# Awel y Môr Offshore Wind Farm

# Category 6: Environmental Statement

## Volume 5, Annex 7.3 Landfall Trenchless Crossing Works HDD

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# LANDFALL TRENCHLESS CROSSING WORKS (HDD)

**Groundwater Risk Assessment**

Prepared for: Awel y Môr Offshore Wind Farm Limited

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# BASIS OF REPORT

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## APPENDICES

# 1.0 Introduction

This groundwater risk assessment assesses the potential impact of the trenchless crossing works that will be used to install cables beneath the North Wales Main Line railway, Robin Hood Bay Caravan Park, Rhyl Golf Club and the proposed East Rhyl Coastal Defence scheme as part of the landfall arrangements for Awel y Môr Offshore Wind Farm (AyM OWF).

This report has been prepared in response to feedback received from Natural Resources Wales (NRW) following statutory consultation, under Section 42 of the Planning Act 2008, which ran from 31 August to 11 October 2021. Within it's response to statutory consultation NRW requested that a groundwater risk assessment should be completed for each major Horizontal Directional Drilling (HDD) crossing associated with the onshore elements of AyM to ensure that all risks are assessed, and any mitigation measures are outlined and implemented during construction and operation. The Major HDD crossings proposed for the onshore elements of AyM are:

- The crossing at landfall required to pass beneath the North Wales Main Line railway, Robin Hood Bay Caravan Park, Rhyl Golf Club and the proposed East Rhyl Coastal Defence scheme (The Landfall HDD crossing);
- The crossing of the A525;
- The crossing of the Afon Clwyd; and
- The crossing of the A55.

This report provides the groundwater Risk Assessment for the Landfall HDD. The Landfall denotes the location where the offshore export cables are brought ashore and jointed to the onshore export cables in Transition Joint Bays (TJBs). The export cables will be installed beneath the North Wales Main Line railway, Robin Hood Bay Caravan Park, Rhyl Golf Club using HDD (or other suitable alternative trenchless techniques such as micro-tunnelling). TJBs would be located to the south of the railway and the likely HDD process would be to drill from the works area located to the south of the railway, which will contain the HDD entry pits, in a northerly direction to HDD exit pits that would be located in the intertidal or shallow subtidal zone (between Mean High Water Spring (MHWS) and 1000m seaward of MHWS). The indicative maximum depth for the HDD would be 20m below ground level.

Further details on the Project infrastructure, installation methodologies and programme can be found in Volume 3, Chapter 1: Onshore Project Description (application ref: 6.3.1) of the Environmental Statement (ES).

This report has been informed by the following ES chapters and technical reports:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (application ref: 6.2.3);
- Volume 3, Chapter 1: Onshore Project Description (application ref: 6.3.1);
- Volume 3, Chapter 5: Onshore Biodiversity and Nature Conservation (application ref: 6.3.5);
- Volume 3, Chapter 6: Ground Conditions and Land Use (application ref: 6.3.6);
- Volume 3, Chapter 7: Hydrology, Hydrogeology and Flood Risk (application ref: 6.3.7);
- Volume 4, Annex 3.1: Water Framework Directive Assessment (application ref: 4.3.1);
- Volume 8, Document 13.1 Outline Code of Construction Practice (application ref: 8.13.1).

This groundwater risk assessment:

- Describes the existing baseline established from desk studies, dedicated surveys and consultation;

- Outlines the potential environmental effects on groundwater receptors arising from the HDD process including groundwater abstractions, groundwater dependent ecological sites and groundwater fed surface water features;
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental impact.

The effects considered in this chapter include those on the hydrological and hydrogeological receptors that form part of the onshore and coastal environment.

# 2.0 Study Area, Baseline Data and Methodology

## 2.1 Study area

The study area for the landfall HDD crossing is shown on Figure 1. Buffer zones of 250 – 500 m from the Order Limits that encompass the Landfall area have been considered appropriate for data collection taking into account the nature of the development and likely zone of influence on hydrological and hydrogeological receptors whilst also allowing for refinement in final location and alignments of onshore infrastructure following detailed design (post consent).

