater for its ecological features of interest.

5.5 Groundwater abstractions

Up until January 2018, the Wylfa Newydd Development Area was located in a geographical area that was exempt from the requirements for licensing of groundwater abstractions greater than 20m^3/day. Licences are now required, although it will be a few years until all existing groundwater abstractions are licenced and NRW does not currently have a list of groundwater abstractions within the study area.

The IACC does maintain a list of PWSs. These are groundwater abstractions that the IACC is aware of under the *Private Water Supplies (Wales) Regulations 2010* whereby the local authority has a duty to monitor private supplies and to make and maintain records for every water supply in its area. However, in the case of a private supply to a single dwelling, the regulations do not compel the local authority to monitor the supply (although it must do so if requested to by the owner or occupier). As such, the list of PWSs maintained by the local authority may not be complete.

The list of PWSs provided by the IACC is shown in appendix F with locations of those within 3km of the Wylfa Newydd Development Area shown on figure 5.3. The IACC has also provided a list of 'public' wells in the vicinity of the Wylfa Newydd Development Area. These are wells that, prior to the introduction of mains supply to this part of Anglesey, were used for water supply. These wells are also shown on figure 5.3 and indicate three wells within the Wylfa Newydd Development Area.

Following discussion with the IACC it is understood that none of these are now used although a survey of the wells by the IACC in the 1980s indicated that some were still present. The status of nine wells marked on OS maps within the Wylfa Newydd Development Area was also investigated by Jacobs/Horizon in 2015 as part of the Site Preparation and Clearance works [RD23]. The results from the assessment are shown in table 5.1 and did not identify any wells that were being used.

Table 5.1: Summary of 2015 well investigation

Easting	Northing	Well status	Notes
234917	393182	Not used	
235056	392816	Not used	
235536	392970	Not used	Rock 0.8m
235937	393267	Not used	
236242	393319	Not used	Could be land drains - Filled in
236147	393324	Not used	Could be land drains - Filled in
236149	393320	Not used	Could be land drains - Filled in
236160	393301	Not used	4m deep, 0.6m diameter. Groundwater at 2.5m depth.
234884	393577	Not used	

As part of the groundwater monitoring in March 2015, a request was made to sample all PWSs within the inner study area; these are at three properties, Foel Fawr, Caerdegog Uchaf and Cae Gwyn. At that time, access permission was refused although subsequently access has been granted to the property at Foel Fawr. Groundwater from the borehole at Foel Fawr is used for agricultural purposes (to provide water to cattle and for washing down) rather than for potable use. Groundwater samples were therefore collected from Foel Fawr in April 2015 and subsequent quarterly groundwater sampling rounds. However, it has not been possible to sample the boreholes at Caerdegog Uchaf and Cae Gwyn to date and so baseline information is not available. These properties are towards the edge of the groundwater study area and up hydraulic gradient of the Wylfa Newydd Development Area.

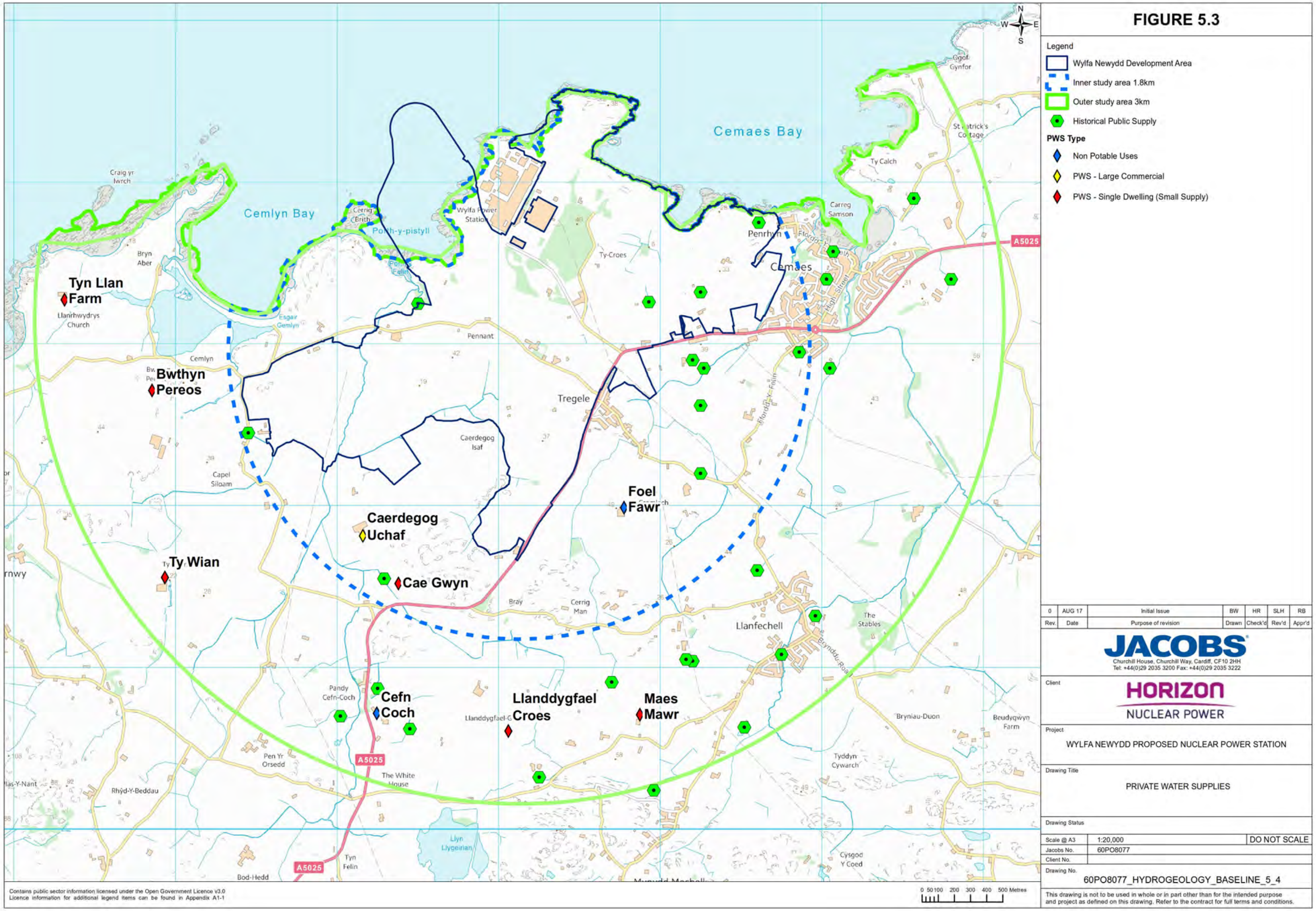


FIGURE 5.3
Legend
Wylfa Newydd Development Area
Inner study area 1.8km
Outer study area 3km
Historical Public Supply
PWS Type
Non Potable Uses
PWS - Large Commercial
PWS - Single Dwelling (Small Supply)
Cemaes Bay
Cemlyn Bay
Tyn Llan Farm
Bwthyn Pereos
Caerdegog Uchaf
Ty Wian
Cae Gwyn
Foel Fawr
Cefn Coch
Llanddygfael Croes
Maes Mawr
Tregele
Cemaes
Llanfechell
A5025
0 | AUG 17 | Initial Issue | BW | HR | SLH | RB
Rev. | Date | Purpose of revision | Drawn | Check'd | Rev'd | Appr'd
JACOBS
Churchill House, Churchill Way, Cardiff, CF10 2HH
Tel: +44(0)29 2035 3200 Fax: +44(0)29 2035 3222
Client
HORIZON NUCLEAR POWER
Project
WYLFA NEWYDD PROPOSED NUCLEAR POWER STATION
Drawing Title
PRIVATE WATER SUPPLIES
Drawing Status
Scale @ A3 1:20,000 DO NOT SCALE
Jacobs No. 60PO8077
Client No.
Drawing No. 60PO8077_HYDROGEOLOGY_BASELINE_5_4
This drawing is not to be used in whole or in part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.
Contains public sector information licensed under the Open Government Licence v3.0
Licence information for additional legend items can be found in Appendix A1-1
0 50 100 200 300 400 500 Metres

6 Groundwater levels and flow

6.1 Groundwater levels

6.1.1 Continuous groundwater level monitoring

Groundwater levels are monitored in boreholes across the Wylfa Newydd Development Area by a combination of manual dipping and pressure transducers, connected to data loggers. Several phases of data logger installation have taken place as outlined below.

1. Seventeen loggers were installed between March and July 2010 after the PSI (12 in bedrock boreholes and five in boreholes completed in the superficial deposits). Some six years' data are available from these (appendix G).
2. Twenty-seven loggers were installed in boreholes after completion of the IOnGI, in July 2011 (13 loggers in bedrock boreholes and 14 in boreholes completed in the superficial deposits). The data from these loggers are summarised in appendix G.
3. In February, March and April 2015 all the loggers were replaced and loggers installed in the boreholes installed in the DOnGI boreholes (excluding borehole RGMBH1S in which a logger was installed in July 2015). In total, 102 new loggers were installed in 2015 within 66 bedrock boreholes and 30 boreholes completed in the superficial deposits and six boreholes with mixed superficial, bedrock or made ground deposits. The boreholes in which loggers are located are shown in appendix B and marked on figure 3.1 with a summary provided in table 6.1. The loggers are currently set to record groundwater levels every hour.
4. Since 2015, 12 out of the 102 loggers installed within the boreholes have stopped recording data or could not be downloaded in August 2017 as shown in table 6.2.

Table 6.1: Summary of groundwater logger monitoring points

Strata*	No. of boreholes in which loggers were installed in 2010	No. of new boreholes in which loggers were installed in 2011	No. of new boreholes in which loggers were installed in 2015
Bedrock	12	13	41
Superficials	5	13	12
Made ground	0	0	0
Mixed lithology	0	1	5
Sub-Total	17	27	58
Total	102		

* Strata shows the lithology in which the well screen is installed

Table 6.2: Summary of loggers no longer recording or could not be accessed in August 2017

Borehole	Date of last recorded data	Reason for loss of logger
302R	26/10/16	Logger failed and not replaced
306R	02/08/16	Borehole location could not be found due to vegetation growth
530R	01/08/16	Logger vandalised and not replaced
787	15/12/15	Logger failed and not replaced
875	14/12/15	Logger removed and borehole backfilled
878	14/12/15	Logger removed and borehole backfilled
524CP	31/01/17	Logger failed and not replaced
524R	31/01/17	Logger failed and not replaced
530CP	01/02/17	Borehole location could not be found
534R	02/02/17	Logger data not saving
801	02/02/17	Borehole not accessed
1013	01/02/17	Data corrupted

When the loggers were downloaded in June 2015, a manual dip of water levels was recorded in each borehole and compared to the logger data (manual dips had not been made prior to this to allow comparison to the logger data). The water levels recorded by the logger differed from the level recorded manually in the majority of boreholes. In summary, of the 87 measurements made at this time, 11 loggers had water levels within 50mm of each other (which could be considered to be of good accuracy), 51 of the loggers recorded a water level which was between 60mm and 300mm different to the manually dipped level and 21 loggers recorded a water level between 300mm and 1m different which is considered to be poor accuracy. In a further four loggers the difference exceeded 1m.

The cause of the discrepancies was identified as an issue regarding the set-up of the equipment due to the length of cable not being accurately measured when the loggers were installed and the loggers were re-set to correct the issues identified. Corrections to the data have been made based on the manually measured water levels and the precision of the water level data recorded by the loggers is considered to be within acceptable limits. Therefore, interpretation of seasonal groundwater trends should not be affected.

6.1.2 Water level fluctuations

Hydrographs for boreholes where the loggers have been installed are shown in appendix G and these demonstrate that seasonal minimum groundwater levels occur around July to September and maximum levels occur around December to January as summarised in table 6.3. Actual peak and low water levels will depend on the rainfall pattern over the seasons. Annual fluctuations in groundwater levels (as measured in 2015 for boreholes with data loggers in) are typically in the order of 3m with the annual variations in the bedrock and superficial deposits being similar.

In BH311CP, a borehole completed in the superficial deposits to the north of the Tre’r Gof SSSI, the water levels show rapid rises and falls during the winter and spring. For example, the water level in this borehole showed a rise of over 5m over a three day period in December 2015 following heavy rainfall. The manual measurements made from mid-2015 onwards confirm that the change in groundwater level is real (as opposed to a logger artefact) with the logger and manual dip measurements being in fair agreement (typically within 100mm). This borehole is completed at considerable depth in the superficial clay and gravel deposits (with the well screen from 23mbgl to

25mbgl) with a thick clay horizon above it. This clay horizon is likely to be confining the groundwater, and recorded groundwater levels are around 1.5mbgl to 2mbgl during the winter and 6mbgl in the summer.

In 2016, the lowest groundwater levels were recorded later in the year than in previous years with groundwater levels showing a low point in September before rising slightly in October and then falling again to record yearly low values in November. Groundwater levels then rose relatively rapidly in November 2016 and the most recent data show that peak winter highs were recorded in late December 2016 and early January 2017. For the data collected up until August 2017 it appears that the summer lows for 2017 had not been reached by August. It is notable, however, that in June 2017 as groundwater levels were receding, most boreholes do show a rise which is likely to be due to heavy rainfall at that time leading to groundwater recharge (although rainfall data for this period have been collected, it was not available at the time that this baseline report was prepared).

Table 6.3: Summer Lows and Winter Highs

Period	Summer Low	Winter High
Summer 2010	July	
Winter 2010/2011		December
Summer 2011	October	
Winter 2011/2012		December
Summer 2012	July	
Winter 2012/2013		December
Summer 2013	September	
Winter 2013/2014		January
Summer 2014	October	
Winter 2014/2015		January and March
Summer 2015	September	
Winter 2015/16		January
Summer 2016	September and November	
Winter 2016/17		December 2016 and January 2017
Summer 2017	Data not available at time of writing	

6.1.3 Vertical hydraulic gradients

In order to assess the degree of interaction between groundwater in the superficial deposits and that in the bedrock the difference in water levels in the two strata have been assessed by comparing groundwater levels in fourteen pairs of boreholes drilled as part of the IOnGI. The data, which are shown in table 6.4, have been assessed for water level low and water level high periods and show that:

- five pairs of boreholes (36%) have a water level difference in excess of 1m;
- eight pairs of boreholes (57%) have a water level difference of between 1m and 0.1m; and
- one pair of boreholes (7%) has a water level difference of less than 0.1m.

Table 6.4: Groundwater levels in paired boreholes

Borehole pairs	Target geology	Borehole depth (mbgl)	Groundwater level (mAOD)		Difference in groundwater level (m)	
			Summer low	Winter high	Summer low	Winter high
303CP	Superficial	16	32.36	33.97	-14.62	-13.76
303R	Rock	26	17.74	20.21		
305R	Rock	5.7	15.30	16.33	0.20	0.33
305AR	Rock	19	15.49	16.66		
309RO	Superficial	2.5	7.26	9.53	0.44	0.04
309R	Rock	35	7.70	9.57		
310R I1	Rock	20	9.07	11.66	0.35	0.52
310R I2	Rock	29	8.72	11.13		
512CP	Superficial	3.7	15.78	17.22	0.20	0.20
512R	Rock	16	15.98	17.41		
516CP	Superficial	3.6	12.17	13.47	0.08	0.21
516R	Rock	16	12.25	13.68		
523RS	Superficial	20	9.60	12.36	-1.09	-1.83
523RD	Rock	51.9	8.51	10.53		
524CP	Superficial	6.5	6.44	7.87	0.01	0.20
524R	Rock	19	6.43	7.67		
525CP	Superficial	5.25	6.56	7.77	0.05	0.09
525R	Rock	12.5	6.51	7.68		
526CP	Superficial	11.8	8.29	8.93	-4.56	-4.38
526RD	Rock	39	3.73	4.55		
529CP	Superficial	3	15.35	16.28	0.26	0.25
529R	Rock	10	15.61	16.52		
530CP	Superficial	3.5	12.06	12.84		0.22
530R	Rock	16	N/A	13.06		
534CP	Superficial	12.8	21.62	22.13	-4.34	-2.54
534R	Rock	42.5	17.29	19.58		
535CP	Superficial	12.6	29.52	32.14	-9.93	-10.62
535R	Rock	32.3	19.59	21.52		
Negative value for difference in water level shows the water level in the shallow borehole (usually superficial deposit) is higher than in the deeper (bedrock) borehole						
Positive value for difference in water level shows the water level in the shallow borehole (usually superficial deposit) is lower than in the deeper (bedrock) borehole						
Summer Low is average water level from loggers from September 2016						
Winter High is average water level from loggers from December 2015						
N/A The logger in BH530R was vandalised in the summer of 2016 and data from this period are not available						

For the five boreholes with the greatest difference, the hydraulic gradient is always downwards from the superficial deposits into the bedrock. For the remainder of the boreholes the gradient is always upwards from the bedrock into the superficial deposits. This upward gradient suggests a degree of confinement by the superficial deposits. At BH524 the direction of the hydraulic gradient changes from winter to summer, although this appears to be limited to this location. Borehole pairs with the highest levels in the bedrock are situated close to the Tre’r Gof SSSI and to the south of the Existing Power Station.

On the higher ground of the drumlins and to the north and north-east of the Tre’r Gof SSSI (the borehole pairs at BH523 and BH526), the groundwater levels are such that the levels in the superficial deposits are significantly higher (in the order of 10m to 14m, for example, in borehole pairs at BH303 and BH535). This suggests local perching of the groundwater in lower permeability superficial deposits within the drumlins. Perching occurs where the ground is locally saturated but is separated from the main groundwater body by an unsaturated soil or rock. This can occur where a low permeability deposit is overlain by a higher permeability deposit such that groundwater infiltration down to the main aquifer body is limited and water accumulates at the boundary. The low permeability layer needs to be underlain by an aquifer that is not saturated for groundwater to be perched.

The differences in water levels between shallow and deep boreholes confirm that the vertical hydraulic gradients differ markedly across the Wylfa Newydd Development Area. This is due to the heterogeneity of the glacial till, combined with variations in topography associated with drumlin fields and fractures, and potentially faults and igneous intrusions, in the bedrock.

In a small number of boreholes (BH512, BH305AR (rock), BH309CP, 309R and BH309RO) artesian conditions have been encountered during the monitoring work by Jacobs at times of high water levels (i.e. water levels are measured as being at or above the ground level). BH512 and BH305AR are completed in the bedrock and the artesian conditions may indicate a degree of confinement in these locations. BH309CP and BH309RO are completed in superficial deposits on the edge of the Tre’r Gof SSSI and the high groundwater levels in these boreholes probably represent a point where the ground level intercepts the shallow groundwater table when groundwater levels are high. In addition, [RD10] identifies artesian conditions in the following boreholes: BH305R, BH310R, BH520, BH712R, BH713R, BH769R, BH950R, BH951R and BH958R. It is noted in [RD10] that the artesian conditions were recorded for these boreholes over the winter months between November and April, and show a groundwater level of between 0.15m and 0.6m above ground level.

6.1.4 Water table maps

Based on the assessment of vertical hydraulic gradients, and taking into account the variability of the strata penetrated in each borehole (as discussed in section 3.2 and evident in the borehole logs in appendix D), it was determined that there is significant variation across the Wylfa Newydd Development Area in how the glacial till behaves. However, it dominantly has a clay matrix and is expected to behave in a hydrogeologically different manner to the fracture bedrock beneath it. For these reasons separate water level maps have been prepared for the superficial deposits and the bedrock. The significant difference in the maps (discussed below) between the two deposits supports this separate assessment of the superficial deposits and bedrock.

Water table maps have been prepared for high water level and low water level periods. Groundwater levels from measurements in September 2016 have been used to create groundwater contour plots for superficial deposits and bedrock deposits to show water levels during a time of low groundwater levels (figures 6.1 and 6.2). Logger data from December 2015 have been used to produce plots of groundwater levels in December 2015 during high water levels (figures 6.3 and 6.4).

These contour plots utilise groundwater level data from boreholes that monitor groundwater levels in the bedrock and the superficial deposits respectively. However, where the data clearly indicate that a perched stratum is being monitored (such as at drumlins in the west of the Wylfa Newydd Development Area) then these data have been excluded for the purposes of the contours. Also, the levels recorded in the piezometers within the Tre'r Gof and Cae Gwyn SSSIs have not been used for drawing the contours as these represent perched water levels in peat.

In general terms, the groundwater levels show that groundwater flow follows the topography. The highest water levels, excluding perched levels, are recorded to the south of the Wylfa Newydd Development Area at over 30mAOD in borehole RGMBH13 recorded in December 2015. Groundwater levels towards the coast are recorded at a minimum of 0.39mAOD (in borehole 852R in September 2015). When considering perched levels, the highest groundwater level is recorded in borehole 303CP which is completed in the superficial deposits at the top of a drumlin with this borehole recording the groundwater level at around 33mAOD. Borehole 303CP is completed in the drumlin with the borehole's response zone being in a very stiff clay horizon at 14mbgl to 16.2mbgl.

The borehole logs (included in appendix D) for these areas of perched groundwater show that the well screens are generally installed in clays and as such the flows through the deposits will be small.

The water table maps for the bedrock groundwater show a groundwater divide trending from the south-east towards the north-west under a slight topographic ridge which passes beneath Tregele village. Groundwater to the west of the divide flows in a north-west direction across the Wylfa Newydd Development Area towards the coast at Cemlyn Bay and Porth-y-pistyll, whilst groundwater east of the divide flows towards Cemaes Bay (and the Tre'r Gof SSSI). A further divide is present to the east close to the line of the surface water catchment.

There is a groundwater high associated with elevated land to the east of the Existing Power Station and the west of the made ground of Dame Sylvia Crowe Mound (including in boreholes BH864, BH866, BH870 and BH871). This high in the groundwater levels (which is also observed in bedrock boreholes and one borehole completed in the superficial deposits) may be caused by water running off the steep slopes of the mound leading to an area of locally higher recharge and/or due to the presence of basements associated with the Existing Power Station forming a barrier to groundwater flow.

With respect to the Tre'r Gof SSSI, the hydraulic gradient in the bedrock is slightly steeper just up-gradient of the SSSI than beneath the SSSI. This is likely to be the effect of the groundwater in the steeply dipping bedrock surface at the Tre'r Gof basin meeting the lower permeability glacial deposits (silts and clays) which infill the basin and an associated buried valley. Groundwater levels continue to decline north of the Tre'r Gof SSSI towards the coast indicating that groundwater in the bedrock is discharging to the sea. The low permeability superficial deposits beneath the Tre'r Gof SSSI suggest that discharge of bedrock groundwater into the wetland will be limited, with some potentially occurring through higher permeability horizons or via emergence at the surface. This is supported by the results of the groundwater model which predicts that the quantity of deeper groundwater input to the drains within the SSSI boundary varies between 17m^3/day and 37m^3/day for a dry and wet period respectively. This is a small proportion of the overall water balance for the SSSI as detailed in appendix D8-5 (Application Reference Number: 6.4.30).

Groundwater contours in the superficial deposits do show a different pattern in certain areas with much greater topographic control than for the bedrock, although ultimately with groundwater flowing towards the coast, as is the case with the bedrock. There are groundwater highs to the south of the Wylfa Newydd Development Area associated with drumlins (as shown by the water levels in boreholes 303CP, 535CP and 1009), and there is a further groundwater high associated with elevated land to the east of the Existing Power Station and the west of the made ground of Dame Sylvia Crowe Mound (in borehole BH866 which is completed largely in a clay horizon although does extend into the bedrock). This high in the groundwater levels (which is also observed in the bedrock boreholes) may be caused by water running off the steep slopes of the mound leading to an area of locally higher recharge.

The borehole logs (appendix D) for these areas of higher groundwater show that the well screens are generally installed in clays and as such the flows through the deposits will be small, even with the apparent steep hydraulic gradients.

Observations on site show that groundwater in the glacial till north of the Tre'r Gof SSSI flows into the SSSI emerging as a seepage line and springs at the wetland edge, although potentially some water could infiltrate to groundwater beneath the SSSI. There is also potential for shallower groundwater to move through the glacial till directly to the coast, especially further north of the SSSI. Data suggest that most of the groundwater in the superficial deposits in the vicinity of the Tre'r Gof SSSI discharges into the wetland as discussed in appendix D8-5 (see Application Reference Number: 6.4.30 for further details of groundwater flows and inputs to the SSSI).