## 2.2 Baseline data

Baseline data with respect to hydrogeology, hydrology and ecology has been taken from publicly available information and opensource data from a range of sources. The data review includes assessing the following:

- Lle Geo-Portal, Welsh Government and Natural Resources Wales (NRW):
  - Main Rivers;
  - Historic and active landfill sites;
  - Statutory and non-statutory environmental designations;
  - Water Framework Directive (WFD) surface water and groundwater classification data; and
  - Groundwater Source Protection Zones (SPZ).
- British Geological Survey (BGS) GeoIndex mapping:
  - Geology – artificial ground, mining, superficial deposits, bedrock;
  - Borehole data; and
  - Aquifer designation and groundwater vulnerability.
- Department for Environment, Food and Rural Affairs (DEFRA) MAGIC website:
  - Statutory and non-statutory environmental designations.
- Cranfield Soil and Agrifood Institute Soilscapes map viewer:
  - Soil type and character.
- North West and North Wales Coastal Group:
  - North West England and North Wales Shoreline Management Plan SMP2; and
  - Denbighshire County Council (DCC): Local Development Plan.

Third party data from bodies such as DCC and NRW has been used to characterise the sensitivity of water features and identify any water dependent designated areas.

Preparation of the groundwater risk assessment has also included data requests and consultation with a number of stakeholders and regulatory bodies that were performed for the production of the Hydrology and Hydrogeology ES chapter. The information and data requested includes:

- NRW - Licenced abstractions, surface water quality, WFD classification data, permitted activities and recorded pollution events.
- DCC - Registered private water supplies in proximity to the onshore Export Cable Corridor (ECC).

## 2.3 Methodology

This groundwater risk assessment has been developed in accordance with relevant Environment Agency (EA)/NRW guidance on completion of groundwater risk assessments and Hydrogeological Impact Appraisals (HIA) and includes the following stages:

- Section 3 provides a baseline assessment of the site. This includes a summary of the site geology and hydrogeology including information on ground conditions, groundwater levels and flows, groundwater quality and the location of potential receptors which could be impacted as a result of construction activities at the site. In addition, a Conceptual Site Model (CSM) of the current hydrogeological regime is provided.
- Section 4 provides an assessment of the potential impact that the Landfall HDD works could have upon the identified receptors and regional hydrogeology and hydrology. Appropriate mitigation measures are outlined where required.
- Section 5 provides a summary of the overall impact that the Landfall HDD works could have upon the local hydrogeology and any identified receptors.

A qualitative risk assessment methodology has been used to assess the potential significance of impact associated with the Landfall HDD works. Two factors are considered using this approach: the sensitivity of the receiving environment and the magnitude of any potential impact. This approach provides a mechanism for identifying whether additional mitigation measures are potentially required to reduce the risk to groundwater or hydraulically connected surface water receptors.

# 3.0 Conceptual Site Model

The geological, hydrogeological and hydrological regime in the vicinity of the Landfall HDD works area is considered under the following headings: location and topography, geological setting and hydrogeological setting, all of which have been used to develop the CSM.

## 3.1 Site Context

The coastal area is between the relatively densely populated settlements of Rhyl and Prestatyn. Pedestrian footpaths are present directly adjacent to the beach, as is a golf course and caravan park. Man-made sea-defences including imported rocks are present, along with groynes which serve shingle and sand beaches.

Land to the east of Rhyl and west of Prestatyn is predominantly agricultural, low-lying land with a network of drainage ditches. Hedgerows and woodland are relatively scarce and limited to field boundaries.

There is an active railway line running approximately parallel to the coastline between the settlements of Rhyl and Prestatyn.

A site context plan is provided as Figure 1.

## 3.2 Geology

### 3.2.1 Soil and Superficial Deposits

The Cranfield Soil and Agrifood Institute Soilscapes online mapping service indicates that there are variable soil types within the study area for this groundwater risk assessment:

- Sand dune soils border the coastline northwards of the trainline. These are considered freely draining.
- Loamy and clayey soils of coastal flats with naturally high groundwater are indicated to be present southwards of the trainline. This soil type is mapped as extending from Rhyl Coast Road to slightly southwards of the Rhyl Cut Watercourse.
- Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils with impeded drainage are indicated to be southwards and inland of the above.

From examination of both the geological map (Geological Survey of Great Britain (1973 and 1985) 1:50,000 Series Solid and Drift Geology Map England and Wales, Sheet 107 – Denbigh, the following deposits are evident. The superficial geology is presented on Figure 4.

Superficial deposits at the beach are mapped as sand. This becomes predominantly blown sand moving inland and beneath the HDD exit pit area.

Within the study area clay, silt and sand tidal flat deposits form the majority of superficial deposits underlying the railway and the southern trenchless crossing compound.

The sands and Tidal Flat Deposits are underlain by diamicton till which extend across the regional area. These deposits typically consist of boulder clay.

Small, disconnected outcrops of glaciofluvial deposits are also present. These occur sporadically directly inland from the raised marine deposits and are not present within the working area.

Historic BGS borehole records within the vicinity of the proposed landfall HDD works are included as Appendix 01 and indicate that layered clayey and sandy superficial deposits underlying the proposed landfall HDD works. The depth of these deposits is unclear across the whole study area, but historic BGS logs suggest they are typically in excess of 10 m, and potentially up to 20 m in thickness.

### 3.2.2 Bedrock

Bedrock at the proposed location for the Landfall HDD works is mapped by the BGS, and presented on Figure 3, as the Kinnerton Sandstone Formation. This sandstone formation of dominantly aeolian origin is described as '*typically red-brown to yellow, generally pebble free, fine- to medium grained, and cross-stratified*'.

Historic BGS borehole logs indicate that the Sandstone underlying the proposed landfall HDD installation is likely to be in excess of 200 m deep.

The geological setting of the AyM onshore infrastructure and ground conditions is further described within ES Volume 3, Chapter 6: Ground Conditions and Land Use (application ref: 6.3.6).

## 3.3 Hydrogeology

### 3.3.1 Recharge

Met Office Climate Averages (1991-2020) for Rhyl (53.259, -3.509) indicate that the study area has a moderately high average annual rainfall value of 828 mm. Monthly and annual climate averages are provided in Table 3-1.

**Table 3-1-**
**Rhyl Climate Averages (1991-2020)**

| Month | Maximum temperature (°C) | Minimum temperature (°C) | Rainfall (mm) | Days of rainfall ≥1 mm (days) |
|---|---|---|---|---|
| January | 8.05 | 2.85 | 74.17 | 14.50 |
| February | 8.39 | 2.90 | 61.68 | 11.83 |
| March | 10.14 | 3.86 | 52.20 | 11.14 |
| April | 12.63 | 5.34 | 49.06 | 10.27 |
| May | 15.62 | 7.70 | 52.16 | 9.77 |
| June | 18.16 | 10.50 | 60.26 | 9.60 |
| July | 19.84 | 12.47 | 62.96 | 11.17 |
| August | 19.50 | 12.41 | 68.90 | 11.83 |
| September | 17.48 | 10.58 | 72.92 | 11.10 |
| October | 14.17 | 8.06 | 89.31 | 13.57 |
| November | 10.83 | 5.40 | 88.23 | 15.97 |
| December | 8.57 | 3.25 | 96.60 | 16.17 |
| **Annual** | **13.64** | **7.13** | **828.45** | **146.92** |

Based on the soils and superficial deposits present beneath the proposed Landfall HDD route recharge rates are likely to be relatively high to the north of the railway line (in vicinity of the HDD exit pit area) where the soils are classified as freely draining with relatively high permeability sand deposits beneath.

To the south of the railway line recharge will be impeded by the poorly draining clayey soils which are likely to promote surface water run-off to nearby watercourses and drains.

### 3.3.2 Hydrogeological Setting

The aquifer characteristics and BGS/NRW aquifer designation of the strata within the immediate vicinity of the works are summarised in Table 3-2-.

**Table 3-2-**
**Aquifer Designations**

| Deposit Type | Age | Formation | Aquifer Designation |
|---|---|---|---|
| Superficial | Quaternary | Marine Beach Deposits / Blown Sand | Secondary A |
| | | Tidal Flat Deposits | Secondary (undifferentiated) |
| | | Diamicton Till | Secondary (undifferentiated) |

| Deposit Type | Age | Formation | Aquifer Designation |
|---|---|---|---|
| Bedrock | Triassic | Kinnerton Sandstone Formation | Principal |

The various classifications are described by the EA as follows:

- Principal Aquifer: 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.
- Secondary A Aquifer: permeable layers that can support local water supplies, and may form an important source of base flow to rivers.
- Secondary B Aquifer: lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin fissures and opening or eroded layers.
- Secondary (undifferentiated): where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value.
- Unproductive Strata: strata that are largely unable to provide usable water supplies and are unlikely to have surface water and wetlands ecosystems dependent on them.