Horizontal hydraulic gradients around the Tre'r Gof SSSI in both bedrock and superficial deposits are relatively steep reflecting the steepness of the local topography. Gradients have been estimated to be between 0.02 and 0.03.

Appendix H shows cross sections (taken from [RD10]) through the Wylfa Newydd Development Area with the groundwater levels relative to the ground level, proposed development platform elevation (although the platform elevation for the development has subsequently changed) and geological strata. Appendix H also shows groundwater contours taken from the DOnGI report ([RD10], drawing numbers 5130177-ATK-XX-ZZ-DR-C-0011A to 12B). These maps are based on the typical minimum and maximum values recorded in the PSI, IOnGI and DOnGI boreholes for the period 2010 to 2016.

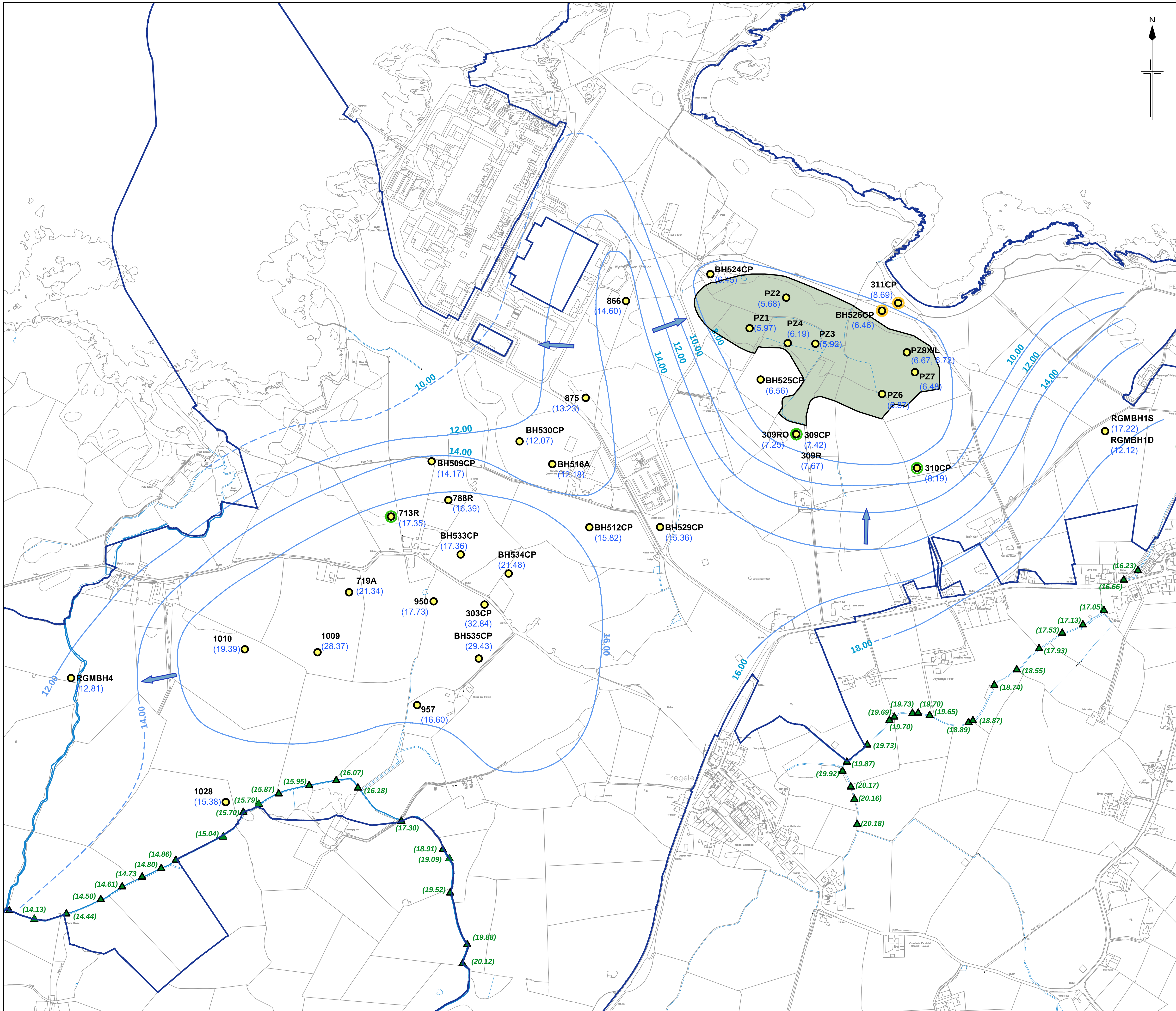


FIGURE 6.1

KEY:

- Wylfa Newydd Development Area
- Groundwater contour (mAOD)
- Groundwater flow direction
- Monitoring borehole
- Artesian conditions have been identified in these boreholes on one or more occasion, although not necessarily on the date for these contours
- Tidal fluctuations observed in these boreholes
- River levels March 2015
- Tre'r Gof SSSI

NOTE:
Groundwater levels for piezometeres and potential perched levels in drumlins have not been used for contouring.

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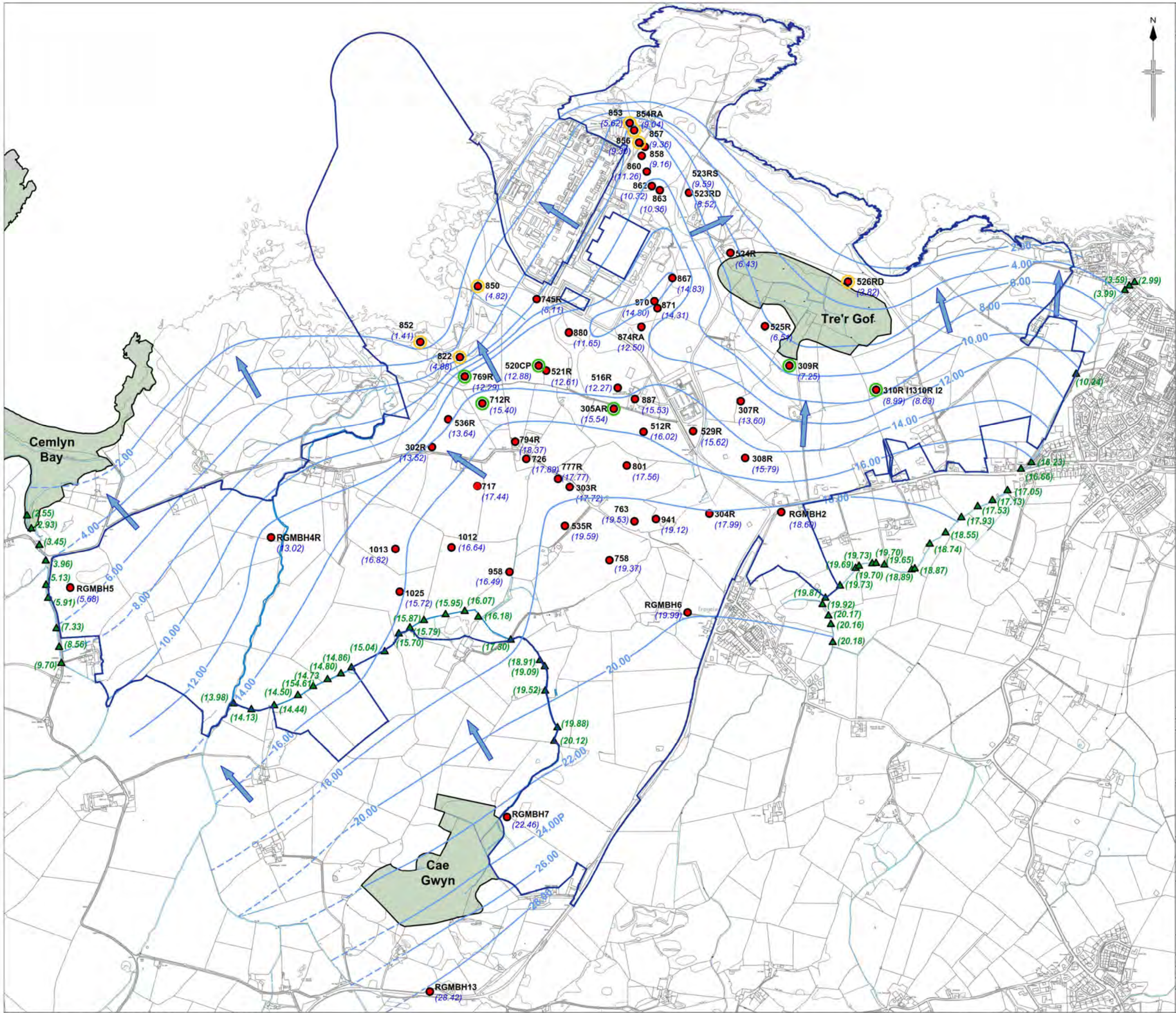

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FIGURE 6.2

KEY:

- Wylfa Newydd Development Area
- Groundwater contour (mAOD)
- Groundwater flow direction
- Monitoring borehole
- Artesian conditions have been identified in these boreholes on one or more occasion, although not necessarily on the date for these contours
- Tidal fluctuations observed in these boreholes
- River levels March 2015
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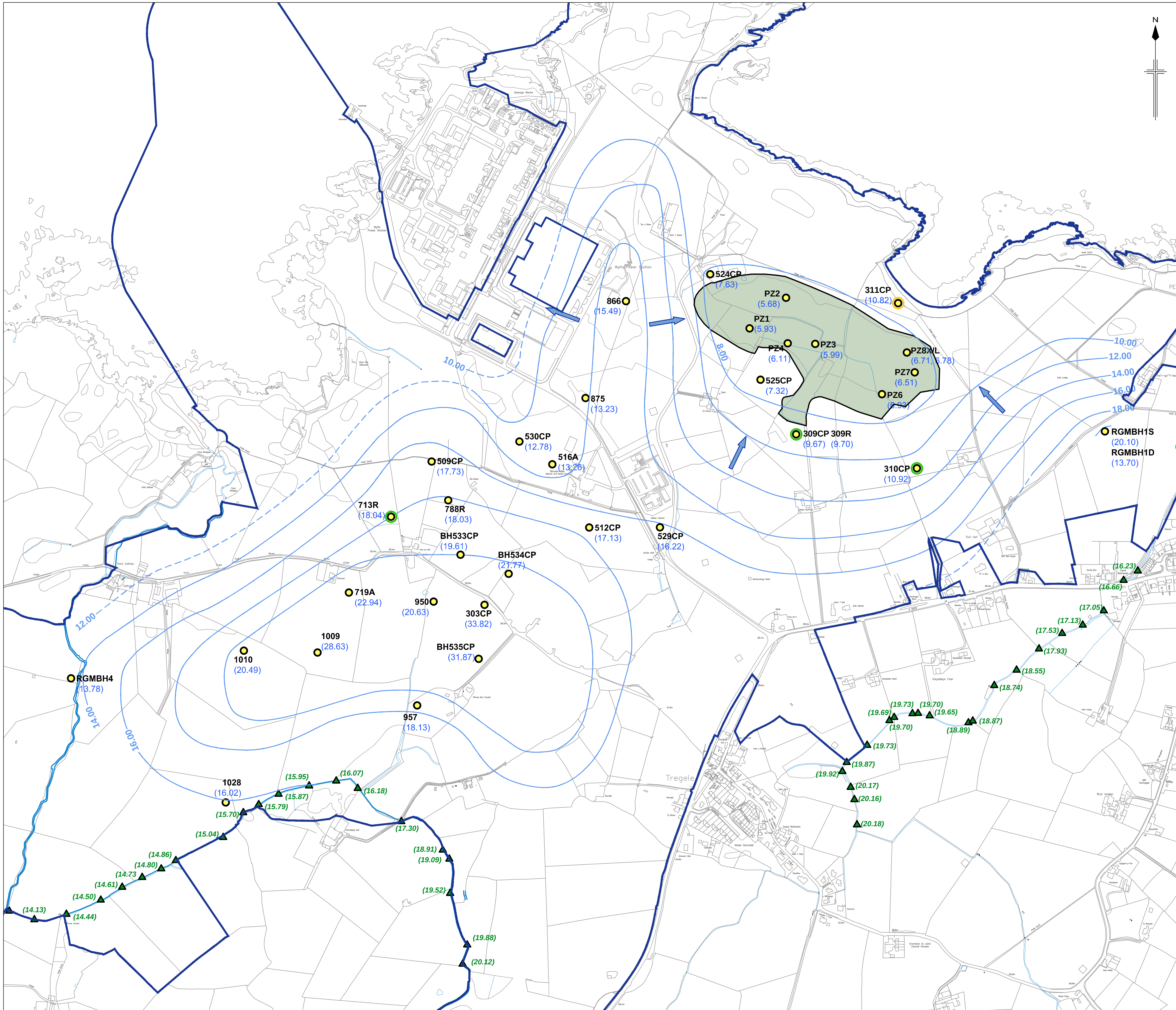
FIGURE 6.3



KEY:

- Wylfa Newydd Development Area
- Groundwater contour (mAOD)
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- Tidal fluctuations observed in these boreholes
- River levels March 2015
- Tre'r Gof SSSI

NOTE:
Groundwater levels for piezometeres and potential perched levels in drumlins have not been used for contouring.

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Drawing No.: 60PO8077_FIGURE 6.3

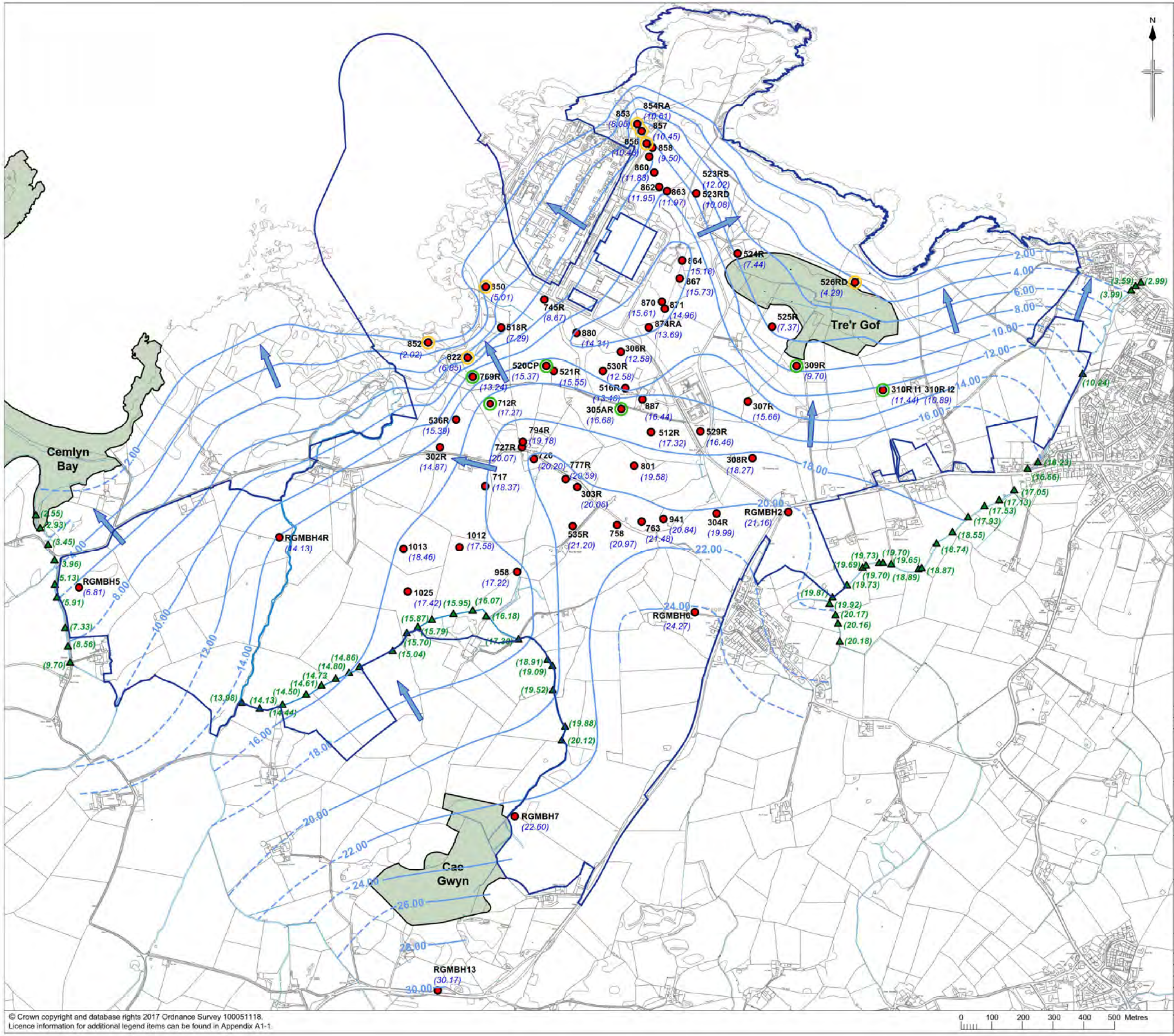

FIGURE 6.4

KEY:

- Wylfa Newydd Development Area
- Groundwater contour (mAOD)
- Groundwater flow direction
- Monitoring borehole
- Artesian conditions have been identified in these boreholes on one or more occasion, although not necessarily on the date for these contours
- Tidal fluctuations observed in these boreholes
- River levels March 2015
- SSSI

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Drawing Status: INITIAL ISSUE

Scale: AS SHOWN — DO NOT SCALE

Jacobs No.: 60PO8099

Client No.:

Drawing No.: 60PO8099_FIGURE 6.4

6.1.5 Groundwater – surface water interactions

A survey of the stream elevations was undertaken in 2015 and data from this indicates that the shallow groundwater and water in the streams are likely to be in continuity in some locations, whilst in others they are likely to be separate. There are too few boreholes close to streams to provide a direct comparison of groundwater and stream levels, but table 6.5 shows the relative stream bed and stream water levels at locations close to four boreholes. The levels indicate that groundwater is likely to be discharging to the streams during the winter months when groundwater levels are higher. During periods of low groundwater levels (such as September 2015), it is possible that in parts of the Wylfa Newydd Development Area the groundwater levels fall below the stream water level elevation and under this scenario recharge to groundwater from the streams is possible. Clearly the amount of water moving between streams and groundwater will depend on the permeability of the stream bed and underlying material and this is likely to vary markedly across the Wylfa Newydd Development Area.

Table 6.5: Water levels in boreholes near to streams and corresponding stream bed and stream water levels (measured March 2015)

Borehole	Groundwater level (mAOD)		Stream bed level (mAOD)	Stream water level (mAOD)
	September 2015	December 2015		
RGMBH4	11.90	13.87	12.4	12.9
RGMBH4R		14.33	12.4	12.9
RGMBH5	5.61	7.00	5.0	5.1
BH1028	15.22	16.13	15.5	15.7

6.1.6 Tidal influence on groundwater level

Of the 102 boreholes in which groundwater level data loggers have been installed, ten boreholes are within approximately 75m of the coast as shown in table 6.6. The data collected by these loggers clearly show tidal influences in five of the boreholes (and possibly a sixth one but changes are very slight and difficult to discern clearly amongst the general "noise" in the logger output) with the maximum fluctuation being approximately 0.4 to 0.8m as observed in borehole BH852R (figure 6.5). This is considered to be due to tidal influence because the groundwater levels vary on a cyclical basis, with two high groundwater levels and two low groundwater levels in a 24 hour period, the same as the tides in the sea. Furthermore, over the longer term, the amplitude of variation varies over an approximate 15 day cycle, representing the spring and neap tides observed in the sea.

From the available logger data, it appears that the tidal influence extends up to around 80m inland, but does vary along the coast with BH311 being only 40m from the coast but showing no tidal influence. The extent to which tidal influences are observed inland will relate in part to the extent of fracturing in the bedrock and if fractures extend from the sea in-land to the monitoring borehole location.

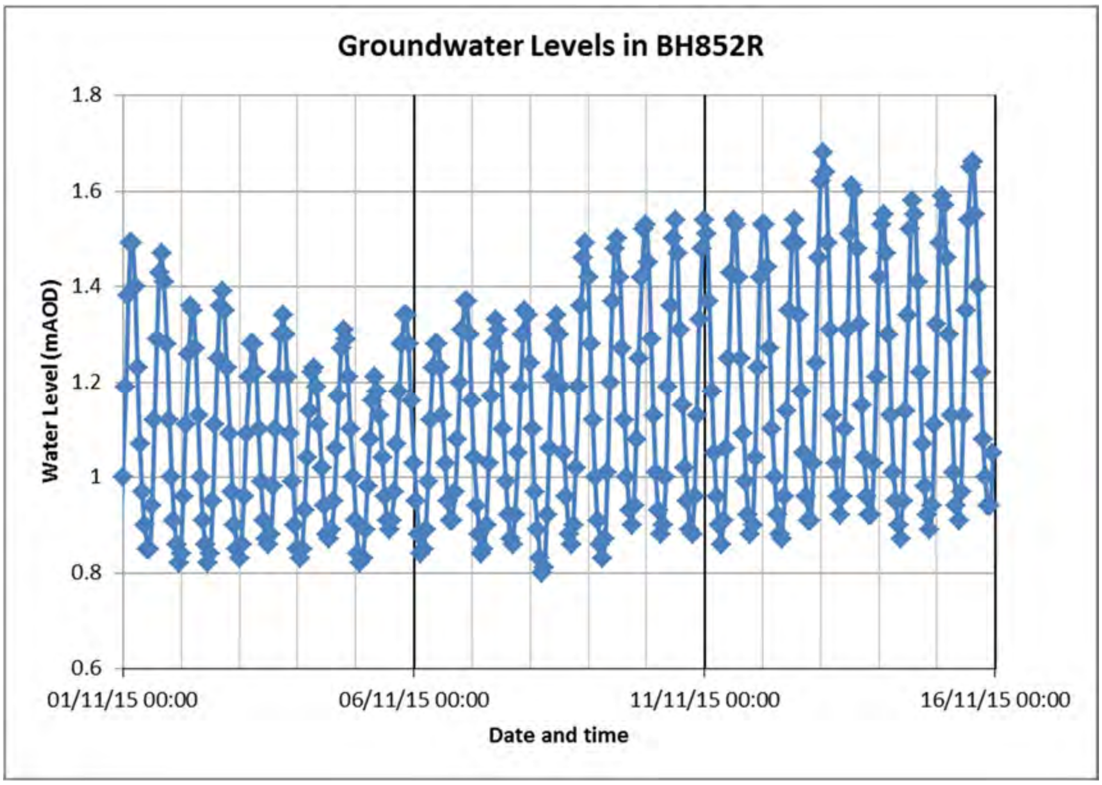
This tidal influence does not necessarily mean that the groundwater is saline at the locations where a fluctuation is monitored, but just that the tidal changes are inducing a head change in the aquifer due to loading or backing up on groundwater outflow to sea.

Table 6.6: Boreholes within 75m of the coast and tidal influence on groundwater levels

Borehole	Distance from coast (m)	Strata	Monitored depth* (mbgl)	Tidal fluctuation (m)
BH853R	25	Bedrock	25.5	Approximately 0.2m
BH852R	30	Bedrock	20.5	0.4 to 0.8m
BH850R	30	Bedrock	13.5	Possible very slight influence but less than 0.02m
BH311	40	Superficial	25	None
BH822R	40	Bedrock	29	0.03 to 0.1m
BH854RA	50	Bedrock	7.3	None
BH526CP	65	Superficial	11.8	None
BH856	70	Bedrock	28.5	None
BH526RD	75	Bedrock	39	0.2m
BH526RS	75	Superficial	23	0.2m

* Depth of base of borehole

Figure 6.5: Tidal influence in borehole BH852R



6.2 Geophysical logging

As part of the various site investigations, geophysical logging of the boreholes has been undertaken. With respect to consideration of hydrogeological data, the following logging is of most relevance:

- calliper logging to identify fracturing;
- fluid temperature logging;
- fluid electrical conductivity logging;
- flow meter logging; and
- heat pulse logging.

Results from this geophysical logging are included in the borehole geological logs for the PSI, IOnGI and DOnGI investigations [RD5], [RD6], [RD10]. The fluid logs (temperature, conductivity, flow meter and heat pulse) were used in determining the optimal depth for the packer and hydrotests.

6.3 Hydraulic conductivity (permeability) testing

Permeability testing has been undertaken in a number of boreholes in the various investigations as shown in table 6.7 with the values recorded presented in appendix I. In summary, the tests outlined below have been undertaken.

I. Falling and rising head tests carried out in accordance with BS5930:1999. Analysis of data has been undertaken using the Hvorslev method.
II. Soakaway tests undertaken in boreholes above the water table in general accordance with recommended practice given in BRE Digest 365 (this details a method for carrying out tests in rectangular pits. However, the methodology may be applied to circular holes provided that no groundwater is present although the DOnGI report notes that calculated soil infiltration rates should be considered tentative).
III. Packer tests whereby permeability was calculated in accordance with BS5930 methodology using the 'Lugeon methodology'. The depth range of the centre section of the test varied between 6.5m and 68.0m while the interval of testing varied between 2.0m and 7.0m, with some of the tests overlapping each other. The interval of testing was chosen following the inspection of the optical televiewer log and the results of the geophysical logging.
IV. Double packer tests were undertaken at testing intervals of around 5m of aquifer each time (but varied between 2.8m and 7.0m). Zones tested were based on the inspection of the optical televiewer logs and geophysical logs and generally targeted at what were considered to be the more permeable zones. The analysis of the test data was carried out to calculate permeability and transmissivity using both the Jacob-Lohman method and equations provided in BS:5930.

The results of tests from the DOnGI (HP) show the hydraulic conductivity (permeability) of the superficial deposits to cover a wide range of values varying between 60m/day for granular material to 0.0005m/day for the most clayey soils (table 6.8).

Analysis of the permeability testing data for the bedrock in preparation of the groundwater modelling work detailed in appendix D8-7 (Application Reference Number: 6.4.32) identified that although the calculated transmissivity values show some increase from around 30m below rock head upward, this was the result of a small number of regionally unrepresentative higher data values at this depth. The main increase in transmissivity identified by the permeability testing was from 5m to 10 m below rock head upwards. No obvious spatial pattern was identified in the bedrock permeability test results.

With respect to the bedrock deposits, the data from the PSI and IOnGI do show that hydraulic conductivity does decrease with depth, from around 0.1m/d to 1m/d at 10m below rock head to 0.001m/d at 50m below rock head (see figures 6.6 and 6.7). The data also show that the hydraulic conductivity does correlate with fracture frequency which is shown to reduce with depth and this would indicate that fracture flow is the dominant groundwater flow mechanism for the bedrock with the greatest flow horizon being close to rock head.

Table 6.7: Permeability testing

Investigation	Falling/rising head tests	Soakaway tests	Packer tests	Double packer tests
PSI	5 tests in 3 boreholes in the drift	4 tests in 1 borehole in the drift	None	Total of 77 tests in 10 rotary cored holes
IOnGI	None	None	17 tests in 2 boreholes	89 tests in 18 boreholes
DOnGI (High priority)	60 tests in 45 boreholes in the bedrock and three boreholes installed in the superficial deposits	53 soakaway tests in 48 boreholes in the drift	125 tests in 43 boreholes	41 hydrotests in 10 boreholes
DOnGI (Low priority)	52 tests (43 falling head tests and 9 rising head tests) in 52 boreholes in the superficial deposits.	62 soakaway tests in 58 boreholes in the drift	160 tests in 43 boreholes	41 hydrotests in 10 boreholes
2015 pumping tests	2 to 4 tests undertaken in each of the two pumping boreholes	None	None	None

Table 6.8: Results of hydraulic conductivity tests in superficial and bedrock deposits from DOnGI (HP) investigation

Material Type	Number of tests/type of test	Minimum	Maximum	Mean	Median
Superficial - granular	13 (V)	0.015	60	10	0.59
Superficial - cohesive	23 (V)	0.00052	1.4	0.16	0.024
Superficial - very gravelly cohesive	10 (V)	0.0079	2.3	0.32	0.048
Bedrock	35 (P)	0.0010	0.84	0.044	-

All Hydraulic conductivity values in m/day
(V) Variable head test (P) Packer test

Figure 6.6: Permeability with depth (from PSI [RD5])

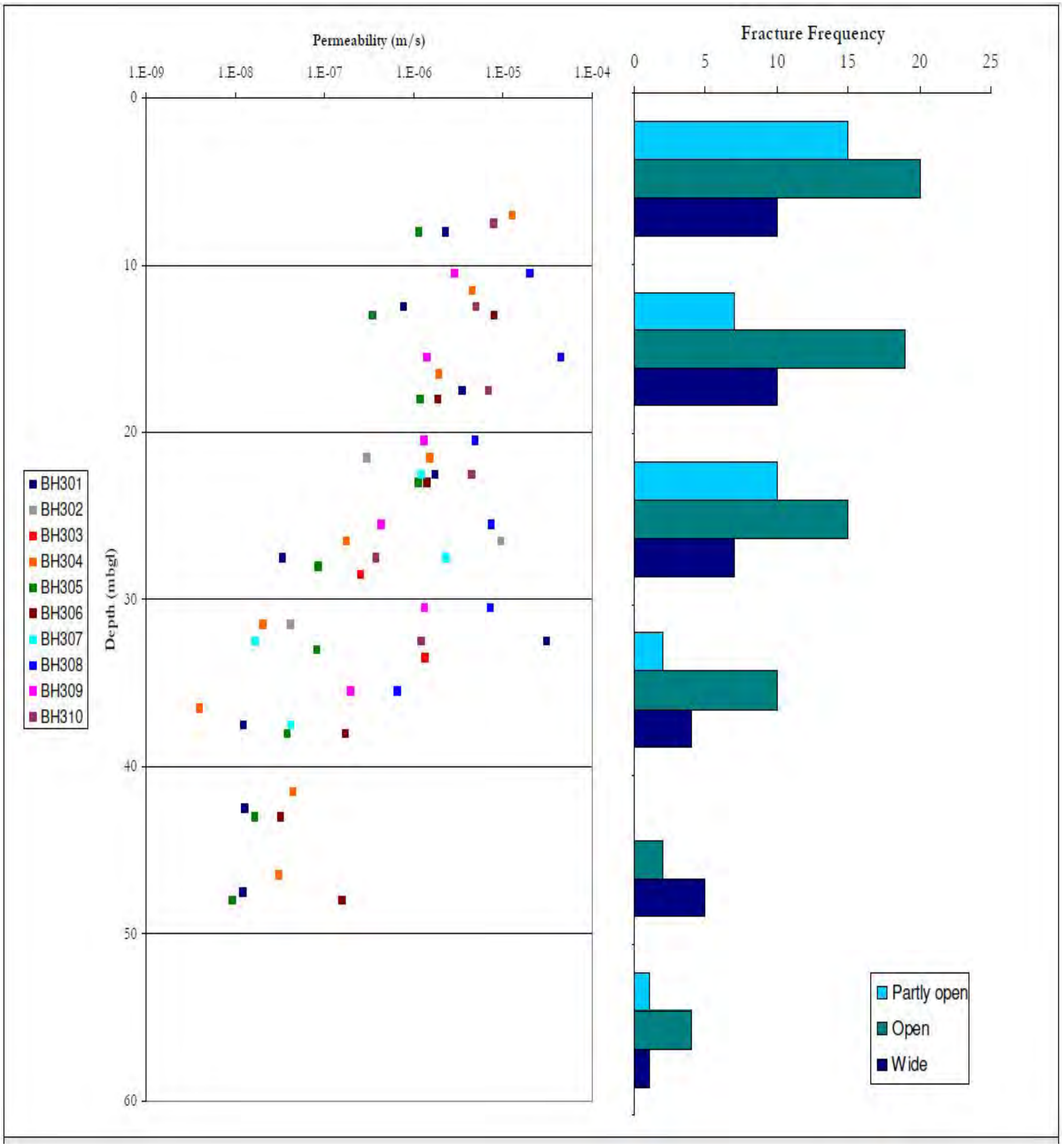
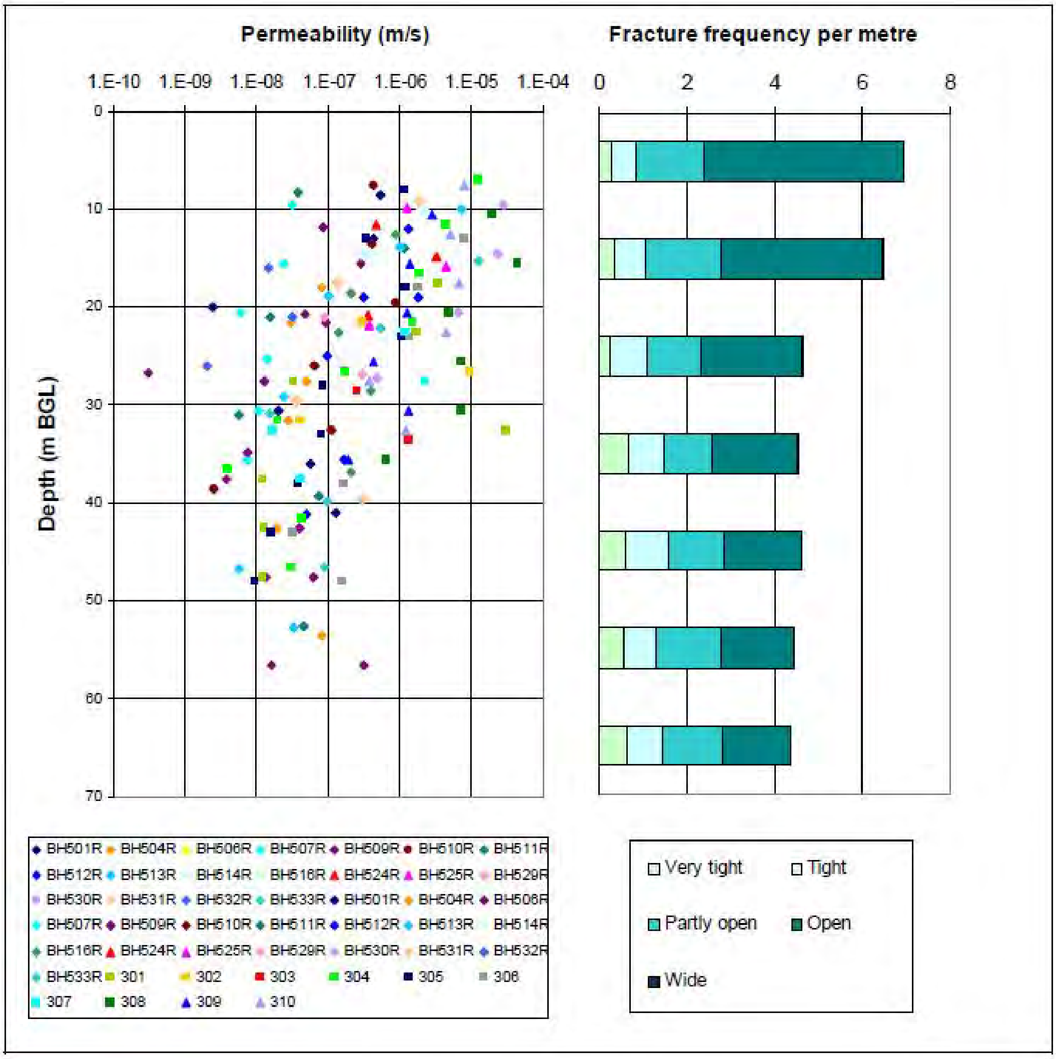


Figure 6.7: Permeability (m/s) with depth (from IOnGI, [RD6])



6.4 Pumping tests

In the autumn of 2015, two pumping tests were undertaken to provide information on the aquifer over a wider extent than is possible with variable head tests or packer tests. The pumping tests involved the installation of two abstraction boreholes and associated observation boreholes with step tests and constant rate tests undertaken [RD12], [RD13]. Interpretation of the pumping test data is provided in [RD14] and [RD15] and summarised below.

For each pumping test, an abstraction borehole and four observation boreholes were drilled, with the latter being approximately 15m from the abstraction borehole, 90° apart. Monitoring from these boreholes and nearby exiting boreholes was undertaken during the pumping tests. The layout of the boreholes is shown in figure A02 of [RD12].

In both abstraction boreholes the geology encountered was similar with a highly fractured zone near the top of the bedrock in which the vast majority of water was observed to flow. However, the two pumping tests showed significantly different results with the test in PW1 showing lower yields and transmissivity values than the test in PW2 with the yield from PW1 around 10% of the yield from PW2. In both tests, the yields decreased over time. In PW2 it was particularly noticeable that once water levels had fallen below the level of the principal fracture zone the yields decreased substantially and after approximately 4 days the rate of decline reduced. PW2 showed a 58% reduction in flow by the end of the test which compares to a reduction in borehole PW1 of around 14% (albeit the latter started at a much lower rate). A summary of the pumping test results is provided in table 6.9.

Table 6.9: Summary of aquifer parameters from pumping tests

	Units	PW1	PW2
Pumping borehole depth	mbgl	46.5	54.5
Length of constant rate test	days	7	8
Rest water level at start of test	mbgl	1.26	14.45
	mAOD	15.94	14.05
Principal flow horizon (identified during drilling and from calliper log)	mbgl	12.0 to 17.5	20.0 to 24.5
	mAOD	5.2 to -0.3	8.5 to 4.0
Borehole yield at start of test	l/s	0.7	9.0
	m^3/day	60	780
Borehole yield at end of test	l/s	0.6	3.8
	m^3/day	52	330
Estimate of transmissivity from constant rate test*	m^2/day	5 to 38	16 to 92
Estimate of transmissivity from recovery test*	m^2/day	8	11 to 57
Storage coefficient	-	9×10^{-11} to 1.2×10^{-4}	3.2×10^{-10} to 2.5×10^{-3}
Maximum distance of recorded drawdown	m	<50	300

* Transmissivity is the product of permeability and aquifer thickness. A range of values is produced for each pumping test as the analysis uses drawdowns observed in a number of observation boreholes and a range of analytical techniques.

The constant rate pumping test from PW1 did not show an effect on groundwater levels in boreholes outside of the observation boreholes installed for the pumping tests (these were situated 15m from the pumped borehole) with the exception of one borehole situated 36m from the pumped borehole. However, for the constant rate pumping test in PW2, water levels in boreholes 300m from the pumped borehole were affected, with water levels falling by approximately 1.5m at this distance. In PW2 there was greater drawdown in a broadly east-west direction, which does correspond to the principal direction of faults and intrusions in the area of the Power Station Site where the pumping tests were undertaken. Neither pumping test affected groundwater levels, nor surface water flows, at the Tre'r Gof SSSI which is approximately 900m from PW1 and 650m from PW2.

The range of transmissivity and storage coefficient values shown in table 6.9 represents the results of analysis of data from a number of boreholes (observation wells) and derived from different analytical techniques and using both pumping data and recovery data (analysis of how the water levels rise after the pump is switched off). For each borehole, the data for transmissivity show a relatively narrow range for the various methods and do demonstrate that permeability is lower in the vicinity of PW1 than PW2. For PW2, estimates of transmissivity from the constant rate testing range between 19m²/day and 74m²/day for the monitoring well array around PW2 (wells situated approximately 15m away) and between 16m²/day and 92m²/day for wells that are further away (up to 300m).

With respect to the storage coefficients, a wide range of values is estimated, dependent on the method of analysis, but the majority are relatively low values. This range occurs due to heterogeneity of the aquifer system and different methods of analysis have different assumptions. However, the data indicate that the bedrock aquifer has low storage due to a low primary porosity and the pumping tests showed that the fractures within the bedrock are relatively quickly dewatered. There is some groundwater storage in the sand and gravel horizons within the superficial deposits but such horizons are limited in occurrence and have limited lateral continuity in this area of the Power Station Site.

6.5 Bulk density, porosity and moisture content

The ground investigations measured bulk density, porosity and moisture content as part of the geotechnical assessments. The results from the PSI, IOnGI and DOnGI are provided in the DOnGI interpretative report [RD10] and summarised in table 6.10.

Table 6.10: Porosity, moisture content and bulk density results from PSI, IOnGI and DOnGI

Lithology	No. of tests	Minimum	Maximum	Mean
Bulk Density				
Granular, clast supported till	26	1.97Mg/m³	2.48Mg/m³	2.26Mg/m³
Cohesive till	144	1.95Mg/m³	2.52Mg/m³	2.28Mg/m³
Periglacial and Alluvial Deposits	No Data	No Data	No Data	No Data
New Harbour Group	4540	2.49Mg/m³	3.07Mg/m³	2.76Mg/m³
Gwna Group	132	2.35Mg/m³	2.79Mg/m³	2.64Mg/m³
Porosity				
Granular, clast supported till	No Data	No Data	No Data	No Data
Cohesive till	No Data	No Data	No Data	No Data
Periglacial and Alluvial Deposits	No Data	No Data	No Data	No Data
New Harbour Group	2103	0.1%	15%	1.8%
Gwna Group	71	2.3%	14%	6.6%
Moisture Content				
Granular, clast supported till	38	3%	24%	12.9%
Cohesive till	364	2.9%	27%	12.4%
Periglacial and Alluvial Deposits	26	8.8%	28%	17.1%
New Harbour Group	3056	0.01%	4.2%	0.3%
Gwna Group	67	0.10%	5.8%	1.4%

7 Groundwater quality

7.1 Groundwater sampling

Groundwater sampling for chemical analysis has been undertaken as part of the various site investigations and ongoing assessments as shown in table 7.1. The boreholes which were sampled in each phase are detailed in appendix J. NRW has no groundwater quality monitoring locations within the study area.

Table 7.1: Groundwater sampling for the ground investigations

Investigation	Groundwater monitoring undertaken
PSI	Sampling from three boreholes around a sump where trichloroethene (TCE) was identified and from BH14* in an area where elevated hydrocarbons had previously been identified. Only targeted sampling was undertaken for the PSI and no general groundwater quality monitoring was undertaken.
IOnGI	Groundwater samples were taken from 24 boreholes from March to July 2011. Samples were tested for a range of inorganic and organic parameters as shown in appendix J.
DOnGI (HP)	Thirty-four groundwater samples were taken from IOnGI boreholes and DOnGI boreholes in July 2014. Samples were tested for a range of inorganic and organic parameters as shown in appendix J.
DOnGI (LP)	All monitoring boreholes installed as part of the DOnGI (LP) works (45 boreholes) were sampled from September 2014 to January 2015. Due to these being the lower priority boreholes, most samples were analysed for a smaller suite which excluded detailed organic analysis than the samples taken from the DOnGI (HP) boreholes.
EIA	As part of the EIA, groundwater sampling has been undertaken to date on 13 occasions as follows: · In November 2014, 39 boreholes were sampled including the sentinel boreholes (RGM series). · In March 2015, 31 boreholes were sampled across the Wylfa Newydd Development Area including the sentinel boreholes. · In June 2015, 34 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes and Foel Fawr PWS. · In September 2015, 34 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes and Foel Fawr PWS. · In December 2015, 33 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes and Foel Fawr PWS. · In January 2016, six groundwater samples were collected from close to Porth-y-pistyll to aid the contaminated land assessment. · In April 2016, 33 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes.

Investigation	Groundwater monitoring undertaken
	· In August 2016, 33 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes and Foel Fawr PWS. · In October 2016, 33 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes. · In January 2017, 30 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes (three boreholes could not be accessed) and Foel Fawr PWS. · In March 2017, three samples were taken from the three boreholes that couldn't be accessed in January 2017. · In May 2017, 26 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes (seven boreholes could not be accessed or could not be sampled due to equipment failure) and Foel Fawr PWS. · In August 2017, 33 samples were collected from across the Wylfa Newydd Development Area and from the sentinel boreholes and Foel Fawr PWS. Testing has been undertaken principally for inorganic substances including major ions and metals. Samples from around the area where TCE had previously been identified were tested for volatile organic compounds (VOCs). The 33 boreholes which have been routinely sampled in the quarterly sampling are shown on figure 7.1.
Pumping tests	Groundwater sampling and analysis was undertaken during the pumping tests to assess the quality of the water for discharge and to assess changes in groundwater quality as pumping progressed. Samples of the abstracted water were tested for major ions, metals and an organic compound suite ([RD12], [RD13]).

* Although the report indicates BH14 was sampled, the log for this borehole shows that it was backfilled after drilling. As such, there is uncertainty as to the actual location that this sample was taken from.

7.2 Groundwater sampling methods

Groundwater sampling methods used for the PSI and IOnGI are not specified in the factual or interpretative reports. For the DOnGI, the groundwater was sampled by low-flow techniques using either a peristaltic pump or bladder pump depending on the depth of the response zone. An in-line flow cell was used to measure wellhead parameters (pH, temperature, electrical conductivity, redox potential and dissolved oxygen) and groundwater samples were then collected once these parameters had stabilised.

For the monitoring undertaken in November 2014 and from March 2015 to August 2017, groundwater was sampled either by use of disposable bailers (bailers were generally used in the boreholes where the saturated horizon in the borehole was less than 3m) or 'HydraSleeves', a no-purge sampling technique (see appendix J for information on how HydraSleeves work). The HydraSleeves were installed at least two days (and in most cases between one week and up to three months) before taking the samples to allow groundwater in the borehole to stabilise. The HydraSleeve sampling methodology does not allow for wellhead parameters to be collected.

The groundwater from the Foel Fawr PWS has been sampled from a tap near the wellhead. It is uncertain how much the borehole had been used prior to each sampling visit.

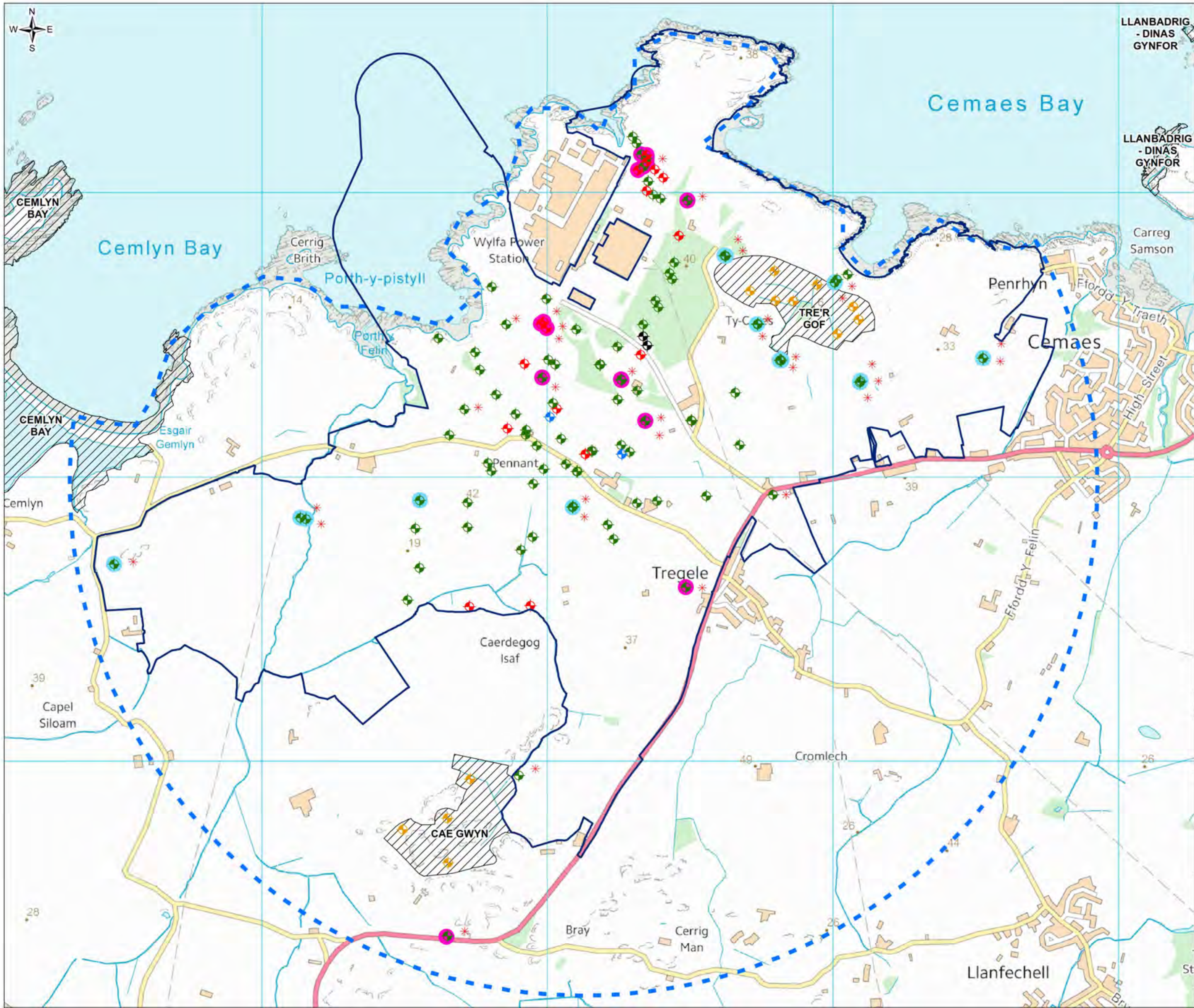


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FIGURE 7.1

Legend

- Wylfa Newydd Development Area
- Borehole routinely sampled in the quarterly monitoring round
- Borehole where TPH has been detected on one or more occasion, no identified anthropogenic source
- Borehole where TPH has been detected on one or more occasion, possible anthropogenic source

Borehole locations

- Borehole with logger installed
- Borehole without logger
- Boreholes backfilled in Jan 2016
- Peizometers in Tre r' Gof and Cae Gwyn
- Pump test borehole array
- Inner study area 1.8km
- SSSI

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	AUG 17	Initial Issue	BW	HR	SLH	RB

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Drawing Status

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7.3 Groundwater sampling results

7.3.1 Field measurements

Where boreholes were purged in the DOnGI and IOnGI investigations, wellhead parameters were measured. Field record sheets of these parameters are provided in appendix G (G02) of the IOnGI factual report [RD24], and appendix G (G02) of the DOnGI (HP) factual report [RD7], and appendix G (G02) of the DOnGI (LP) report [RD8].