The superficial deposits are all classified as secondary aquifers however due to the typically clayey nature of the tidal flat deposits and diamicton it is considered that these will typically act as a barrier to groundwater flow, potentially allowing for a perched aquifer within the overlying sands (where present).

The proximity of the beach deposits / blown sands to the coast makes it unlikely that these deposits will act as a significant resource as any groundwater will likely be in hydraulic continuity with the coast and therefore be highly saline.

Due to the variable composition of the tidal flat deposits and diamicton deposits within the study area, lenses of higher permeability may support perched water tables. These are likely to be discontinuous and limited in extent and as such have limited groundwater potential.

Groundwater beneath the study area for this groundwater risk assessment is present within the Principal bedrock aquifer of the Kinnerton Sandstone Formation. It is expected that the sandstone has moderately high transmissivity and groundwater hydraulic conductivity values.

The nearest available information on depth to groundwater within the sandstone is at BGS borehole SJ08SW1 in Rhyl (approximately 2.5 km west of the study area) indicating groundwater 10 m below ground level, likely to be confined by overlying diamicton.

The Kinnerton Sandstone Formation forms part of the Clwyd Permo-Triassic Sandstone WFD groundwater body.

### 3.3.3 Abstractions

NRW have indicated that there is one licensed abstraction located within a 2 km radius of the Landfall HDD works, this appears to be the same location as a private water supply, information for which was provided by DCC. Details of the abstraction are outlined in Table 3-3-.

**Table 3-3-**
**Private Water Abstractions**

| ABstraction Type | Location | Usage |
|---|---|---|
| Borehole (Sandstone) | NGR 303143, 381385 (c. 500m SW) | Drinking water for Caravan Park |

The location of the above private water abstraction is also provided on Figure 4. It is understood that the supply is abstracting from the bedrock Kinnerton sandstone aquifer.

No groundwater Source Protection Zones (SPZs) are noted within the study area.

## 3.4 Hydrology

The Landfall site is located at Ffrith Beach, on the coastline between Rhyl and Prestatyn. The Irish Sea extends northwards from the coast.

NRW main rivers within the vicinity of the landfall HDD works include:

### 3.4.1 Rhyl Cut

The Rhyl Cut is a main river watercourse that runs parallel to the coast from the outskirts of Prestatyn, taking flows from Prestatyn Gutter. The watercourse flows west across agricultural land to the south of the North Wales Main Line railway, through the centre of Rhyl and discharges to the Clwyd Estuary approximately 1.5 km upstream of the estuary mouth. The onshore ECC crosses the Rhyl Cut on agricultural land to the east of Rhyl, with an upstream catchment of approximately 6.5 $km^2$ from this point.

The proposed HDD works are likely to be northwards and eastwards of the Rhyl Cut, but in relatively close proximity. The Rhyl Cut flows directly south of the proposed trenchless crossing compound closest to the coastline.

Westwards of the proposed HDD works there is the Rhyl Cut Pump House Leg. This flows within the Order Limits for the project and meets the Liverpool Bay SPA to the north.

The Rhyl Cut also appears to be fed by the Pydew Drain North and Pydew Drain South. These drains are located south eastwards of the proposed HDD works, with the Pydew Drain North located c.200-250 m eastwards of the proposed Onshore ECC at its closest point.

The Rhyl Cut primarily underlain by tidal flat deposits which are typically low permeability and will provide limited surface water baseflow.

### 3.4.2 Aberkinsey Drain

Agricultural land to the southeast of Rhyl is served by Aberkinsey Drain main river, which flows northwards from Glanffyddion Stream, through the east of Rhyl where it joins the Rhyl Cut (via Maes Gwilym Drain). The onshore ECC crosses Aberkinsey Drain on agricultural land to the southeast of Rhyl, with a small upstream catchment of approximately 0.5 $km^2$ from this point.