7.3.2 Laboratory results

Results of the groundwater sampling to date are shown in appendix J with a summary for selected determinands shown in table 7.2 (these being for determinands where there has been a number of exceedances of the WQSs or are important for understanding the overall groundwater quality). It should be noted that provision and assessment of surface water quality data are included in the Surface water baseline report (Application Reference Number: 6.4.26).

To put the groundwater results into context, appendix J also includes water quality standards (WQSs) that are frequently used in the UK for assessing environmental impacts. These can be broadly divided into three categories as follows:

- Environmental Quality Standards (EQSs) associated with freshwater which assess the potential impact of groundwater on surface water features such as streams and SSSIs. A small number of the freshwater EQSs for certain metals are based on dissolved organic carbon (DOC), calcium and pH to estimate the bio-available metals and for cadmium the EQS for a particular river relates to the river water's hardness. For a small number of other parameters, the EQS relates to the river's alkalinity. For the purposes of this assessment, where the EQS relates to any of these parameters the following water parameters have been assumed.
    - Water hardness has been set at 165mg/l and the alkalinity at 126mg/l (these being the average values of twelve surface water samples collected between July 2014 and January 2015).
    - For groundwater, DOC has not been measured in the historical samples as the requirement for this to compare quality of certain metals to EQS at the start of 2016. Therefore, for this assessment a value of 8.6mg/l has been used which is the average value of DOC measured in the stream water from 17 samples collected in November 2015 and February 2016. Following this period, the DOC concentrations in the groundwater samples collected have been used to estimate the bioavailable metals. Using the groundwater DOC values gives a more accurate value for the bioavailable metals in groundwater discharging to surface waters than the surface water DOC concentrations.
    - Where a pH value is not available for estimating the bio-available metal in a groundwater sample, the mean pH of all remaining groundwater samples has been used (this being 7.9).
    - Where a calcium concentration is not available for estimating the bio-available metal in a groundwater sample, the mean calcium concentration of all remaining groundwater samples has been used (this being 74 mg/l).
- EQSs associated with saline waters have been considered to assess the potential impact of groundwater discharging to coastal waters.

- Drinking Water Standards (DWSs) which consider groundwater that is or may be used as a drinking water supply.

Table 7.2: Summary of selected chemical determinands in groundwater from all sampling rounds*

	pH**	Electrical conductivity+	Chloride	Ammoniacal nitrogen as NH_4	Nitrate as N
No. of samples	459	445	468	465	464
No. of results < LoD	0	0	0	235	49
WQS^	6 to 9	2,500μS/cm	250mg/l	0.5mg/l	11.3mg/l
Minimum	5.98	15.6μS/cm	20.6mg/l	<0.01mg/l	<0.07mg/l
Maximum	11.28	1,510μS/cm	285mg/l	21.3mg/l	87.8mg/l
Average	7.60	553μS/cm	60.1mg/l	0.51mg/l	3.51

	Sulphate	Arsenic	Copper	Lead	Manganese
No. of samples	472	405	405	405	469
No. of results < LoD	6	121	125	223	33
WQS^	250mg/l	10μg/l	2,000μg/l	10μg/l	50μg/l
Minimum	<2mg/l	<0.12μg/l	<0.85μg/l	<0.02μg/l	<1μg/l
Maximum	384mg/l	48.1μg/l	134μg/l	88.9μg/l	9400μg/l
Average	37.34mg/l	1.25μg/l	6.85μg/l	0.80μg/l	540μg/l

LoD – Limit of detection
For calculation of the average (mean), results reported as being below the level of detection are taken as zero
*Excludes samples from Foel Fawr private water supply which is some distance from the Wylfa Newydd Development Area and data collected during the two pumping tests. Data from Foel Fawr and from PW1 and PW2 taken during the pumping tests are included as separate tables in appendix J.
+. Elevated electrical conductivity values (>2,000μS/cm) are suspected to be caused by contamination with cement grout used in borehole construction and where elevated results are suspected, the results are not used in the above summary. See below text for further consideration of this grout contamination.
** Elevated pH values (>11.3) are suspected to be caused by contamination with cement grout used in borehole construction and where elevated results are suspected, the results are not used in the above summary. See below text for further consideration of this grout contamination.
^ Where an EQS and a DWS are available, the WQS in the table shows the lower of the two values

The findings of the groundwater laboratory analysis are summarised below.

I. Apart from manganese and ammoniacal nitrogen, most water samples show the groundwater quality to be better than the WQSs for the tested parameters. Manganese values appear particularly high, probably reflecting mineralisation from both rock and superficial deposits, and are generally higher in the shallow groundwater. Elevated manganese concentrations are reported for groundwater in a number of areas in the Gwna Group which are directly associated with mineralised hotspots. A maximum value of 5,830μg/l is reported for the Gwna Group in Anglesey by the Environment Agency (2007). Within and adjacent to the Wylfa Newydd Development Area, three samples exceeded this value, these being in RGMBH2 (on two occasions) and in RGMBH5, indicating mineralised water. However, in these boreholes, the manganese concentrations have varied significantly throughout the sampling programme, with concentrations in RGMBH2 varying from 2.9μg/l to 9200μg/l.

II. Concentrations of metals do not generally exceed the WQSs. However, in a small number of samples, concentrations of aluminium, arsenic, bioavailable nickel, lead, (bioavailable) copper and (bioavailable) zinc do exceed either the DWS or one of the EQSs. Iron shows a more widespread elevated concentration in comparison to the water quality standards. It should be noted that the elevated mercury concentrations identified in 2014 were investigated further and were found to be due to laboratory cross-contamination. The chromium concentrations, which are shown to be elevated, represent the total dissolved chromium but are compared, as a conservative approach, to the EQS for chromium (vi). However, in most groundwater systems chromium (vi) is usually a very minor part of the total chromium for which the analysis is undertaken. It should be noted though that concentrations do also exceed the EQS for chromium (iii) (which is more likely to be present in the groundwater) in some of the samples.

III. pH is neutral or slightly alkaline. Where greatly elevated pH is recorded (i.e. highly alkaline conditions) it is suspected that this is due to cement grout entering the borehole. This is suspected due to the samples that were taken from BH1010 where the groundwater was discoloured grey and had a frothy appearance indicative of grout contamination (in this borehole the pH was recorded at around 12.5 and the electrical conductivity at over 4,500µS/cm). Other boreholes which are suspected of having been contaminated by grout (as indicated by high pH and electrical conductivity) are BH717, BH726, BH758, BH822, BH864, BH870, BH871, BH874 and BH878. Excluding these boreholes, the highest pH value was 11.3. The lowest pH value (i.e. the most acidic sample) was 6.0 recorded in BH535CP in July 2014.

IV. Concentrations of the major ions (including sulphate, calcium and chloride) are generally low. This results in a relatively low electrical conductivity (when excluding those boreholes contaminated by grout) and may be indicative of relatively short residence times for water in the groundwater system. However, nitrate concentrations are elevated and exceed the DWS in a small number of boreholes. The nitrate is most likely to be derived from an agricultural (fertilizer) source.

V. When samples are considered with respect to the groundwater flow gradient, there is no clear evidence of concentrations of any measured parameters increasing or decreasing down hydraulic gradient as groundwater flows across the Power Station Site to discharge at the coast. However, the concentrations of parameters including sodium, potassium and sulphate in BH536R are greatly elevated with a correspondingly high electrical conductivity. This borehole is relatively close to the coast but the chloride concentration is not sufficiently elevated to suggest that the elevated ions are the result of sea water. Similar high concentrations of these parameters were observed in BH1010. It is likely that the results from BH536R are the result of cement grout in the borehole, whilst the sample from BH1010 was visually observed to be contaminated by grout.

VI. Organic compounds are generally below the level of detection. However, in borehole BH312 chlorinated solvents (principally TCE) are detected. The TCE concentration in BH312 exceeds the DWS and EQS of 10μg/l, with the maximum concentration being recorded at 61.5μg/l in August 2017. 1,2-dichloroethene has also been detected in this borehole at up to 4.2μg/l. These contaminants are located near to a sump which is thought to have been connected to the Existing Power Station and as such the contamination is likely to be associated with historical contamination from the Existing Power Station.

VII. Total petroleum hydrocarbons (TPHs) are detected in a small number of boreholes. In borehole BH14 to the north-east of the Existing Power Station, over 180mg/l of TPHs were identified in the sample collected in 2010 but the concentration had reduced to 0.105mg/l by January 2016 (the only sample taken between these dates was in 2014 when the measured TPH concentration was below the limit of detection). During the first round of sampling of this borehole in 2010, free hydrocarbon product was identified at 2.6mbgl in this borehole. It is reported that this borehole has a response zone completed at 14 to 15mbgl [RD5] and in the PSI interpretative report it is speculated that the identification of TPH in this borehole is due to contamination in shallow deposits and groundwater leaking through the bentonite seal to greater depth. This contamination is thought to be associated with historical contamination from the Existing Power Station although it has not been possible to identify a specific source. Halcrow [RD5] speculated that the most likely source was a buried tank and/or pipeline within the ground around the vicinity of BH14 although no further evidence for this is provided. Furthermore, as noted earlier in the report, the borehole log for BH14 shows that the borehole was backfilled so there is uncertainty over whether the borehole sampled on each occasion was really BH14.

VIII. TPHs have also been detected in a small number of other boreholes with the highest concentration being detected in the December 2015 monitoring round in BH526CP at 3.5mg/l. This borehole is situated to the north of the Tre'r Gof SSSI and TPH has been detected in 7 of the 11 samples submitted for this borehole, with the hydrocarbons being detected in the C10 to C40 carbon range (no lighter fraction hydrocarbons have been identified). Given the location of this borehole and the sporadic occurrence of TPH in this and other boreholes (such as other boreholes around Tre'r Gof and the sentinel boreholes RGMBH1D, RGMBH4A, RGMBH5 and RGMBH6) it is considered likely that these detected TPH concentrations are due to natural occurrence of organic compounds (from degradation of vegetation) as there are no identifiable plausible sources for these areas (figure 7.1). For boreholes to the south and north-east of the Existing Power Station where made ground and activities associated with the Existing Power Station has been identified (ACP7, APC19 and APC9), the TPH may have an anthropogenic source. Whilst the borehole close to Tregele (RGMBH6) is down hydraulic gradient of a petrol station there is no evidence that the low concentrations of TPH identified in this borehole in the first two sampling rounds is related to the petrol station (TPH has not been detected here since March 2015). In April 2016 and May 2017, TPH was detected at relatively low concentrations (48µg/l and 69µg/l respectively) in Sentinel borehole RGM13 situated close to the A5025 It is possible that this TPH is associated with road runoff.

Assessment of the ionic balances for the major ions and Piper plots[4] for groundwater are shown in appendix K for samples taken across the groundwater study area as part of the quarterly monitoring. The data show that groundwater is generally of the calcium bicarbonate type with sodium chloride type groundwater present in a small number of samples. These types of groundwater were identified by the Environment Agency [RD11] as being present in the Gwna Group in Anglesey. No specific groundwater types are identified for the different strata (bedrock and superficial deposits) or geographically across the study area suggesting that groundwater across the study area are similar and that the shallow and deep deposits are likely to be in hydraulic connection.

[4] A Piper plot provides a graphical representation of the distribution of cations and anions of water samples and can be used to determine waters of different origins.

Groundwater (along with surface water) sampling has also been undertaken with respect to the Tre'r Gof and Cae Gwyn SSSIs. Details of the Tre'r Gof SSSI water quality are provided in appendix D8-5 (Application Reference Number: 6.4.30). The hydrochemistry of groundwater (and surface water) samples collected from within and around the Tre'r Gof SSSI reflects fresh calcium bicarbonate water with a neutral to slightly acidic pH and low electrical conductivity. The low electrical conductivity in groundwater is thought to be indicative of short residence times in the ground.

With respect to Cae Gwyn, the groundwater quality assessment, which is detailed in appendix D8-6 (Application Reference Number: 6.4.31), shows that the Northern Basin and Western Basin have similar major ion groundwater chemistry, whilst the groundwater chemistry in the Southern Basin is closer to that of the surface water in the outflow channel. The water quality for the Northern Basin and Western Basin is distinctly different to the majority of other groundwater around the Wylfa Newydd Development Area. In these two basins the waters are predominantly of sodium-chloride type, whereas elsewhere they tend to be calcium-carbonate dominated. This is suspected to be because the piezometers in the Northern and Western basins are installed in mineral soils. The sampled water is therefore likely to be of a rainwater origin. The Environment Agency [RD11] states that the majority of the sodium in the Anglesey waters appears to be marine derived, rather than from rocks; and chloride is not typically a lithologically-derived parameter.

With respect to the Foel Fawr PWS, groundwater from this borehole has been sampled on seven occasions (June 2015 to August 2017, although in September 2015 and August 2017 only bacteriological analysis was undertaken). The groundwater from the borehole was analysed for the same determinands as the other groundwater samples with the addition of bacteriological analysis to test for pathogens including e-coli. The results of the monitoring are shown in appendix J and indicate that the groundwater quality is similar to that of the ground investigation boreholes. With respect to the DWSs, the only exceedance was for manganese. The well's owner has not reported any problems with the water from this borehole in terms of quality or the supply drying up.

8 Groundwater conceptual model

The data obtained and assessed during the various ground investigations, hydrogeological assessments and the groundwater modelling presented earlier in this report have been used to formulate a conceptual model of the groundwater beneath the Wylfa Newydd Development Area as outlined below and shown in figure 8.1. A compilation of the borehole logs used to construct this conceptual model is contained in appendix D.

8.1 Geology

The geology of the Wylfa Newydd Development Area comprises superficial deposits (primarily glacial deposits) overlying metamorphic bedrock (principally the New Harbour Group, but also the Gwna Group in the north-west of the Wylfa Newydd Development Area).

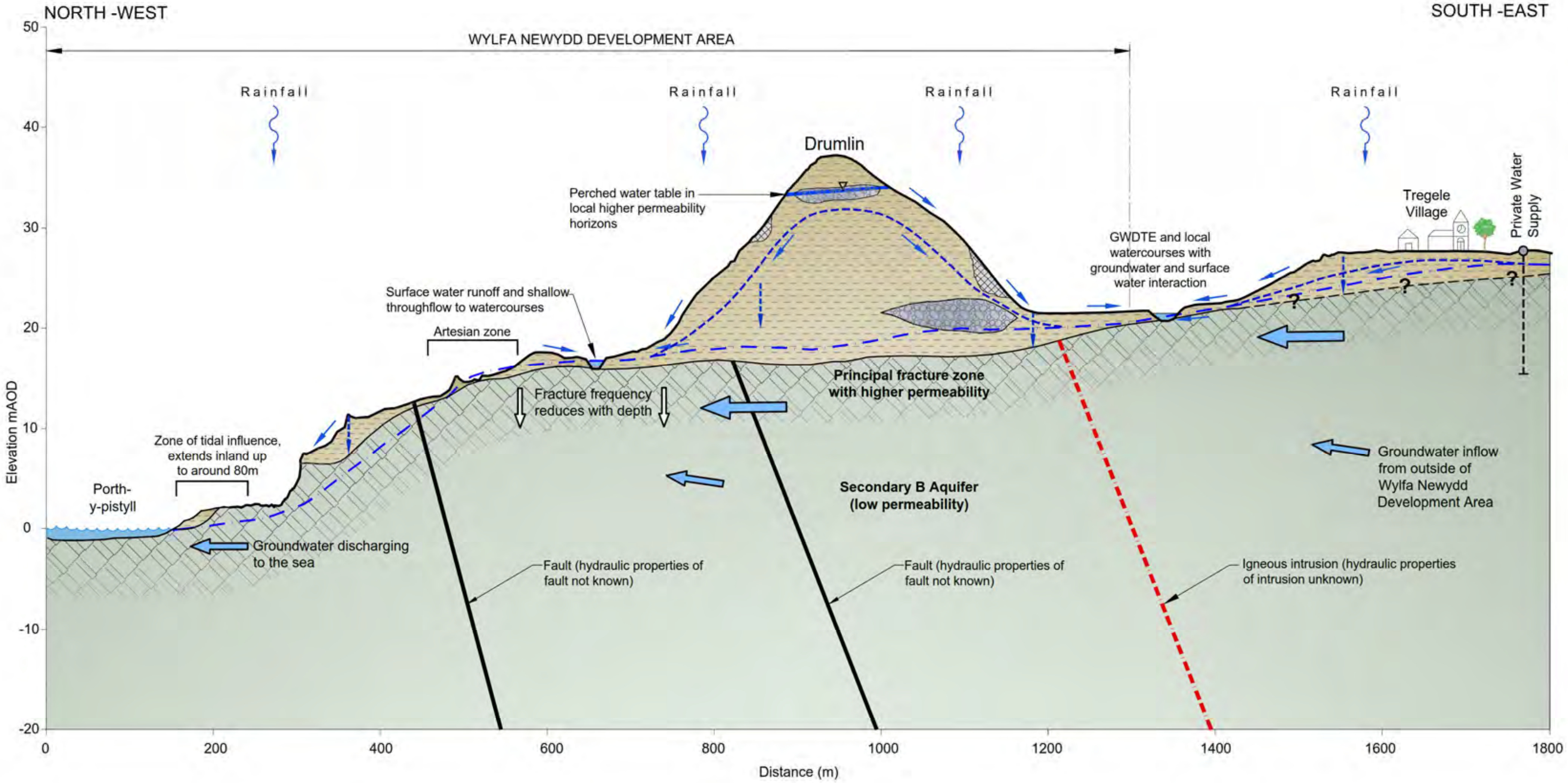
The bedrock consists predominantly of horizontally layered phyllite and psammite. This bedrock is fractured and often shows a weathered upper surface, typically recorded as gravel or boulders in borehole logs. There is anticipated to be significant groundwater flow and storage in this weathered rock. Groundwater flow in the bedrock will be exclusively via fractures and fissures, and with the number and permeability of fractures observed to reduce with depth below about 20 to 30mbgl, the upper layer will form the principal groundwater flow horizon in the bedrock. Extensive permeability testing showed no obvious spatial pattern in bedrock transmissivity across the Wylfa Newydd Development Area. Nevertheless, borehole logs identify significant fractures to at least 30m below rock head and bedrock groundwater flow will be dominated by the most transmissive features, with significant local variation likely.

Fractures recorded in the bedrock borehole logs are predominantly sub-horizontal, typically at 30 to 40 degrees (and predominantly within the range 20 to 60 degrees). Occasional sub-vertical fractures are recorded, typically crossing the sub-horizontal sets (although it is noted that borehole/fracture alignment will tend to mean that vertical fractures are not intersected as effectively as horizontal fractures). Sub-vertical fractures are rarely recorded where there is no sub-horizontal fracturing. There is no obvious variation in recorded bedrock fracture occurrence across the Power Station Site.

Given that effective groundwater flow within the body of this bedrock will be exclusively via fractures this suggests a high degree of vertical anisotropy is likely, with horizontal flow dominating. In addition, faulting has occurred within the bedrock and igneous intrusions are also present and these features may also influence groundwater flow patterns. However, no significant effects on the near surface groundwater flow system have been identified.

The superficial deposits overlying the bedrock are dominantly low permeability materials, consisting predominantly of variable silty, sandy, gravelly clay, with variable cobble/boulder content and occasional coarser sand/gravel layers. Recorded thickness varies from being absent in some areas (where bedrock is present at the surface) to over 30m thick where drumlins are present. Thick superficial deposits are also present in what is suspected to be a buried valley feature or kettle hole in the vicinity of the Tre'r Gof SSSI.

FIGURE 8.1



NOTE:
Faults and igneous intrusion are for illustrative purposes only.
They do not represent known actual features.

LEGEND

- Piezometric surface in bedrock
- Water Table
- Superficial (clay dominated)
- Sand and gravel horizons within clay-dominated superficial deposits
- Made ground locally present
- Bedrock (New Harbour Group)
- Zone of highest fracturing
- Groundwater flow direction
- Surface water runoff and shallow throughflow through soils
- Recharge to bedrock through superficial deposits. Higher recharge rates where the superficial deposits are thin or absent

Rev.	Date	Purpose of Revision	Drawn	Check'd	Rev'd	App'd
0	MAR 17	INITIAL ISSUE	AR	MB	SH	SH

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Client
HORIZON NUCLEAR POWER

Project
WYLFA NEWYDD PROPOSED NUCLEAR POWER STATION

Drawing Title
SCHEMATIC CONCEPTUAL SECTION THROUGH WYLFA NEWYDD DEVELOPMENT AREA

Drawing Status
INITIAL ISSUE

Scale	AS SHOWN	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		
Drawing No.	60PO8077_HYDROGEOLOGY_BASELINE_8.1	

Granular superficial deposits, expected to be more permeable and consisting of variably clayey, silty sand and gravel, are present across the south-western part of the Wylfa Newydd Development Area. These include examples where significant layers of both low permeability and granular materials are present. The ground investigation information suggests that granular materials become the predominant superficial deposits broadly to the south-west of a line between Tregele village and Porth-y-pistyll. Low permeability, clay dominated deposits are still present in this area and are observed further to the south-west in the vicinity of Cae Gwyn. Granular superficial deposits are also recorded in smaller areas to the east and north of the Power Station Site, including on the line of the proposed cooling water tunnels.

Water strike information available from the ground investigations is limited, primarily due to the drilling methods employed (i.e. a high proportion of cored rotary boreholes, addition of flush water) which, in conjunction with the low permeability nature of much of the superficial deposits, limited the information that could be observed. However, good records of standing water levels in boreholes were recorded in many cases and have been used in constructing the CSM.

8.2 Water inputs to the groundwater system

Water input to the groundwater in the study area will be derived from rainfall and groundwater flowing into the study area from up hydraulic gradient. Potentially, a small amount of water enters the groundwater system from leakage from local streams, particularly in late summer when groundwater levels are at their lowest.

Where the superficial deposits are of low permeability this will reduce the amount of rainfall that reaches the bedrock. Groundwater modelling studies show that the majority of the effective rainfall results in surface water runoff or shallow interflow, principally to the local streams. It is estimated that recharge to the bedrock is in the order of 30 to 100mm/year, with the lowest recharge rates being where the ground is steepest and superficial deposits thickest (at drumlins) and highest where the superficial deposits are absent or thin.

As would be anticipated in the UK, groundwater recharge occurs principally during the winter months. This is seen in the Wylfa Newydd Development Area and the recharge causes groundwater levels to rise typically by around 2m to 3m between the summer and the winter. However, in a small number of boreholes a greater rise is observed, with this rise being in the order of 5m in BH311 adjacent to the Tre'r Gof SSSI.

8.3 Groundwater levels and flow

Groundwater levels in the bedrock and superficial deposits are often a similar order of magnitude and across most of the Power Station Site there is no significant unsaturated zone evident between superficial deposits and bedrock, indicating that there is a degree of hydraulic connection between the two groundwater units over much of the area. However, there are significant differences in some areas and across the Wylfa Newydd Development Area there is a substantial amount of variation.

Groundwater flows in the bedrock are towards the coast. Upward hydraulic gradients are observed in several boreholes and confined pressure conditions, both beneath superficial deposits and at depth in the bedrock, are also indicated in some boreholes.

There are low groundwater flow rates in the low permeability superficial deposits which are predominant across most of the Wylfa Newydd Development Area but the water table broadly mirrors the topography. However, there is some local perched groundwater in higher elevation areas, supported by lower permeability layers. Particularly in areas with thicker superficial deposits, such as where drumlins are present. For example, BH311 and BH535 where perched water is indicated in upper sandy gravelly clay superficial layers.

Due to the variability in the nature and distribution of the superficial deposits and variability of bedrock fracture density and interconnection, as noted above, at a small scale, groundwater flow patterns will be complex. Across most of the Wylfa Newydd Development Area there is some degree of continuity in saturated groundwater conditions between the bedrock and superficial deposits. However, in several areas, due to the low permeability nature of the superficial deposits and contrast in permeability compared to the more permeable upper bedrock zone, along with upward gradients in the bedrock, groundwater flows in the two zones will behave differently.

The water table maps for the superficial deposits (figures 6.1 and 6.3) show groundwater flows tending to follow the topography, towards the coast and radially away from areas of higher ground, such as the drumlins. The piezometric surface maps for the bedrock groundwater (figures 6.2 and 6.4) show a groundwater divide trending from the south-east towards the north-west under a slight topographic ridge which passes beneath Tregele village. Groundwater therefore flows predominantly either north westwards to the coast at Cemlyn Bay and Porth-y-pistyll, or north eastwards to the coast at Cemaes Bay. This effect may also be associated with slightly higher recharge through coarser, more permeable superficial deposits, which begin to predominate in this area.

In a small number of locations groundwater is confined and artesian conditions are present during times of high groundwater levels. Artesian or sub-artesian conditions occur locally where bedrock groundwater levels become confined beneath the low permeability superficial deposits in topographically low areas. This may also be related to the distribution of water bearing fracture networks in the bedrock, with confined pressures potentially also generated at depth within the bedrock in some places.

The faults and igneous intrusions within the bedrock have the potential to act as barriers to flow, particularly if the faults are infilled with low permeability deposits. However, faults and intrusions could also act as pathways along their length if the faults are open or the intrusions are associated with a higher degree of fracturing. It is also possible that these features have no effect on groundwater movement (e.g. if they are fractured to the same degree as the surrounding bedrock). The pumping test in borehole PW2 showed a greater drawdown in a broadly east-west direction, which does correspond to the principal direction of faults and intrusions in the area, although the extent of this was limited. There is no evidence from the water level data across the Power Station Site of the influence of faults or intrusions.

Groundwater and surface water level and water quality data indicate that groundwater and surface water are likely to be in hydraulic connection across several parts of the Wylfa Newydd Development Area. The data indicate that during the winter, groundwater would discharge to the watercourses within the Wylfa Newydd Development Area, although in summer, the groundwater levels in some locations do fall below the stream surface water level and there is potential for leakage from the streams to the groundwater.

Tidal influences on the groundwater are generally very slight and restricted to a maximum of approximately 80m from the coast, although the effect is observed to be very variable. This is considered likely to be due to variability in the degree of fracturing and fracture connection in the vicinity of the coast.

8.4 Aquifer classification and groundwater abstractions

The bedrock is defined as a Secondary B aquifer, whilst the glacial till is defined as a Secondary (Undifferentiated) aquifer. No current groundwater abstractions are identified within the Wylfa Newydd Development Area, although a small number of historical public wells have been identified. An assessment of these wells shows they are no longer used. Within the inner groundwater study area, but outside of the Wylfa Newydd Development Area, three private water supplies have been identified. These three wells are all up hydraulic gradient of the proposed Power Station.

8.5 Permeability and groundwater storage

Within the superficial deposits, groundwater flow is through the soil pores. The permeability of these deposits varies, largely depending upon the clay content. Measurements show a median hydraulic conductivity for the superficial deposits of 0.6m/d for granular deposits and 0.02m/d for the clay dominated cohesive deposits.

Within the bedrock, groundwater flow will be within the fracture zone, with the rock itself having a low primary permeability. An assessment of data from geological logs showing fracture frequency and results of permeability testing at different depths, shows an increase in transmissivity from around 30m below rock head upwards, with the highest transmissivity in the weathered bedrock. Fracture density reduces with depth and below the upper fractured zone permeability is relatively uniform and low. However, even in the upper fractured zone permeability is not particularly high with hydraulic conductivity values typically being in the order of 0.3m/d to 1m/d.

The results of tests within individual boreholes will depend on the nature of the fractures within the test interval. The precise nature and connectivity of fractures on a wider scale is not known. Results from two pumping tests, which assess a much larger volume of aquifer than tests in individual boreholes, do show that the nature and connectivity of the fractures does vary across the Power Station Site as pumping from the two tests showed considerably different yields could be maintained.

In terms of groundwater storage, the bedrock aquifer has low storage due to a low primary porosity. The pumping tests showed that the fractures within the bedrock are relatively quickly dewatered. There would be some groundwater storage in the sand and gravel horizons within the superficial deposits but such horizons are limited and the stream monitoring data within the Wylfa Newydd Development Area does show that many of the smaller watercourses within the Wylfa Newydd Development Area do dry up in the summer.

8.6 Groundwater quality

The groundwater quality data reflects the mineralogy of the surrounding rocks with only minor anthropogenic influences recorded. Baseline groundwater quality compared to WQSs shows the water to be generally of good quality. However, manganese and iron concentrations do exceed the WQSs in many of the boreholes which reflects the mineralogy of the rocks and soils in and around the Wylfa Newydd

Development Area. In addition, in a number of boreholes there are exceedances of WQSs for nitrate, ammoniacal nitrogen and certain metals.

Relatively low concentrations of TPH have been identified at a small number of locations around the Wylfa Newydd Development Area. Whilst at some locations near to the Existing Power Station this TPH may have an anthropogenic source, the elevated TPH concentrations situated in other areas, including around the Tre'r Gof SSSI, are more likely to be derived from a natural source derived from degradation of vegetation. Low concentrations of other organic contaminants are identified in two locations likely to be due to historical activities at the Existing Power Station.

Concentrations of major ions (including sulphate, calcium and chloride) are generally low. This results in a relatively low electrical conductivity and may be indicative of relatively short residence times for water within the groundwater system.

There is no evidence of saline intrusion into the aquifer.

8.7 GWDTE

Two GWDTE have been identified within and adjacent to the Wylfa Newydd Development Area, the Tre'r Gof SSSI and the Cae Gwyn SSSI. At the Tre'r Gof SSSI, due to the thick layer of low permeability superficial deposits underlying the SSSI, groundwater in the bedrock is not anticipated to flow upward into the SSSI basin, although there may be some inflow around the periphery of the basin. In contrast, groundwater in the superficial deposits will discharge to the SSSI during the winter months when the water table is high. The deep peat soil across the fen also maintains a high water table through the summer months by storing winter recharge.

The Cae Gwyn SSSI appears to be predominantly supported by direct rainfall, with limited groundwater inflow except in small areas.

8.8 Groundwater receptors

Table 8.1 identifies receptors that could potentially be affected by changes to the groundwater regime brought about by construction or operation of the Power Station.

Table 8.1: Summary of potential groundwater receptors

Receptor group	Potential receptors	Comment
Local watercourses	Afon Cafnan and its tributaries	Potential for change in groundwater/surface water interaction due to changes in groundwater levels or flow direction.
	Nant Cemaes	
	Nant Cemlyn	
	Drains to Tre'r Gof SSSI	
	Cemlyn Lagoon	
GWDTE	Tre'r Gof SSSI	Situated within the Wylfa Newydd Development Area.
	Cae Gwyn SSSI	Situated to the southwest of the Wylfa Newydd Development Area.
PWSs	Foel Fawr	These three PWSs are up hydraulic gradient of the
	Caerdegog Uchaf	
	Cae Gwyn	

Receptor group	Potential receptors	Comment
		Wylfa Newydd Development Area.
Buildings and services	Existing Power Station	Drawdown of groundwater levels could lead to subsidence of buildings.
	Residential properties outside of the Wylfa Newydd Development Area	

9 Evolution of groundwater baseline

This section summarises how the groundwater baseline might evolve in the future if the Power Station did not proceed. The factors assessed are those which are reasonably foreseeable and are considered likely to affect groundwater resources in some way.

9.1 Evolution due to development

Developments on the Isle of Anglesey and the potential that these would have for cumulative effects to the groundwater environment within the Wylfa Newydd Development Area have been considered in chapter I4, Intra-project cumulative effects (Application Reference Number: 6.9.4) and chapter I5 Inter-project cumulative effects (Application Reference Number: 6.9.5). This has identified that in the vicinity of the Wylfa Newydd Development Area, three developments have the potential to impact groundwater as follows:

- decommissioning of the Existing Power Station; and
- installation of below ground services for the Power Station.

Due to the minor nature of the below ground services, the developments are unlikely to affect groundwater quality or quantity (and if the construction of the Power Station did not proceed, it is unlikely that these two would take place). The Environmental Statement for the decommissioning of the Existing Power Station identifies that with appropriate mitigation the decommissioning would not have a significant impact on the groundwater environment. As such, these developments are unlikely to affect the evolution of the groundwater baseline.

9.2 Evolution due to climate change

Over the medium and long term, groundwater resources in the Study Area may be affected by climate change. There are a number of models covering the UK which simulate the change in climate. The UK Climate Impact Programme [RD25] indicates that in the future winters may be generally wetter and summers substantially drier for the whole of the UK.

The direct effect of climate change on groundwater resources depends primarily upon the change in the volume and distribution of groundwater recharge. If drier, warmer summers lead to the seasonal deficits in the moisture content of soils extending into the autumn, the winter groundwater recharge season may be shortened. This could be compensated, at least to some extent, by an increase in winter rainfall. However, aquifers are recharged more effectively by prolonged steady rain, which continues into the spring, rather than short periods of intense rainfall, which often result in a high proportion of rapid surface runoff rather than infiltration.

The effects of climate change on groundwater in the UK therefore may include:

- a long-term decline in groundwater storage;
- increased frequency and severity of groundwater droughts;
- increased frequency and severity of groundwater-related floods;
- mobilisation of pollutants due to seasonally high water tables; and
- saline intrusion in coastal aquifers, due to sea level rise and resource reduction.

With respect to the Wylfa Newydd Development Area and surrounding area, therefore, these effects could result in locally significant impacts on the stream flows that are sustained in part by groundwater flow. In addition, a reduction in groundwater levels during prolonged dry periods could affect private water supplies and GWDTE that are sustained by shallow groundwater flows. If seasonally high groundwater levels are encountered, due to increased winter rainfall, then groundwater levels could rise into the areas of made ground that are currently not in contact with groundwater and could lead to groundwater contamination. Due to the low groundwater usage in the area, a rise in sea level is unlikely to result in a change to saline intrusion, although a sea level rise is likely to result in a rise in groundwater level adjacent to the coast.

9.3 Evolution due to changes in groundwater abstraction

Currently there is no reason to suspect any significant changes in groundwater abstractions across northern Anglesey, although it is possible that if there are drier summers these will result in more people looking to groundwater for small scale supplies. Currently the groundwater resource is not under stress from abstractions and this is not anticipated to change.

9.4 Evolution due to changes in groundwater quality

NRW is currently reporting poor groundwater quality across parts of Anglesey, due to contamination from former mines in the Parys Mountain area. Provided that there is no change to the mine hydrology, contaminant levels in the Parys Mountain area are anticipated to decline in the long term due to natural attenuation. Any changes in this area would not affect groundwater quality in the Wylfa Newydd Development Area.

9.5 Overall evolution

In the short to medium term, it is considered that no significant changes to the groundwater system in the Wylfa Newydd Development Area would take place if the WNDA Development did not progress. In the longer term, given that the aquifer is not a significant groundwater resource, and that there would not be major development in the area, changes brought about by abstractions and impacts to groundwater quality are likely to be minimal. The main change is likely to come about due to climate change, although this is likely to result in slow changes over time.

10 References

Table 10.1 Schedule of references

ID	Reference
RD1	Department of Energy and Climate Change. 2011. National Policy Statement for Nuclear Power Generation (EN-6). London: The Stationery Office.
RD2	Environment Agency, What's in your Backyard? Website Available [Online]. [Accessed in March 2015]. http://apps.environment-agency.gov.uk/wiyby/default.aspx
RD3	Ordnance Survey Maps 1:10,000, 1:25,000, 1:50,000 Scales. © Crown copyright and database rights 2014 Ordnance Survey 0100031673.
RD4	British Geological Survey. 2016. Geology of Britain Viewer. [Online]. [Accessed on 16/10/16]. Available from: http://mapapps.bgs.ac.uk/geologyofbritain/home.html
RD5	Halcrow Group Ltd. July 2010, Wylfa 'B' Power Station Interpretative Report on 2009 Preliminary Site Investigation (for Horizon Nuclear Power).
RD6	Halcrow Group Ltd. February 2012, Wylfa New Build Intermediate Onshore Ground Investigation Geotechnical Interpretative Report (WYB0002) (for Horizon Nuclear Power).
RD7	Structural Soils Limited. 2014. Factual Report on Wylfa Newydd Detailed Onshore Ground Investigation Volume 1. Report Number 728599.
RD8	Structural Soils Limited. 2015. Factual Report on Wylfa Newydd Detailed Onshore Ground Investigation Volume 2. Report Number 728599.
RD9	Structural soils. 2015. Factual Report for Task Order 002 - SPC1. Report No: 730399.
RD10	Atkins. 2017. Wylfa Newydd Nuclear Power Station – Detailed Onshore Ground Investigation (Final Interpretative Ground Investigation Report, 15 August 2017). DCRM Ref Number WN02.03.01-ATK-SDT-REP-00001.
RD11	Environment Agency. 2007. Groundwater Quality and Supply Survey: The Precambrian Gwna Group, Anglesey.
RD12	Structural Soils Limited. 2015. Factual Report for Task Order 001 – PW1 Pump Test Report No: 730398.
RD13	Structural Soils Limited. 2016. Factual Report for Task Order 001 – PW2 Pump Test. Report No: 730398.
RD14	Structural Soils Limited. 2016. Interpretive Report for Task Order 001 – PW1 Pump Test Report No: 730398.
RD15	Structural Soils Limited. 2016. Interpretive Report for Task Order 001 – PW2 Pump Test. Report No: 730398.
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RD17	National River Flow Archive. 1988-2014. Cefni at Bodffordd. [Online]. [Accessed 16/04/15]. Available from: http://www.ceh.ac.uk/data/nrfa/data/station.html?102001

ID	Reference
RD18	Wealthall, G.P., Brandon, A., Inglethorpe S.D.J. and Entwistle, D.C. 1997. The Hydrogeological Classification of Superficial Clay: The hydrogeological characteristic of glacial till and glacio-lacustrine sediments in Shropshire. R&D Technical Report W29. Environment Agency. Bristol.
RD19	Environment Agency. 2017. New Groundwater Vulnerability Mapping Methodology in England and Wales. Report – SC040016/R. Environment Agency. Bristol.
RD20	Natural Resources Wales. 2016. Water Watch Wales Map Gallery. [Online]. [Accessed 19/10/16]. Available from: http://waterwatchwales.naturalresourceswales.gov.uk/en/
RD21	Countryside Council for Wales. 1988. TRE'R GOF SSSI. [Online]. [Accessed 19/10/16]. Available from: http://angleseynature.co.uk/webmaps/trergof.html
RD22	Countryside Council for Wales. 1982. CAE GWYN SSSI. [Online]. [Accessed 19/10/16]. Available from: http://angleseynature.co.uk/webmaps/caegwyn.html
RD23	Jacobs. 2016. Site Preparation and Clearance – Phase 3 Definition. Numbered Appendices Series 200 - Site Clearance. Rev. 3.0.
RD24	Structural Soils Limited. December 2011. Factual Report on Wylfa New Build Intermediate Onshore Ground Investigation. Report No: 725061.
RD25	The UK Climate Impact Programme. 2015. [Online]. [Accessed 2/07/15]. Available from: http://www.ukcip.org.uk/

Appendix A Glossary

Full title	Definition
Alluvium	A deposit of clay, silt and sand left by flowing floodwater in a river valley or delta, typically producing fertile soil.
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.
Baseline conditions (or baseline environment)	The environment as it appears (or would appear) immediately prior to the implementation of the Wylfa Newydd Project together with any known or foreseeable future changes that will take place before completion of the Wylfa Newydd Project. (Source: http://www.dft.gov.uk/ha/standards/dmrb/vol11/section2/ha2180 8.pdf)
Bedrock	Solid rock formations underlying superficial deposits (if present).
Borehole	A constructed hole made in the ground, usually narrow and vertical, especially to assess geological conditions and to locate groundwater.
British Geological Survey (BGS)	The BGS is a part of the Natural Environment Research Council (NERC) and provides expert services and impartial advice in all areas of geoscience.
Bulk Density	Defined as the dry weight of soil per unit volume of soil. Bulk density considers both the solids and the pore space; whereas, particle density considers only the mineral solids.
Conceptual Site Model (CSM)	A CSM synthesises data relating to hydrogeology, geology, hydrology and climate in order to develop a comprehensive understanding of how a groundwater system operates and interacts with other systems. A CSM can be presented as text or as images. It is often used as a starting point for impact assessment.
Devensian	The name Devensian glaciation is used by British geologists and archaeologists and refers to what is often popularly meant by the latest Ice Age.
Detailed Onshore Ground Investigation (DOnGI)	Ground investigation at the Wylfa Newydd Development Area which commenced on 3rd March 2014 and terminated on 23rd January 2015.
Drinking Water Standards (DWS)	Water quality standards set for drinking water in accordance with the *Water Supply (Water Quality) Regulations 2000* (as amended).
Drumlins	A low oval mound or small hill, typically one of a group, consisting of compacted boulder clay moulded by past glacial action.
Ediacaran Period	The Ediacaran Period is the last geological period of the Neoproterozoic Era and of the Proterozoic Eon, immediately preceding the Cambrian Period.
Environment Agency (EA)/Natural Resources Wales (NRW)	The government agency responsible for environmental permitting with a mandate to protect and improve the environment, and to promote sustainable development.
Environmental Impact Assessment (EIA)	The process in which the likely significant effects of a development on the environment are identified and assessed.
Environmental Quality Standard (EQS)	An Environmental Quality Standard (EQS) is the maximum permissible concentration of a potentially hazardous chemical in an environmental sample, generally of air or water. These are set within the context of European and National legislation.

Full title	Definition
Geomorphology	The study of landforms and the processes which create them.
Geophysical Logging	Borehole geophysics is the science of recording and analysing measurements of physical properties made in wells or test holes. Probes that measure different properties are lowered into the borehole to collect continuous or point data that is graphically displayed as a geophysical log.
Groundwater	All water which is below the surface of the ground in the saturation zone (below the water table) and in direct contact with the ground or subsoil.
Groundwater-Dependent Terrestrial Ecosystems (GWDTE)	GWDTE are wetlands which critically depend on groundwater flows and /or chemistries.
Gwna Group	Geological bedrock strata comprising grit, phyllite, quartzite, limestone, jasper, graphitic phyllite, spilitic pillow lavas and tuffs.
Habitats Regulations Assessment	The aim of the Habitats Regulations Assessment is to identify any aspects of the emerging Local Plan that would have the potential to cause a likely significant effect on Natura 2000 or European sites (Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites), (either in isolation or in combination with other plans and projects), and to begin to identify appropriate mitigation strategies where such effects are identified.
Hydraulic conductivity/ permeability	Permeability or hydraulic conductivity is a measure of the ease with which water will pass through an aquifer.
Hydraulic gradient	The gradient or pressure head of groundwater in an aquifer.
Hydrogeology	The branch of geology concerned with water occurring underground.
Hydrology	The science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the Earth
Intermediate Onshore Ground Investigation (IOnGI)	Ground investigation at the Wylfa Newydd Development Area which commenced on 3 March 2014 and terminated on 23 January 2015.
Isle of Anglesey County Council (IACC)	The local authority governing the area within which the Power Station is intended to be constructed.
Lodgement Till	A glacial deposit as identified in the Wylfa Newydd Development Area as sandy clay deposits.
Mica Schist	Schist is a crystalline metamorphic rock, mostly composed of tabular and elongated minerals with grainsize coarse enough to be visible to the unaided eye. Mica-schist contains quartz and mica as the man minerals.
New Harbour Group	Geological bedrock strata comprising fissile green mica schist, gritty green mica schist, with bedded jasper, jaspery phyllite and pelitic lava.
Piezometer	An instrument for measuring the pressure of a liquid or gas, or something related to pressure (such as the compressibility of liquid). Piezometers are often placed in boreholes to monitor the pressure or depth of groundwater.
Piper plot/diagram	A Piper diagram is a graphical representation of the chemistry of a water sample or samples. The cations and anions are shown by separate ternary plots.
Pressure transducer/groundwater data logger	An instrument which is installed into a borehole or piezometer and automatically records water level/pressure.
Preliminary Site Investigation (PSI)	Ground investigation at the Wylfa Newydd Development Area which was undertaken between 22 October 2009 and 12 February 2010.

Full title	Definition
Private Water Supplies (PWS)	In general terms a private water supply (PWS) is any water supply which is not provided by a water company except 'Regulation 8 supplies' where the water is further distributed from a public main.
Psammite	A sedimentary rock consisting of sand consolidated with some cement (clay, quartz).
Secondary B aquifer	Predominantly lower permeability rock or soil layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.
Site of Special Scientific Interest (SSSI)	Sites designated for their flora, fauna or geological or physiographical features under the *Wildlife and Countryside Act 1981* (as amended).
Special Area of Conservation (SAC)	Special Areas of Conservation (SACs) are strictly protected sites designated under the EC Habitats Directive.
Special Protection Area (SPA)	A Special Protection Area (SPA) is a designation under the European Union Directive on the Conservation of Wild Birds. Under the Directive, Member States of the European Union have a duty to safeguard the habitats of migratory birds and certain particularly threatened birds.
Study Area	The spatial area within which environmental effects are assessed (i.e. extending a distance from the Wylfa Newydd Project footprint in which significant environmental effects are anticipated to occur).
Superficial deposits	Unconsolidated (loose) deposits overlying the bedrock.
Surface water catchment	A drainage/basin area within which precipitation drains into a river system and eventually into the sea.
Water Framework Directive (WFD)	A substantial piece of European Union water legislation that came into force in 2000, with the overarching objective to get all water bodies in Europe to attain Good or High Ecological Status. River Basin Management Plans (RBMP) have been created which set out measures and potential mitigation to ensure that water bodies in England and Wales achieve 'Good Ecological Status'.

Appendix B Boreholes Completed as Groundwater Monitoring Points

Borehole No.	Investigation Phase	Coordinates mE	Coordinates mN	Borehole Datum (mAOD)	Datum Point	Borehole Completed Depth (m)	Screened Interval (mbgl) from	Screened Interval (mbgl) to	Screened Interval (mAoD) from	Screened Interval (mAoD) to	Zone monitored
BH14	pre-PSI	235360	394140	Borehole Logs Not Available							
BH15	pre-PSI	235360	394120								
BH16	pre-PSI	235320	394100								
BH17	pre-PSI	235400	394090								
BH20	pre-PSI	235420	394050								
BH21	pre-PSI	235330	394060								
BH24	pre-PSI	235370	394030								
RN1A	pre-PSI	235370	394100	13	Ground Level	7					
301R	PSI	234918	393397	14.77	Ground Level	120.5	31.5	34	-16.73	-19.23	Bedrock
302R	PSI	234655	393148	21.37	Ground Level	100	10	12	11.37	9.37	Bedrock
303CP	PSI	235104	393021	34.32	Ground Level	16.95	14	16	19.8	17.8	Superficial
303R	PSI	235102	393019	34.34	Ground Level	100	24	26	10.34	8.34	Bedrock
304R	PSI	235556	392933	21.65	Ground Level	99.8	9	11	12.65	10.65	Bedrock
305AR	PSI	235248	393277	16.57	Ground Level	100.6	17	19	-0.43	-2.43	Bedrock
305R	PSI	235248	393277	16.57	Ground Level	16	4.7	5.7	11.87	10.87	Bedrock
306R	PSI	235244	393458	14.87	Ground Level	99.3	16	20	-1.13	-5.13	Bedrock
307R	PSI	235657	393297	16.24	Ground Level	100	25	29.5	-8.76	-13.26	Bedrock
308R	PSI	235672	393113	21.22	Ground Level	100	26	32.5	-4.78	-11.28	Bedrock
309CP	PSI	235816	393411	9.45	Ground Level	40	1.7	2.5	7.75	6.95	Superficial
309R	PSI	235816	393411	9.45	Ground Level	40.2	30	35	-20.55	-25.55	Bedrock
309RO	PSI	235813	393410	9.54	Ground Level	3	1.8	2.4	7.74	7.14	Superficial
310CP	PSI	236094	393333	11.86	Ground Level	5.22	4.6	5.1	7.26	6.76	Superficial
310R I1	PSI	236097	39334	11.98	Ground Level	40	18	20	-6.02	-8.02	Bedrock
310R I2	PSI	236097	39334	11.98	Ground Level	40	25	29	-13.02	-17.02	Bedrock
311CP	PSI	236051	393712	11.96	Ground Level	25	23	25	-11.04	-13.04	Superficial
312	PSI	234986	393545	8.91	Ground Level	3	1.5	3	7.41	5.91	Made Ground
313	PSI	234997	393523	9.26	Ground Level	3	1.5	3	7.76	6.26	Made Ground
314	PSI	234977	393539	8.8	Ground Level	3	1.1	3	7.7	5.8	Made Ground
BH509CP	IOnGI	234981	393349	17.944	Ground Level	8.25	1.2	7.8	16.744	10.144	Superficial
BH512CP	IOnGI	235342	393197	17.87	Ground Level	5.16	1.4	3.7	16.47	14.17	Superficial
BH512R	IOnGI	235342	393197	18	Ground Level	45	6	16	12	2	Bedrock
BH516A	IOnGI	235258	393342	15.333	Ground Level	4.61	1.8	3.6	13.533	11.733	Superficial
BH516R	IOnGI	235258	393340	15.39	Ground Level	40.3	9	16.6	6.39	-1.21	Bedrock
BH518R	IOnGI	234855	393536	9.63	Ground Level	71.1	7.5	18	2.13	-8.37	Bedrock
BH520CP	IOnGI	235002	393411	15.446	Ground Level	16.4	12	14.9	3.446	0.546	Superficial
BH521R	IOnGI	235026	393395	16.55	Ground Level	28	14	19.3	2.55	-2.75	Bedrock/Superficial
BH523RD*	IOnGI	235489	393972	19.74	Ground Level	70.5	39	52	-19.26	-32.26	Bedrock
BH523RS*	IOnGI	235489	393972	19.74	Ground Level	70.5	14	20.1	5.74	-0.36	Bedrock
BH524CP	IOnGI	235620	393778.2	9.633	Ground Level	7.35	3	6.5	6.633	3.133	Superficial
BH524R	IOnGI	235624	393777	9.56	Ground Level	25	7.5	19	2.06	-9.44	Bedrock
BH525CP	IOnGI	235735	393536	10.849	Ground Level	6.15	3.4	5.25	7.449	5.599	Superficial
BH525R	IOnGI	235736	393538	10.76	Ground Level	25.5	6.6	12.5	4.16	-1.74	Bedrock
BH526CP	IOnGI	236014	39369	9.748	Ground Level	23	5.2	11.8	4.548	-2.052	Superficial
BH526RD	IOnGI	236006	393683	7.89	Ground Level	41.5	26.5	39	-18.61	-31.11	Bedrock
BH526RS	IOnGI	236006	393683	7.89	Ground Level	41.5	17	23	-9.11	-15.11	Superficial
BH529CP	IOnGI	235505	393198	16.767	Ground Level	3.6	1	3	15.767	13.767	Superficial
BH529R	IOnGI	235503	393200	17.087	Ground Level	30.2	5	10	12.087	7.087	Bedrock
BH530CP	IOnGI	235182	393394	14.787	Ground Level	4.2	1.2	3.5	13.587	11.287	Superficial
BH530R	IOnGI	235185	393395	14.77	Ground Level	30.5	3	16	11.77	-1.23	Bedrock
BH533CP	IOnGI	235047	393135	22.717	Ground Level	6.4	1	5.7	21.717	17.017	Superficial
BH534CP	IOnGI	235157	393091	30.91	Ground Level	13.4	3	12.8	27.91	18.11	Superficial
BH534RA	IOnGI	235153	393092	30.825	Ground Level	74.83	27.5	43	3.325	-12.175	Bedrock
BH535CP	IOnGI	235089	392896	32.745	Ground Level	14	2.6	12.6	30.145	20.145	Superficial
BH535R	IOnGI	235087	392893	32.485	Ground Level	80.2	20	32.5	12.485	-0.015	Bedrock
BH536R	IOnGI	234708	393238	16.732	Ground Level	50.4	1	11	15.732	5.732	Bedrock
717	DOnGI-HP	234802	393021	32.76	Ground level	103.15	42	52	-9.24	-19.24	Bedrock
726	DOnGI-HP	234961	393110	20.88	Ground level	91.04	18.5	22.5	2.38	-1.62	Bedrock
758R	DOnGI-LP	235230	392782	23.28	Ground level	21.25	8.8	15.3	14.48	7.98	Bedrock
763	DOnGI-HP	235312	392908	26.91	Ground level	24	8.7	11	18.21	15.91	Bedrock
801	DOnGI-LP	235287	393088	26.67	Ground level	44.03	14.5	24.5	12.17	2.17	Bedrock
802	DOnGI-LP	235257	393113	26.47	Ground level	53.15	14.5	24.5	11.97	1.97	Bedrock
822	DOnGI-LP	234746	393439	8.88	Ground level	39.36	19	29	-10.12	-20.12	Bedrock
850	DOnGI-LP	234804	393669	5.38	Ground level	14.1	4.5	13.5	0.88	-8.12	Bedrock
852	DOnGI-LP	234617	393488	8.65	Ground level	29.49	10.5	20.5	-1.85	-11.85	Bedrock
853	DOnGI-LP	235298	394197	12.98	Ground level	33.54	9.5	25.5	3.48	-12.52	Bedrock
856	DOnGI-LP	235328	394134	12.91	Ground level	33	17.5	28.5	-4.59	-15.59	Bedrock
857	DOnGI-LP	235346	394120	12.83	Ground level	32.93	11.5	15.5	1.33	-2.67	Bedrock
858	DOnGI-LP	235336	394091	12.5	Ground level	33.23	2.5	12.5	10	0	Bedrock/Superficial
860	DOnGI-LP	235352	394039	14.85	Ground level	35.65	1.5	6.5	13.35	8.35	Bedrock
862	DOnGI-LP	235369	393993	16.62	Ground level	38.26	20.5	27.5	-3.88	-10.88	Bedrock
863	DOnGI-LP	235395	393979	17.52	Ground level	39.3	11	18	6.52	-0.48	Bedrock
864	DOnGI-LP	235443	393754	19.07	Ground level	39.6	12.5	19.5	6.57	-0.43	Bedrock
866	DOnGI-LP	235427	393717	16.1	Ground level	38.3	1.2	4.3	14.9	11.8	Bedrock/Superficial
867	DOnGI-LP	235435	393695	16.81	Ground level	39	7.5	25.5	9.31	-8.69	Bedrock
870	DOnGI-LP	235377	393619	21.1	Ground level	42.95	11.5	22.5	9.6	-1.4	Bedrock
871	DOnGI-LP	235387	393597	20.05	Ground level	40.63	10	21	10.05	-0.95	Bedrock
875*	DOnGI-LP	235334	393494	15.11	Ground level	35.55	1.9	5.4	13.21	9.71	Superficial
878*	DOnGI-LP	235348	393462	15.06	Ground level	40.05	12.5	18.5	2.56	-3.44	Bedrock
880	DOnGI-LP	235100	393519	20.28	Ground level	16.5	11.5	15.5	8.78	4.78	Bedrock
887	DOnGI-LP	235314	393304	16.84	Ground level	46.05	10.5	17.5	6.34	-0.66	Bedrock
941	DOnGI-LP	235382	392915	22.23	Ground level	20.75	6.5	13.5	15.73	8.73	Bedrock
950	DOnGI-LP	234985	393027	21	Ground level	16.5	1.5	6	19.5	15	Superficial
951	DOnGI-LP	234949	392976	20.5	Ground level	27.21	11.5	19.5	9	1	Bedrock
957	DOnGI-LP	234947	392789	19.11	Ground level	23.05	2.4	5.2	16.71	13.91	Superficial
958	DOnGI-LP	234907	392743	17.12	Ground level	27.68	15.5	26.5	1.62	-9.38	Bedrock
967	DOnGI-LP	235460	393849	18.34	Ground level	50.52	12.5	19.5	5.84	-1.16	Bedrock
971	DOnGI-LP	235326	393430	14.45	Ground level	55.5	7.5	15	6.95	-0.55	Bedrock
1009	DOnGI-LP	234719	392910	41.53	Ground level	38.76	11.3	17.5	30.23	24.03	Superficial
1010	DOnGI-LP	234552	392917	25.03	Ground level	22.8	3	7	22.03	18.03	Superficial
1012	DOnGI-LP	234719	392823	34.59	Ground level	31.8	24.5	31.5	10.09	3.09	Bedrock
1013	DOnGI-LP	234537	392818	21.67	Ground level	19.85	10	17	11.67	4.67	Bedrock
1025	DOnGI-LP	234551	392680	18.33	Ground level	15.85	3	13	15.33	5.33	Bedrock
1028	DOnGI-LP	234508	392567	16.7	Ground level	20.8	15.7	12.4	1	4.3	Superficial
712R	DOnGI-HP	234819	393290	17.01	Ground level	87.25	-25.5	-34.6	42.51	51.61	Bedrock
713R	DOnGI-HP	234888	393222	18.04	Ground level	88.3	17	15	1.04	3.04	Bedrock/Superficial
719A	DOnGI-HP	234791	393049	31.41	Ground level	102.77	9.6	11.55	21.81	19.86	Superficial
727R	DOnGI-HP	234922	393149	20.42	Ground level	91.7	18.5	28.5	1.92	-8.08	Bedrock
729D	DOnGI-HP	235132	393080	31.06	Ground level	102.25	13.7	15	17.36	16.06	Bedrock/Superficial
729S	DOnGI-HP	235132	393080	31.06	Ground level	102.25	9.3	10.4	21.76	20.66	Superficial
745R	DOnGI-HP	234995	393627	12.02	Ground level	22.14	6.5	13.5	5.52	-1.48	Bedrock
769R	DOnGI-HP	234762	393376	12.95	Ground level	43.23	1.5	14.5	11.45	-1.55	Bedrock
775R	DOnGI-HP	234859	393171	19.61	Ground level	39.65	24.5	31.5	-4.89	-11.89	Bedrock
777R	DOnGI-HP	235064	393045	28.1	Ground level	47.5	8.7	14	19.4	14.1	Superfical/Bedrock
787R	DOnGI-LP	235031	393240	18.58	Ground level	42.5	14	21	4.58	-2.42	Bedrock
788R	DOnGI-LP	235019	393260	18.6	Ground level	42.35	1	2.6	17.6	16	Superficial
794R	DOnGI-LP	234925	393166	19.67	Ground level	42.73	1.5	12.5	18.17	7.17	Bedrock
854RA	DOnGI-LP	235312	394174	12.54	Ground level	32.8	1.7	7.3	10.84	5.24	Bedrock

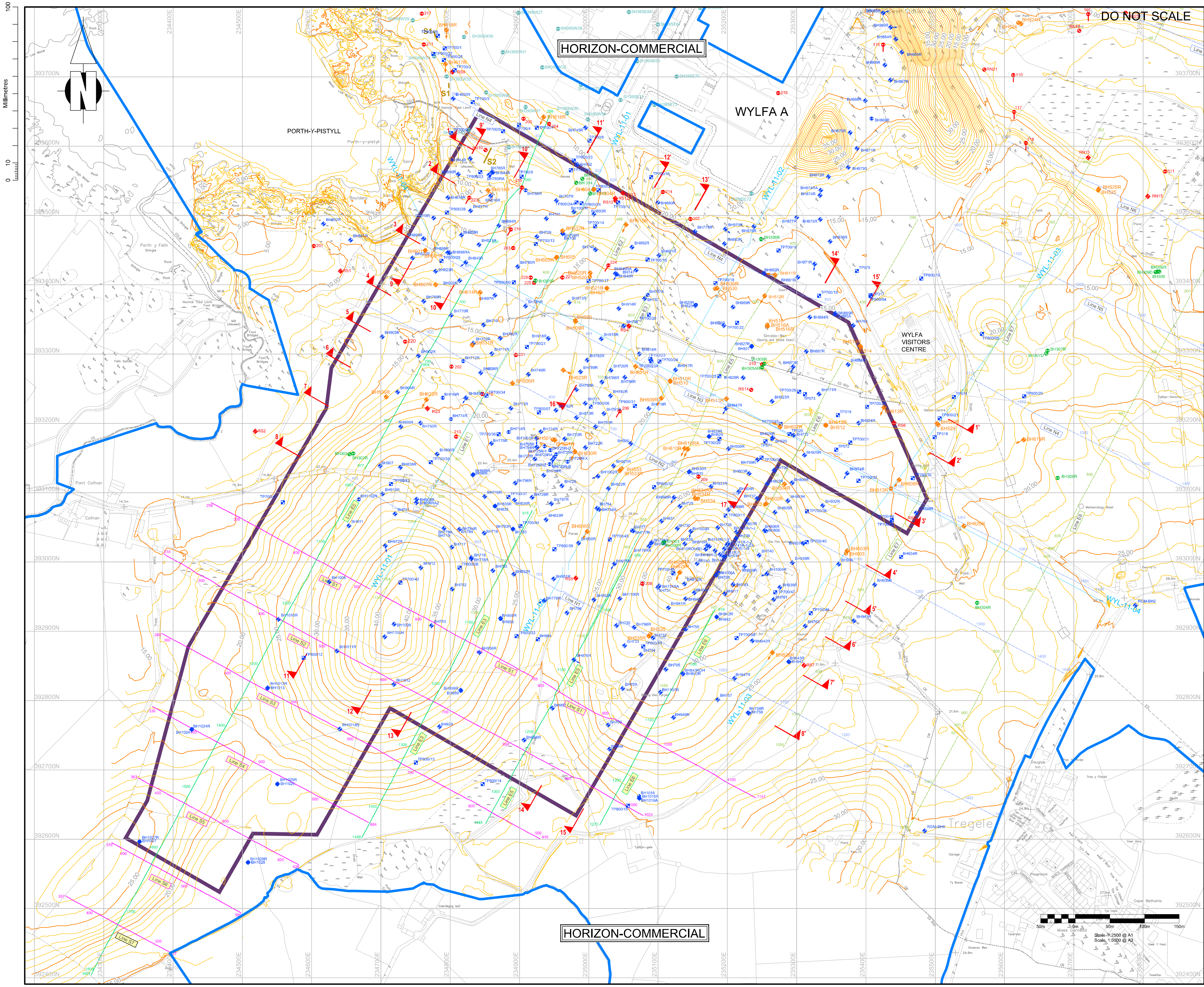
Yellow highlights indicate borehole has a logger installed.

Borehole No.	Investigation Phase	Coordinates mE	Coordinates mN	Borehole Datum (mAOD)	Datum Point	Borehole Completed Depth (m)	Screened Interval (mbgl) from	Screened Interval (mbgl) to	Screened Interval (mAoD) from	Screened Interval (mAoD) to	Zone monitored
874RA	DOnGI-LP	235335	393536	15.65	Ground level	36.2	6.5	13.5	9.15	2.15	Bedrock
947A	DOnGI-LP	235210	392832	26.77	Ground level	24.14	1.5	9.5	25.27	17.27	Superficial
RGMBH13	DOnGI-LP	234648	391386	31.69	Ground level	12.4	2	12.4	29.69	19.29	Bedrock
RGMBH1D	DOnGI-LP	236526	393418	21	Ground level	31.7	19	11	2	10	Superficial
RGMBH1S	DOnGI-LP	236525	393418	21	Ground level	31.7	2	10	19	11	Superficial
RGMBH2	DOnGI-LP	235789	392938	25.63	Ground level	14.95	4	14.9	21.63	10.73	Bedrock
RGMBH4	DOnGI-LP	234153	392851	13.9	Ground level	4.2	0.75	4.2	13.15	9.7	Superficial
RGMBH4R	DOnGI-LP	234133	392856	14.84	Ground level	15.9	0.5	15.9	14.34	-1.06	Bedrock/Superficial
RGMBH5	DOnGI-LP	233481	392693	9.21	Ground level	11.1	1	11.1	8.21	-1.89	Bedrock
RGMBH6	DOnGI-LP	235485	392612	25.5	Ground level	14.3	3.5	14.3	22	11.2	Bedrock
RGMBH7	DOnGI-LP	234899	391950	24.65	Ground level	13.95	3	13.95	21.65	10.7	Bedrock
BH2201A	2015 GI	234939	392547	18.39	Ground level	6.7	1	4	17.39	14.39	Superficial
BH2203	2015 GI	234726	392544	17.44	Ground level	4.8	1	4	16.44	13.44	Superficial
PW1	Pumping test	235008	393211	17.2	Ground level	45.5	9	45.5	8.2	-28.3	Bedrock
PTOBH1-S	Pumping test	234997	393223	16.91	Ground level	12.5	2	12.5	14.91	4.41	Superficial
PTOBH1-D	Pumping test	234997	393223	16.91	Ground level	25.5	16	25.5	0.91	-8.59	Bedrock
PTOBH2-S	Pumping test	235018	393222	17.65	Ground level	5.5	2	5.5	15.65	12.15	Superficial
PTOBH2-D	Pumping test	235018	393222	17.65	Ground level	22.5	8	22.5	9.65	-4.85	Bedrock
PTOBH3-S	Pumping test	235019	393201	17.49	Ground level	7	2	7	15.49	10.49	Superficial
PTOBH3-D	Pumping test	235019	393201	17.49	Ground level	29	14	29	3.49	-11.51	Bedrock
PTOBH4-D	Pumping test	234998	393201	17.47	Ground level	22.5	3.5	22.5	13.97	-5.03	Bedrock
PW2	Pumping test	235260	393080	28.5	Ground level	55	20	54.5	8.5	-26	Bedrock
PTOBH5-S	Pumping test	235249	393091	28.45	Ground level	8.5	2	8.5	26.45	19.95	Superficial
PTOBH5-D	Pumping test	235249	393091	28.45	Ground level	31.5	12	31.5	16.45	-3.05	Bedrock
PTOBH6-S	Pumping test	235271	393091	27.6	Ground level	14.5	2	14.5	25.6	13.1	Superficial
PTOBH6-D	Pumping test	235271	393091	27.6	Ground level	34	16.5	34	11.1	-6.4	Bedrock
PTOBH7-S	Pumping test	235270	393069	28.69	Ground level	12.5	2	12.5	26.69	16.19	Superficial
PTOBH7-D	Pumping test	235270	393069	28.69	Ground level	31.5	16	31.5	12.69	-2.81	Bedrock
PTOBH8-S	Pumping test	235249	393070	29.47	Ground level	14.5	2	14.5	27.47	14.97	Superficial
PTOBH8-D	Pumping test	235249	393070	29.47	Ground level	32.6	18	32.6	11.47	-3.13	Bedrock
PZ1A	Tre'r Gof	235710	393654	6.41	Ground level	2.33					Superficial
PZ2	Tre'r Gof	235794	393724	6.35	Ground level	2.73					Superficial
PZ3	Tre'r Gof	235861	393618	6.53	Ground level	2.91					Superficial
PZ4A	Tre'r Gof	235798	393620	6.75	Ground level	2.4					Superficial
PZ5	Tre'r Gof	235944	393676	6.48	Ground level	2.19					Superficial
PZ6	Tre'r Gof	236014	393503	7.27	Ground level	2.91					Superficial
PZ7	Tre'r Gof	236089	393554	7.06	Ground level	2.92					Superficial
PZ8	Tre'r Gof	236071	393599	7.4	Ground level	2.91					Superficial
PZ8 (Unanchored)	Tre'r Gof	236071	393599	7.26	Ground level	2.92					Superficial
PZS	Cae Gwyn	234651	391643	27.82	Ground level	26.62					Superficial
PZW	Cae Gwyn	234493	391760	24.62	Ground level	24.22					Superficial
PZN	Cae Gwyn	234649	391800	25.61	Ground level	25.37					Superficial
PZPOB	Cae Gwyn	234729	391936	22.88	Ground level	21.15					Superficial

Shaded cell shows logger installed
Shaded cell shows logger has stopped working or logger could not be downloaded in August 2017

* Logger removed and borehole backfilled January 2016

Appendix C Selected Geological Figures from the Ground Investigations



NOTES

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2. Topographic contours generated by Atkins from a 3D surface created using point data sourced from Wylfa B Power Station, Site Topographic Survey (Williamson Technical Services, 2010) and survey data obtained at historical and DOnGI borehole locations.
3. DOnGI borehole positions are plotted from as-built co-ordinates provided in AGS format (AGS version 35, Structural Soils Ltd Factual Report February 2015).
4. DOnGI geophysics points are plotted from data provided by RSK (February 2015).
5. Historical borehole positions taken from Halcrow drawing TQHOWA/402 Rev.2.
6. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

- WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017)
- NUCLEAR LICENSED SITE BOUNDARY
- 5.0m TOPOGRAPHIC CONTOUR (mOD)
- 1.0m TOPOGRAPHIC CONTOUR (mOD)
- TP316 — AS-BUILT DOnGI TRIAL PIT LOCATION
- BH726 — AS-BUILT DOnGI BOREHOLE LOCATION
- BH965R — AS-BUILT DOnGI INCLINED BOREHOLE LOCATION (ARROW GIVES AZIMUTH OF HOLE)
- RGM-BH6 — AS-BUILT DOnGI SENTINEL (RGM SERIES) BOREHOLE LOCATION
- 2 — 2' — ATKINS SECTION LINE

GEOPHYSICS

- 'S-SERIES' SURVEY LINES (RSK 2014)
- 'E-SERIES' SURVEY LINES (RSK 2014)

HISTORICAL GROUND INVESTIGATION

2011 INTERMEDIATE ONSHORE SITE INVESTIGATION

- WYL-11-04 — SEISMIC REFLECTION SURVEY LINES
- 'N-SERIES' SURVEY LINES (RSK 2011)
- 'E-SERIES' SURVEY LINES (RSK 2011)
- BH6xxR — IOnGI BOREHOLE
- BH6xxR — IOnGI INCLINED BOREHOLE (Arrow gives azimuth of hole, all inclined at 55° from horizontal)

2009 PRELIMINARY SITE INVESTIGATION

- BH301 — BOREHOLE (SUFFIX 'R' DENOTES ROTARY CORED HOLE; OTHER SUFFIXES DENOTE REDRILLED HOLES)

HISTORICAL ONSHORE SITE INVESTIGATION

- BH8 — SOIL MECHANICS, 1998 BOREHOLE
- 221/RS12 — WIMPEY, 1987 BOREHOLE
- 224 — WIMPEY, 1987 INCLINED BOREHOLE
- SH...... — WYLFA A BOREHOLE CIRCA. 1959-1964

Rev.	Date	Description	By	Chk'd	App'd
P9	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P8	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P7	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P6	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P5	03 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 3.0	DH	RH	MW
P4	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P3	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW
P2	28 NOV 2014	FOR INTERIM GIR	DH	RH	MW
P1	14 NOV 2014	FOR DRAFT INTERIM GIR	DH	RH	MW

Drawing Status: FOR ISSUE

Suitability: S2

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Client: HORIZON NUCLEAR POWER WYLFA LTD

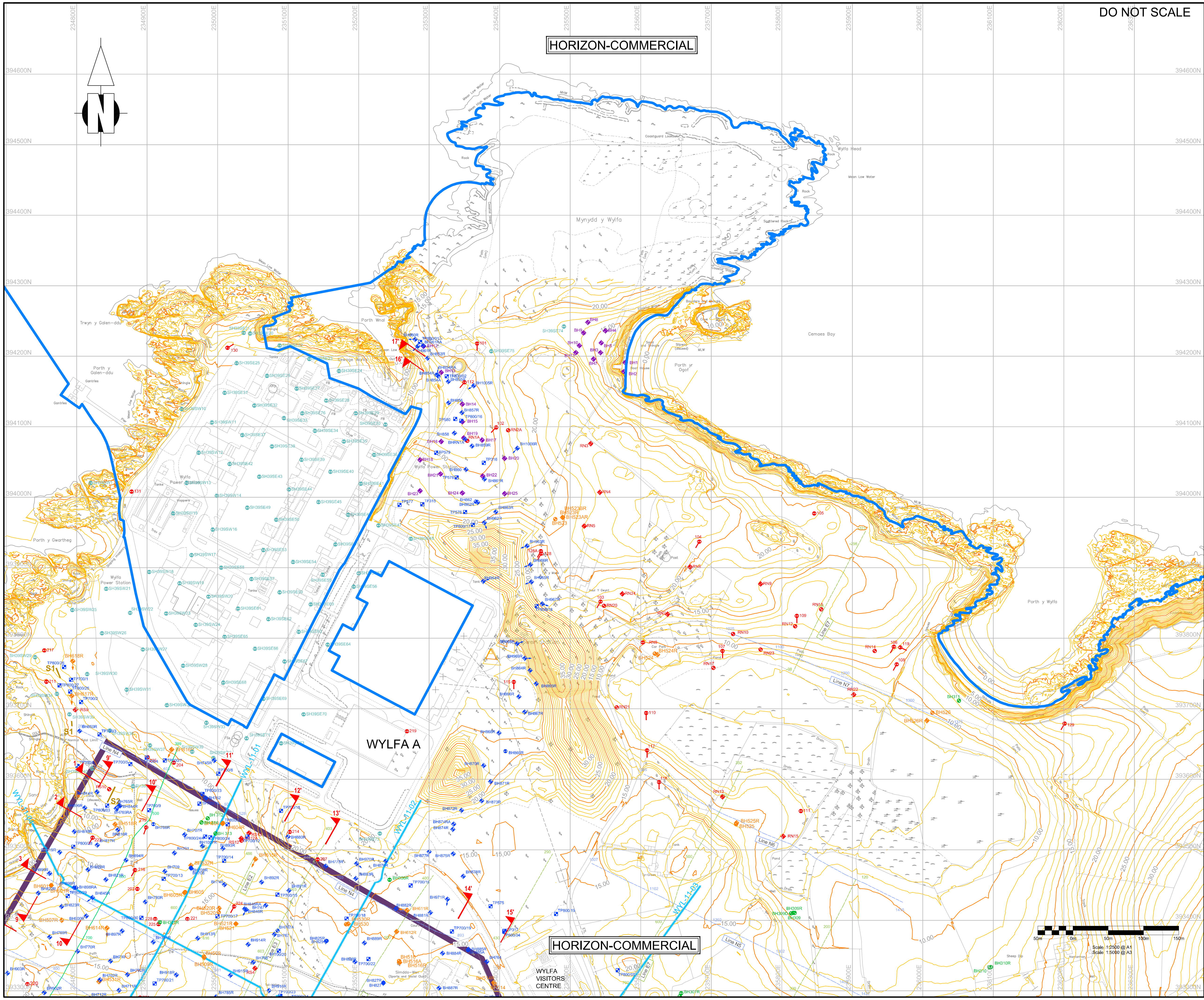
Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

Drawing Title: HISTORICAL AND DOnGI BOREHOLE AND SURFACE GEOPHYSICS LOCATION PLAN

Scale	Designed	Drawn	Checked	Authorised
1:2500	CB	DH	RH	MW
Original Size	Date	Date	Date	Date
A1	07 NOV 14	07 NOV 14	07 NOV 14	07 NOV 14

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0003A

Revision: P 9



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- 2 — 2' — ATKINS SECTION LINE

GEOPHYSICS

- 'S-SERIES' SURVEY LINES (RSK 2014)
- 'E-SERIES' SURVEY LINES (RSK 2014)

HISTORICAL GROUND INVESTIGATION

2011 INTERMEDIATE ONSHORE SITE INVESTIGATION

- WYL-11-04 — SEISMIC REFLECTION SURVEY LINES
- 'N-SERIES' SURVEY LINES (RSK 2011)
- 'E-SERIES' SURVEY LINES (RSK 2011)
- BH6xxR — IOnGI BOREHOLE
- BH6xxR — IOnGI INCLINED BOREHOLE (Arrow gives azimuth of hole, all inclined at 55° from horizontal)

2009 PRELIMINARY SITE INVESTIGATION

- BH301 — BOREHOLE (SUFFIX 'R' DENOTES ROTARY CORED HOLE; OTHER SUFFIXES DENOTE REDRILLED HOLES)

HISTORICAL ONSHORE SITE INVESTIGATION

- BH8 — SOIL MECHANICS, 1998 BOREHOLE
- 221/RS12 — WIMPEY, 1987 BOREHOLE
- 224 — WIMPEY, 1987 INCLINED BOREHOLE
- SH...... — WYLFA A BOREHOLE CIRCA. 1959-1964

Rev.	Date	Description	By	Chk'd	App'd
P6	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P5	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P4	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P3	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P2	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P1	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW

Drawing Status: FOR ISSUE

Suitability: S2

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Client: HORIZON NUCLEAR POWER WYLFA LTD

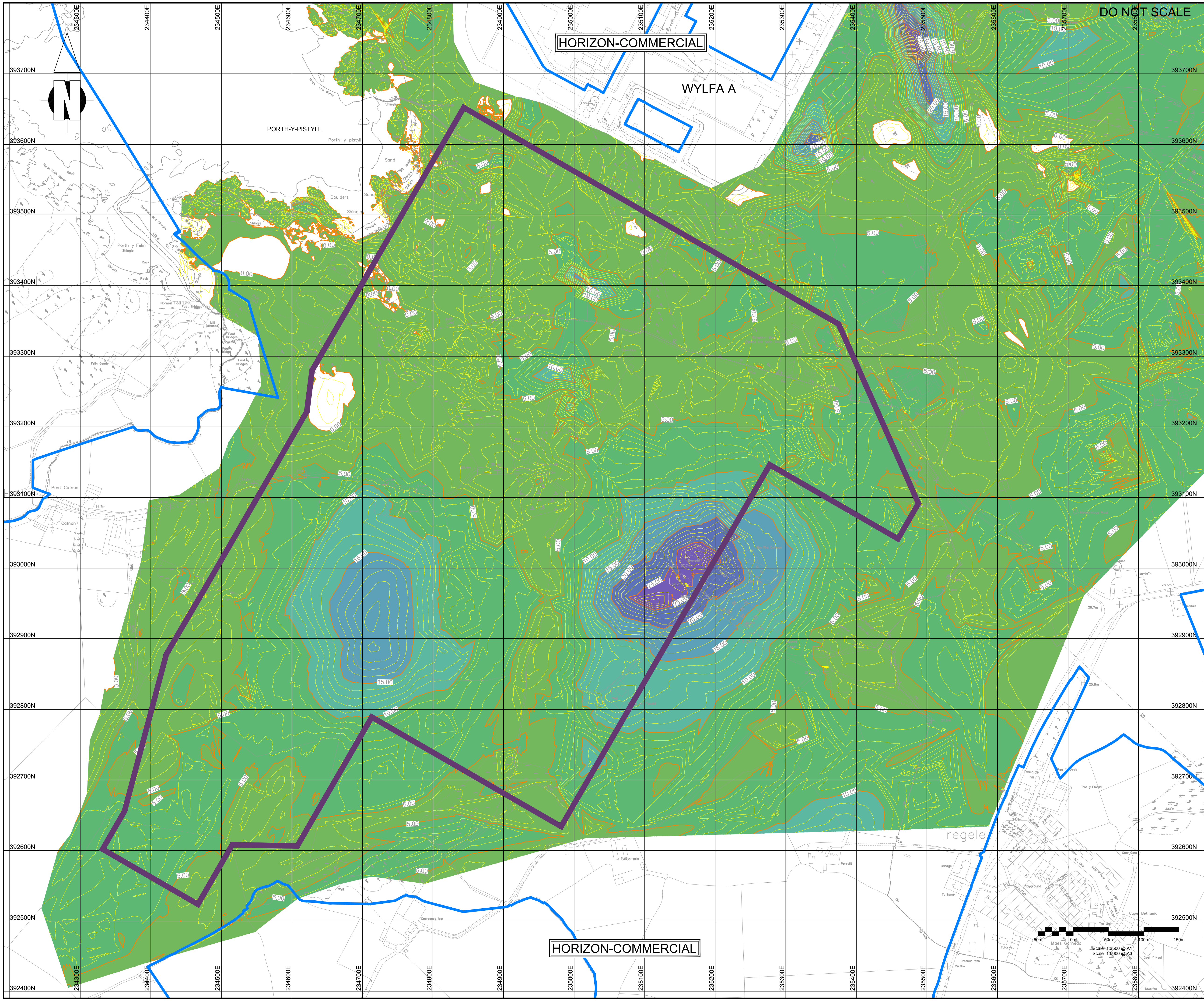
Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

Drawing Title: HISTORICAL AND DOnGI BOREHOLE AND SURFACE GEOPHYSICS LOCATION PLAN

Scale	Designed	Drawn	Checked	Authorised
1:2500	RF	DH	RH	MW
Original Size: A1	Date: 8 MAY 15	Date: 8 MAY 15	Date: 8 MAY 15	Date: 8 MAY 15

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0003B

Revision: P 6



NOTES

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2. Thickness of superficial deposits has been calculated by subtraction of the interpreted rockhead surface (drawing 5130177-ATK-XX-ZZ-DR-C-0006A and 5130177-ATK-XX-ZZ-DR-C-0006B) from the topographic ground surface. Both surfaces are generated by interpolation between points, and as such contain inherent inaccuracies resulting from the averaged surface profile. The thickness of the superficial deposits is therefore subject to the same inaccuracies, true thicknesses may therefore differ from the indicative thicknesses shown on this plan.
3. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

- WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017) (blue line)
- NUCLEAR LICENSED SITE BOUNDARY (purple line)

THICKNESS OF MADE GROUND AND SUPERFICIAL DEPOSITS

MINIMUM THICKNESS (m)	MAXIMUM THICKNESS (m)	COLOUR
0.00	5.00	
5.00	10.00	
10.00	15.00	
15.00	20.00	
20.00	25.00	
25.00	30.00	
30.00	35.00	

Rev.	Date	Description	By	Chk'd	App'd
P8	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P7	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P6	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P5	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P4	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P3	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW
P2	28 NOV 2014	FOR INTERIM GIR	DH	RH	MW
P1	14 NOV 2014	FOR DRAFT INTERIM GIR	DH	RH	MW

Drawing Status: FOR ISSUE

Suitability: S2

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Client: HORIZON NUCLEAR POWER WYLFA LTD

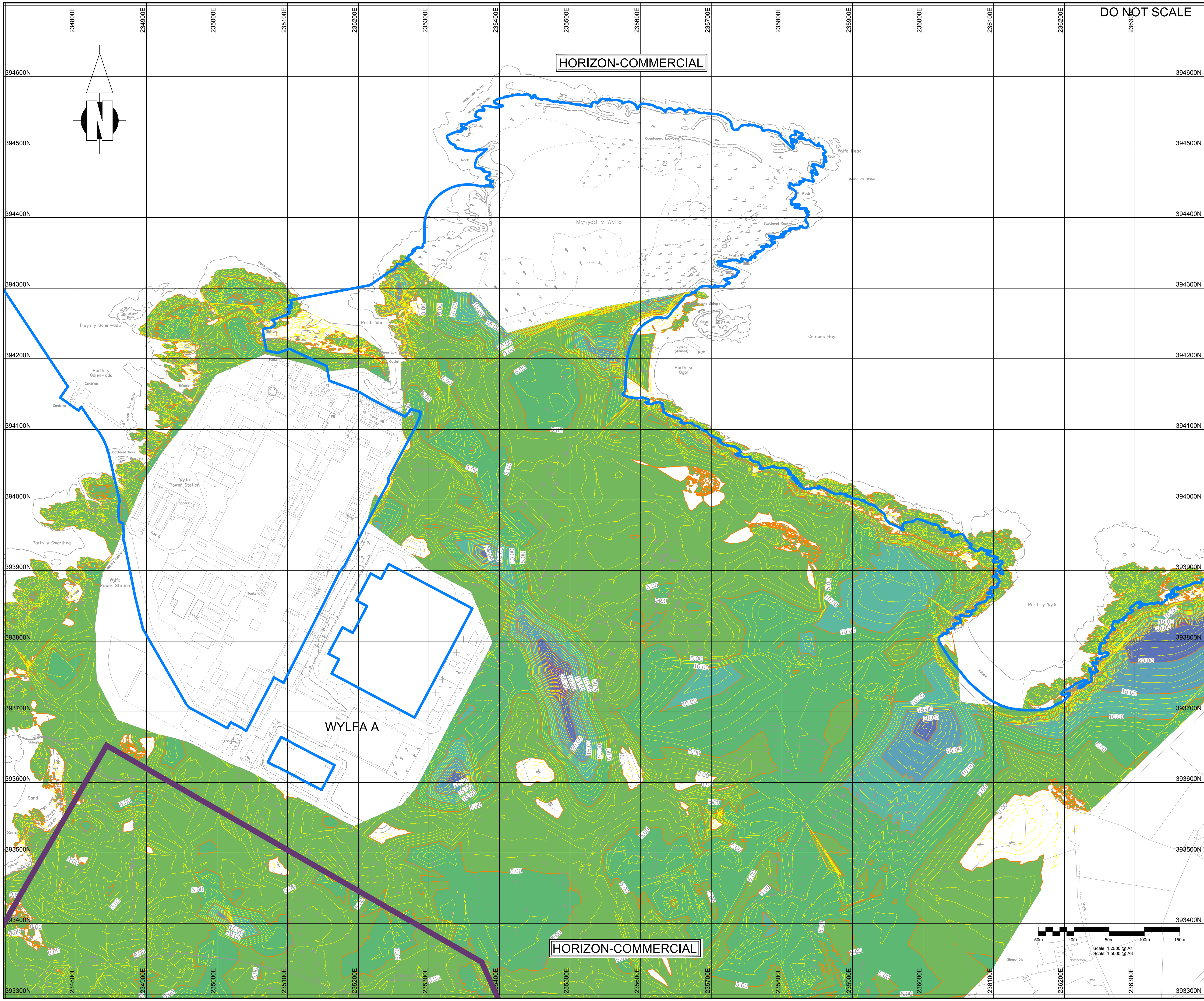
Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

Drawing Title: THICKNESS OF MADE GROUND & SUPERFICIAL DEPOSITS ISOPACHS

Scale	Designed	Drawn	Checked	Authorised
1:2500	CB	DH	RH	MW
Original Size A1	Date 07 NOV 14	Date 07 NOV 14	Date 07 NOV 14	Date 07 NOV 14

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0005A

Revision: P 8



NOTES

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2. Thickness of superficial deposits has been calculated by subtraction of the interpreted rockhead surface (drawing 5130177-ATK-XX-ZZ-DR-C-0006A and 5130177-ATK-XX-ZZ-DR-C-0006B) from the topographic ground surface. Both surfaces are generated by interpolation between points, and as such contain inherent inaccuracies resulting from the averaged surface profile. The thickness of the superficial deposits is therefore subject to the same inaccuracies, true thicknesses may therefore differ from the indicative thicknesses shown on this plan.
3. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

- WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017)
- NUCLEAR LICENSED SITE BOUNDARY

THICKNESS OF MADE GROUND AND SUPERFICIAL DEPOSITS

MINIMUM THICKNESS (m)	MAXIMUM THICKNESS (m)	COLOUR
0.00	5.00	
5.00	10.00	
10.00	15.00	
15.00	20.00	
20.00	25.00	
25.00	30.00	
30.00	35.00	

Rev.	Date	Description	By	Chk'd	App'd
P6	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P5	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P4	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P3	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P2	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P1	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW

Drawing Status: FOR ISSUE
Suitability: S2

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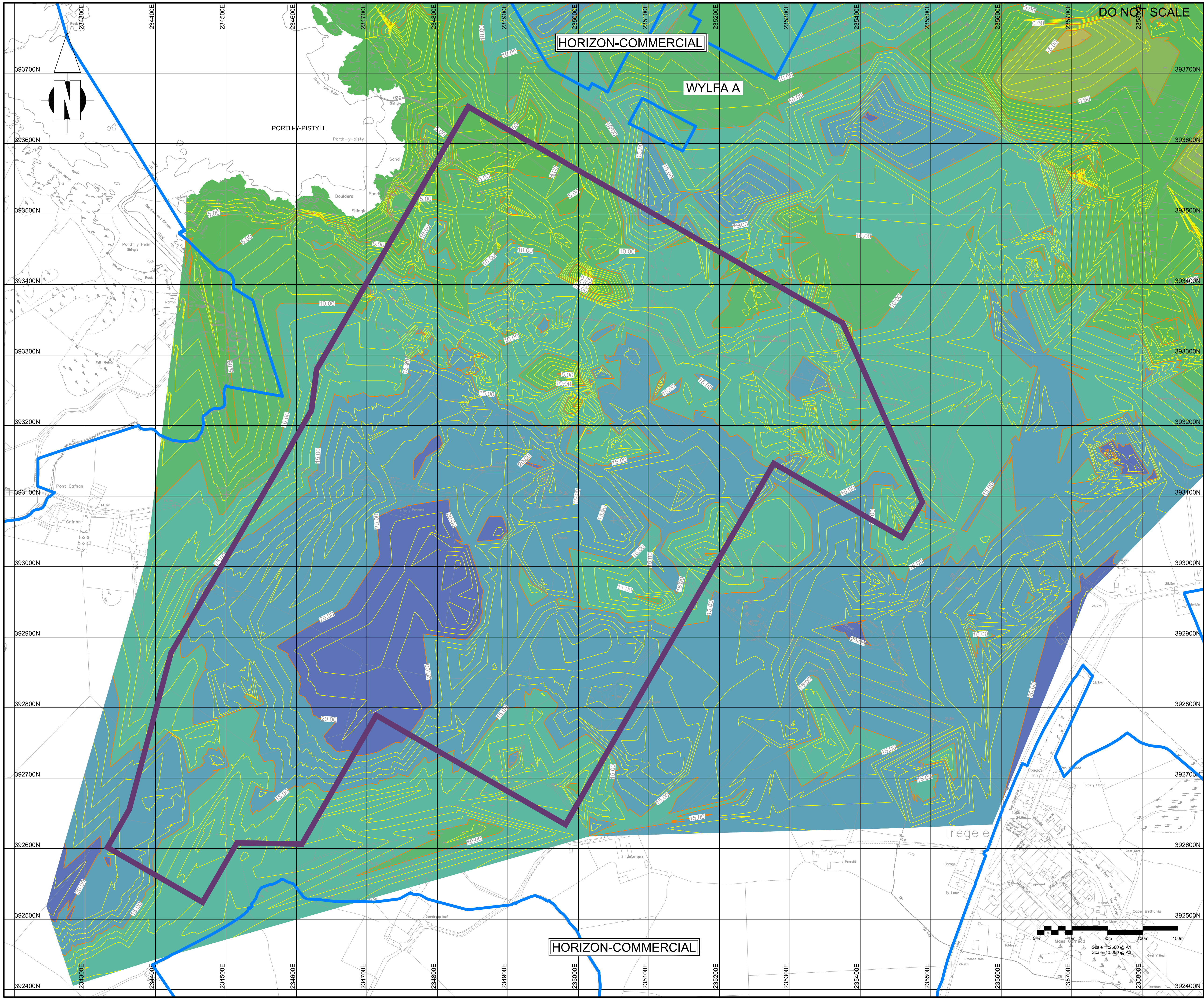
Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

Drawing Title: THICKNESS OF MADE GROUND & SUPERFICIAL DEPOSITS ISOPACHS

Scale	Designed	Drawn	Checked	Authorised
1:2500	RF	DH	RH	MW
Original Size: A1	Date: 8 MAY 15	Date: 8 MAY 15	Date: 8 MAY 15	Date: 8 MAY 15

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0005B
Revision: P 6



NOTES

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2. Rockhead elevation has been contoured from a 3D surface generated from point data sourced from DOnGI boreholes, DOnGI geophysics, and previous GI phases (IOnGI and historical sources, as detailed in Section 4.6 of the Final Interpretative GIR).
3. Several contour anomalies have been identified to the north of the Tre'r Gof SSSI. These anomalies may be due to conflict between borehole data and geophysics data, or may be related to the boundary with the Gwna Group. These anomalies are outside the main construction area, and have therefore not been addressed at this stage.
4. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

- WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017)
- NUCLEAR LICENSED SITE BOUNDARY

ROCKHEAD ELEVATION		
MINIMUM ELEVATION (mOD)	MAXIMUM ELEVATION (mOD)	COLOUR
-15.00	-10.00	
-10.00	-5.00	
-5.00	0.00	
0.00	5.00	
5.00	10.00	
10.00	15.00	
15.00	20.00	
20.00	25.00	
25.00	30.00	
30.00	35.00	

Rev.	Date	Description	By	Chk'd	App'd
P8	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P7	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P6	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P5	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P4	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P3	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW
P2	28 NOV 2014	FOR INTERIM GIR	DH	RH	MW
P1	14 NOV 2014	FOR DRAFT INTERIM GIR	DH	RH	MW

Drawing Status: FOR ISSUE
Suitability: S2

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Client: HORIZON NUCLEAR POWER WYLFA LTD

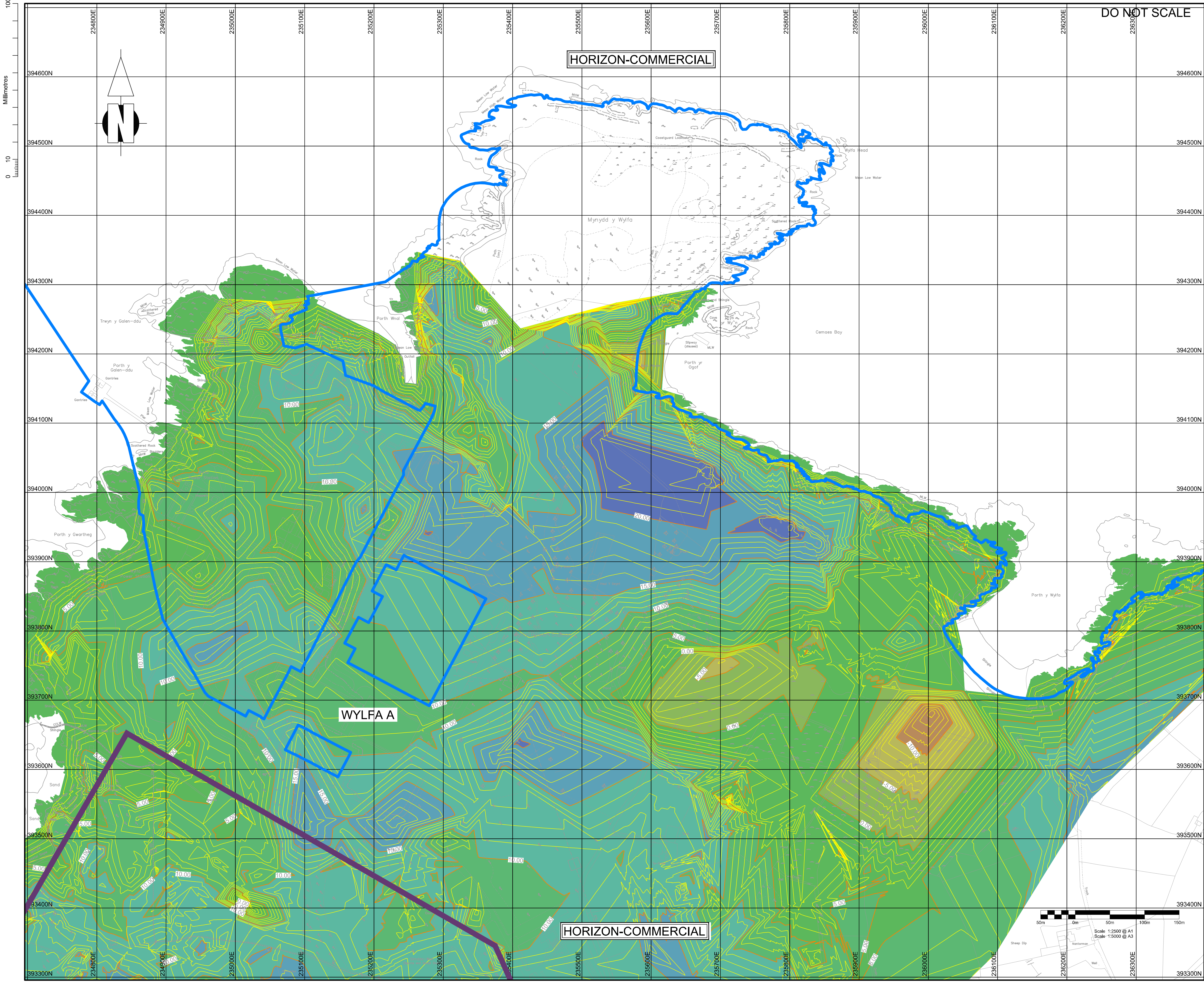
Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

Drawing Title: ROCKHEAD ELEVATION CONTOUR PLAN

Scale	Designed	Drawn	Checked	Authorised
1:2500	CB	DH	RH	MW
Original Size	Date	Date	Date	Date
A1	07 NOV 14	07 NOV 14	07 NOV 14	07 NOV 14

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0006A
Revision: P 8

DO NOT SCALE



NOTES

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2. Rockhead elevation has been contoured from a 3D surface generated from point data sourced from DOnGI boreholes, DOnGI geophysics, and previous GI phases (IOnGI and historical sources, as detailed in Section 4.6 of the Final Interpretative GIR).
3. Several contour anomalies have been identified to the north of the Tre'r Gof SSSI. These anomalies may be due to conflict between borehole data and geophysics data, or may be related to the boundary with the Gwna Group. These anomalies are outside the main construction area, and have therefore not been addressed at this stage.
4. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017)

NUCLEAR LICENSED SITE BOUNDARY

ROCKHEAD ELEVATION		
MINIMUM ELEVATION (mOD)	MAXIMUM ELEVATION (mOD)	COLOUR
-15.00	-10.00	
-10.00	-5.00	
-5.00	0.00	
0.00	5.00	
5.00	10.00	
10.00	15.00	
15.00	20.00	
20.00	25.00	
25.00	30.00	
30.00	35.00	

Rev.	Date	Description	By	Chk'd	App'd
P6	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P5	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P4	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P3	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P2	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P1	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW

Drawing Status: FOR ISSUE

Suitability: S2

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Client

HORIZON NUCLEAR POWER WYLFA LTD

Project Title

WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

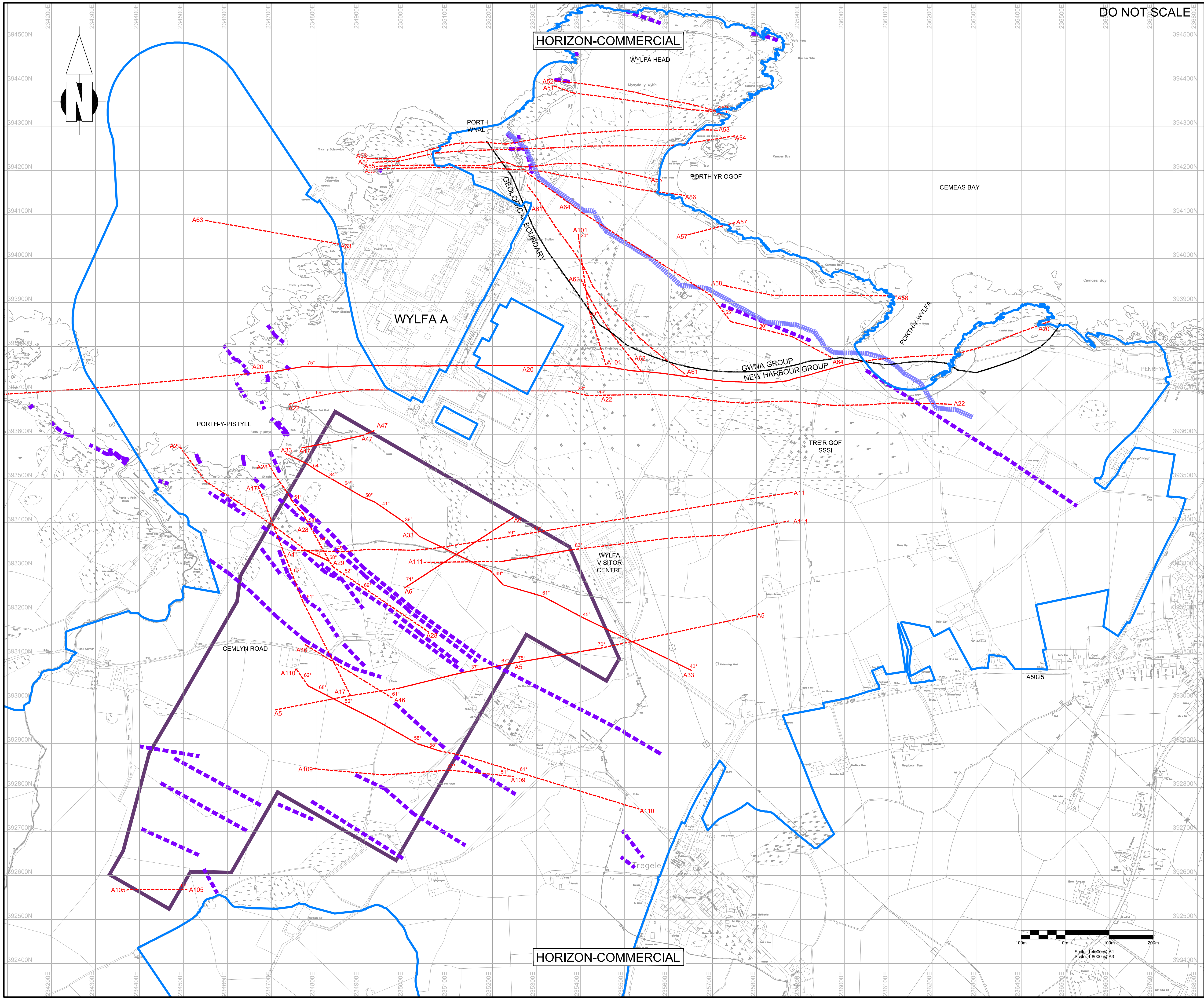
Drawing Title

ROCKHEAD ELEVATION CONTOUR PLAN

Scale	Designed	Drawn	Checked	Authorised
1:2500	RF	DH	RH	MW
Original Size	Date	Date	Date	Date
A1	8 MAY 15	8 MAY 15	8 MAY 15	8 MAY 15

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0006B

Revision: P 6



NOTES

1. OS tiles provided by Horizon Nuclear Power Wylfa Ltd. Reproduced from Ordnance Survey map data by permission of Ordnance Survey, © Crown Copyright OS License 100051118.
2. The alignment of intrusions has been taken from the Halcrow drawing TQHOWA/409 and their model produced at IOnGI stage (WYB0002, Feb 2012). Multiple intrusion intersections have been observed at DOnGI stage; the intrusion model has not been updated for the DOnGI Interpretative GIR stage.
3. Interpreted plan locations of faults and intrusions are shown at 0mOD.
4. A-series faults were identified by Arup & BGS; these were agreed upon in a collaborative meeting with Atkins held on 23rd April 2015.
5. Estimated dip angles for faults have been taken from Appendix C of Arup Report Ref: REP/214898/6/001/Rev 0.1 (22nd May 2015). Estimated fault dip angles are shown on the down dip side of the fault. In reality, such geological features may be curved, or include splays/branches.
6. Faults A59 and A60 are located to the north of Wylfa Head; these faults lie beyond the northern extent of this plan.
7. Arup's assessment of the confidence placed in the fault correlation has been based on the following criteria:
   a. Higher confidence in geological faults correlated between two or more boreholes or trenches and then on to coastal mapping, geophysics etc. (such faults are identified as A-SERIES FAULTS in the Key below); and,
   b. Lower confidence in geological faults correlated between a single borehole or trench and then on to coastal mapping, geophysics etc. (such faults are identified as A-SERIES FAULTS (INFERRED) in the Key below).
8. This drawing should be read in conjunction with Atkins' Final Interpretative GIR 5130177/301/011.

KEY

- WYLFA NEWYDD DEVELOPMENT AREA BOUNDARY (MAY 2017)
- NUCLEAR LICENSED SITE BOUNDARY
- A6 71° A6 — A - SERIES FAULTS (SEE NOTES 3, 4, 5, 6 & 7)
- A17 61° A17 — A - SERIES FAULTS (INFERRED) (SEE NOTES 3, 4, 5, 6 & 7)
- 54° — ESTIMATED DIP SHOWN ON DOWN DIP SIDE
- PALEOZOIC INTRUSIONS (SEE NOTES 2 & 3)
- TERTIARY INTRUSION (SEE NOTES 2 & 3)
- INFERRED GWNA GROUP - NEW HARBOUR GROUP GEOLOGICAL BOUNDARY

Rev.	Date	Description	By	Chk'd	App'd
P8	28 JULY 2017	FOR FINAL INTERPRETATIVE GI REPORT	DH	RH	MW
P7	29 MAY 2017	FOR FINAL INTERPRETATIVE GI REPORT	ATP	RH	MW
P6	29 JAN 2016	FOR FINAL INTERPRETATIVE GIR ISSUE 5.0	DH	RH	MW
P5	24 JULY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 4.0	DH	RH	MW
P4	29 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 2.0	DH	RH	MW
P3	8 MAY 2015	FOR FINAL INTERPRETATIVE GIR ISSUE 1.0	DH	RH	MW
P2	28 NOV 2014	FOR INTERIM GIR	DH	RH	MW
P1	14 NOV 2014	FOR DRAFT INTERIM GIR	DH	RH	MW

Drawing Status: FOR ISSUE

Suitability: S2

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Client: HORIZON NUCLEAR POWER WYLFA LTD

Project Title: WYLFA NEWYDD DETAILED ONSHORE GROUND INVESTIGATION

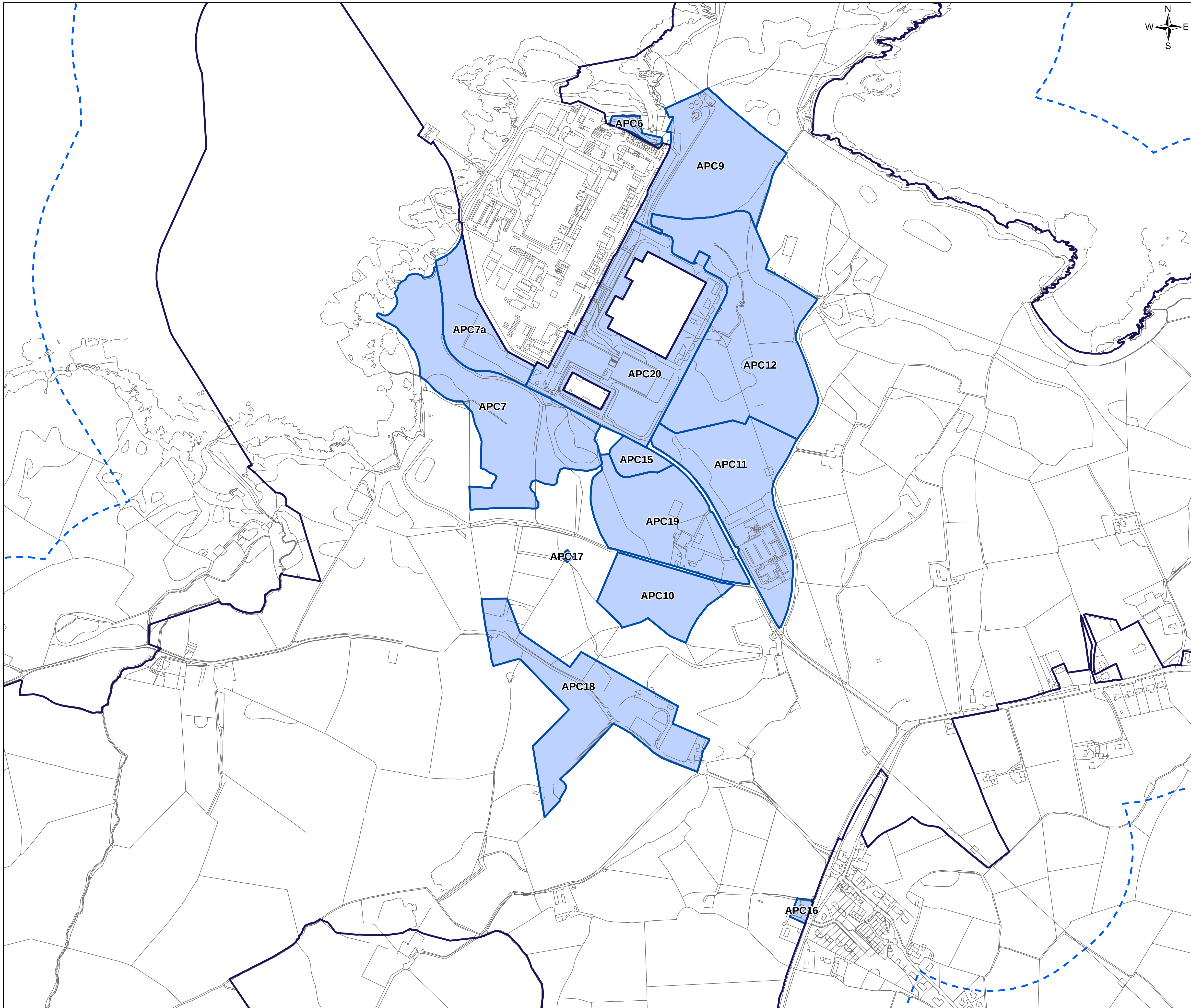
Drawing Title: FAULTS AND INTRUSIONS PLAN

Scale	Designed	Drawn	Checked	Authorised
1:4000	CB	DH	RH	MW
Original Size: A1	Date: 07 NOV 14	Date: 07 NOV 14	Date: 07 NOV 14	Date: 07 NOV 14

Drawing Number: 5130177-ATK-XX-ZZ-DR-C-0007

Revision: P 8

FIGURE 7



Legend

- Wylfa Newydd Development Area
- Study area
- Area of Potential Concern

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	AUG 17	Initial Issue	AD	CC	KY	RB

Client

HORIZON NUCLEAR POWER

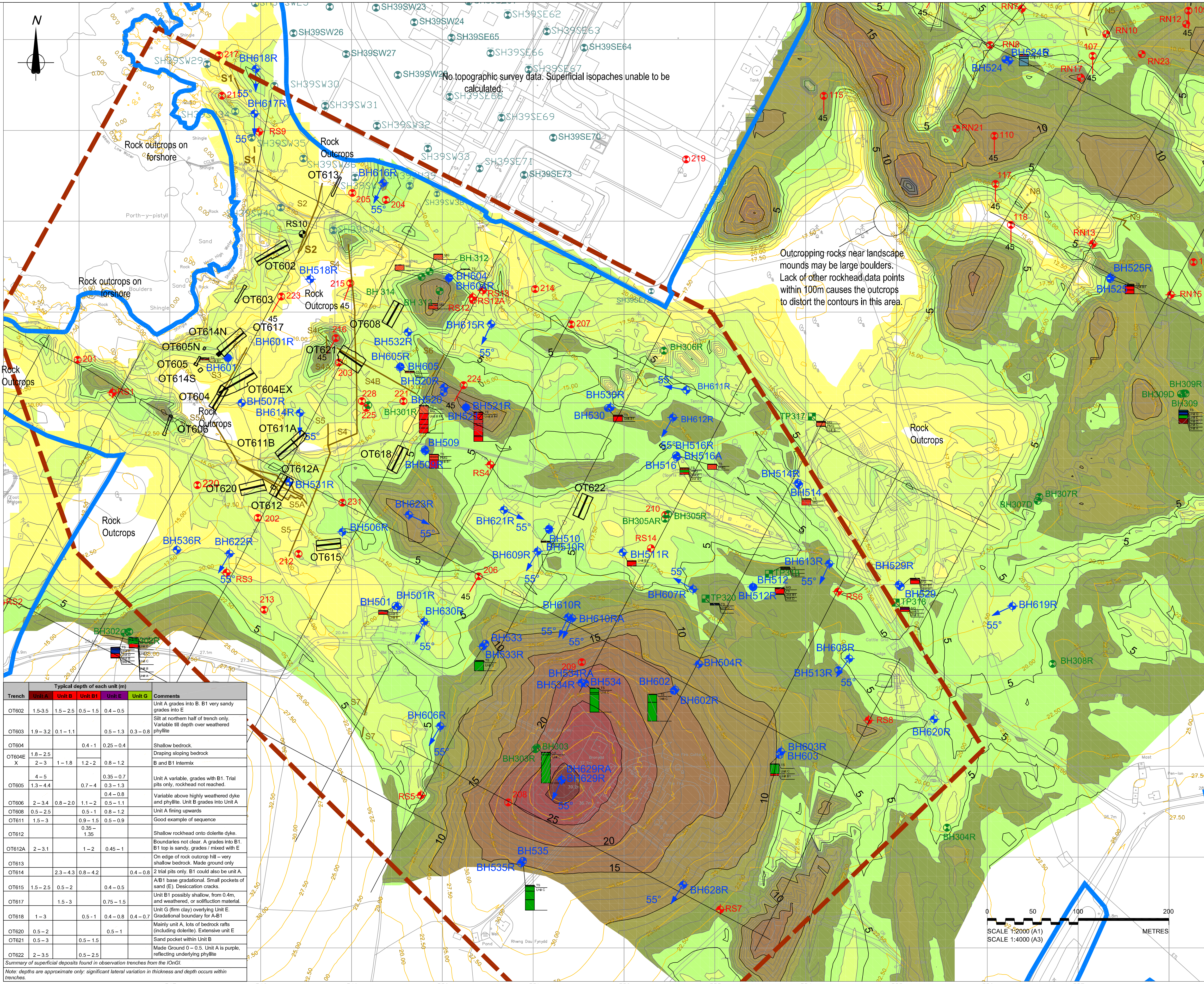
Project

WYLFA NEWYDD PROPOSED NUCLEAR POWER STATION
BASELINE CONDITIONS REPORT

Drawing Title

AREAS OF POTENTIAL CONCERN

Scale @ A3	1:7,500	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		
Drawing No.	60PO8077_DCO_BCR_07	



Trench	Typical depth of each unit (m)					Comments
	Unit A	Unit B	Unit B1	Unit E	Unit G	
OT602	1.5-3.5	1.5 – 2.5	0.5 – 1.5	0.4 – 0.5		Unit A grades into B. B1 very sandy grades into E
OT603	1.9 – 3.2	0.1 – 1.1		0.5 – 1.3	0.3 – 0.8	Silt at northern half of trench only. Variable till depth over weathered phyllite
OT604			0.4 - 1	0.25 – 0.4		Shallow bedrock.
OT604EX	1.8 – 2.5					Draping sloping bedrock
	2 – 3	1 – 1.8	1.2 - 2	0.8 – 1.2		B and B1 intermix
OT605	4 – 5			0.35 – 0.7		Unit A variable, grades with B1. Trial pits only, rockhead not reached.
	1.3 – 4.4		0.7 – 4	0.3 – 1.3		
OT606	2 – 3.4	0.8 – 2.0	1.1 – 2	0.4 – 0.8		Variable above highly weathered dyke and phyllite. Unit B grades into Unit A
				0.5 – 1.1		
OT608	0.5 – 2.5		0.5 - 1	0.8 – 1.2		Unit A fining upwards
OT611	1.5 – 3		0.9 – 1.5	0.5 – 0.9		Good example of sequence
OT612			0.35 – 1.35			Shallow rockhead onto dolerite dyke.
OT612A	2 – 3.1		1 – 2	0.45 – 1		Boundaries not clear. A grades into B1. B1 top is sandy, grades / mixed with E
OT613						On edge of rock outcrop hill – very shallow bedrock. Made ground only
OT614		2.3 – 4.3	0.8 – 4.2		0.4 – 0.8	2 trial pits only. B1 could also be unit A.
OT615	1.5 – 2.5	0.5 – 2		0.4 – 0.5		A/B1 base gradational. Small pockets of sand (E). Desiccation cracks.
OT617		1.5 - 3		0.75 – 1.5		Unit B1 possibly shallow, from 0.4m, and weathered, or solifluction material.
OT618	1 – 3		0.5 - 1	0.4 – 0.8	0.4 – 0.7	Unit G (firm clay) overlying Unit E. Gradational boundary for A-B1
OT620	0.5 – 2			0.5 – 1		Mainly unit A, lots of bedrock rafts (including dolerite). Extensive unit E
OT621	0.5 – 3		0.5 – 1.5			Sand pocket within Unit B
OT622	2 – 3.5		0.5 – 2.5			Made Ground 0 – 0.5. Unit A is purple, reflecting underlying phyllite

Summary of superficial deposits found in observation trenches from the IOnGI.

Note: depths are approximate only: significant lateral variation in thickness and depth occurs within trenches.

PROTECT – COMMERCIAL

Notes

1. OS background provided by Horizon Nuclear Power. Reproduced from Ordnance Survey map data by permission of Ordnance Survey, © Crown copyright.
2. Due to the complex and variable geological conditions present at the site, the superficial isopaches should be considered as indicative.
3. See drawing TQHOWA/404 for key to data sources and TQHOWA/405 for rockhead contours.

Data Sources

Intrusive Investigations

1. Wylfa New Build. Report on Intermediate Onshore Ground Investigation (IOnGI). (Structural Soils, 2011)
2. Wylfa New Build. Preliminary Ground Investigation Factual Report (Structural Soils, 2010). Report No. 761404
3. C.E.G.B. Wylfa B Pre-Application Studies. Site Investigation Contract WYB/C2.3. Report on Site Investigation (Wimpey, 1987)
4. Magnox Electric PLC. Porth Yr Ogof CCGT Power Station. Residual Ground Risk Report (Allott and Lomax, 1998). Rockhead contour interpretation. Contours based on borehole data from Ground Investigation for Porth Yr Ogof CCGT (BL / E / 57431) Factual Report (Soil Mechanics, 1998)
5. Analysis of Groundwater Conditions, Wylfa Power Station. (Aspinwall & Co., 1996). Wylfa A Power Station bedrock levels.

Geophysical Surveys

1. Wylfa New Build. Report on Intermediate Onshore Ground Investigation (IOnGI). Appendix C1 (Structural Soils, 2011)
2. C.E.G.B. Wylfa B Pre-Application Studies. Geophysical Survey. (Wimpey, 1985). Note: geophysical lines in close proximity to boreholes or trial trenches not included as source data.
3. Wylfa Power Station Preliminary Nearshore Geophysical Investigation. Volume 2: Results Report (CS0257/R2/V1). (Titan Environmental Surveys, 2010).

Rock Outcrops

1. C.E.G.B. Generation Development and Construction Division. Wylfa B Pre-Application Studies. Interim Report. Geological mapping of outcrops. (Allott and Lomax, 1987)
2. Wylfa B Power Station. Site topographic survey (Williamson Technical Services, 2010)

Processing

1. Each point on the 10m gridded rockhead surface model (see drawings TQHOWA404_rev 2 and TQHOWA405_rev 2) was draped over the ground surface model to derive a ground elevation vertically above each rockhead point. The isopach model was created from the difference between these two models.

Key

Main construction platform

Nominated land boundary

Borehole Legend

- Topsoil
- Made Ground
- Unit A
- Unit B / B1
- Unit C
- Unit D
- Unit E
- Unit F

Isopaches of Made Ground and Superficial Deposits (m)

- 0 to 2m
- 2 to 4m
- 4 to 6m
- 6 to 8m
- 8 to 10m
- 10 to 15m
- 15 to 20m
- 20 to 25m
- 25 to 30m
- 30 to 35m

1m Superficial isopaches

5m Superficial isopaches

2.5m Ground surface contour

Borehole Depth (m): 0, 10, 20, 30

Rev	By	Chkd	Apprvd	Date	Description
3	PK	GSG	GFGG	27/02/2012	SCALE AND TEXT SIZE REVISED. GRID COORDINATES ADDED
2	SH	GSG	GFGG	01/02/2012	FINAL REPORT ISSUE. DRIFT ISOPACHES RECONTOURED FOLLOWING UPDATE TO ROCKHEAD MODEL.
1	SH	GSG	GFGG	23/12/2011	FINAL REPORT ISSUE. TABLE BORDER ADDDED.
0	SH	GSG	GFGG	09/11/2011	DRAFT REPORT ISSUE

Client

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A CH2M HILL COMPANY
Halcrow

Project

WYLFA NEW BUILD

Drawing

INTERMEDIATE ONSHORE GROUND INVESTIGATION ISOPACHES ON MADE GROUND & SUPERFICIAL DEPOSITS

Drawn by : SH — Date : 23/12/2011

Checked by : GSG — Date : 23/12/2011

Approved by : GFGG — Date : 23/12/2011

Drawing No. TQHOWA406 — Revision 3

Drawing Scale : 1:2000 at A1

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