This drain is also underlain by tidal flat deposits and therefore it is anticipated that there will also be a limited groundwater baseflow component to this watercourse.

### 3.4.3 Non-main river watercourses

There are a number of existing field drains, ditches and irrigation channels to the south of the proposed HDD works. The majority of the surface water channels crossed are non-main river and form tributaries to the watercourses detailed above. These features are detailed in Figure 4.

The majority of these watercourses are located on low permeability tidal flat deposits with limited groundwater baseflow component.

### 3.4.4 Water Quality

Surface water quality is measured as part of the WFD classifications for main rivers. The WFD Cycle 2 (2018 Interim) Status of waterbody catchments within the study area for the onshore elements of AyM are presented in the ES at Volume 3, Chapter 7: Hydrology, Hydrogeology and Flood Risk (application ref: 6.3.7). The landfall HDD does not fall within an assessed WFD Cycle 2 (2018 Interim) river waterbody area. -

The landfall HDD is located within the Clwyd Permo-Triassic Sandstone WFD groundwater unit. This was assessed in 2015 as having a good overall, quantitative and chemical status.

The coastal waters are also monitored as the North Wales coastal waterbody and the Clwyd transitional waterbody, both of which have moderate overall classification and moderate ecological status. With regard to chemical status, the North Wales coastal waterbody fails and the Clwyd transitional waterbody is classified as good.

Based on 2021 data, bathing water quality at Abergele and Rhyl East is given a 'good' quality classification and bathing water at Rhyl and Maine Lake, Rhyl is given a 'sufficient' quality classification. Further east of landfall, the bathing water quality at Prestatyn is classified as Excellent. These results mean that the waters meet the criteria for the stricter UK guideline standards of the European Bathing Water Directive (see EIA Volume 2, Chapter 3 and Volume 4, Annex 3.1 for further details).

There are no recorded 'significant' pollution incidents within the study area.

## 3.5 Ecologically Designated sites

There are no hydrologically designated sites within the study area for this groundwater risk assessment. Watercourses designated for their ecological interest are identified in EIA Volume 3, Chapter 5 (application ref: 6.3.5).

The Liverpool Bay is designated as a Special Protection Area (SPA), with the designation boundary located approximately 450 m seaward of MHWS (and within which the area where the HDD exit pits could be located). The site qualifies under the Birds Directive (2009/147/EC) for a number of Annex 1 and migratory bird species. Liverpool Bay SPA therefore influences the sensitivity of the near-shore coastal waters which are included as a potentially sensitive environmental receptor.

## 3.6 Conceptual Site Model Summary

The assessment of the baseline conditions of the Landfall HDD Crossing Works indicate that the proposed crossing area is underlain by a Principal Kinnerton Sandstone Formation aquifer which has the potential to provide significant groundwater flows for abstractions or baseflow to watercourses.

Within the vicinity of the trenchless crossing works these are overlain by up to 20 m of typically low permeability till and tidal flat deposits which are likely to confine the underlying sandstone aquifer.

The proposed HDD works will drill to a maximum depth of 20 m below ground level, there is therefore the potential that the drilling will encounter the Kinnerton sandstone aquifer, although this is uncertain.

The superficial deposits have the potential for limited groundwater flow within any sandy horizons however these tend to be variable and unconnected and are therefore unlikely to provide significant flows for either abstractions or surface water baseflow.

To the north of the railway line the tidal flat deposits are overlain by blown sand which will potentially form a shallow perched groundwater system, however given the proximity to the coast is likely to be in hydraulic continuity with the sea and therefore be highly saline.

One groundwater abstraction has been identified, approximately 500 m south-west of the proposed works, abstracting groundwater from the Kinnerton Sandstone Formation aquifer.

There are several drains and main rivers located within the vicinity of the crossing, notably to the south of the railway line. These are all located on tidal flat deposits and are not considered to be groundwater fed.

No groundwater dependent ecological sites have been identified within proximity of the Landfall HDD crossing works.

# 4.0 Hydrogeological and Hydrological Impact Assessment

A description of the proposed HDD activity at the Landfall location is provided in the ES, Volume 3, Chapter 1: Onshore Project Description (application ref: 6.3.1).

The potential impact of the proposed HDD trenchless crossing on groundwater receptors are outlined below using qualitative risk assessment methodology based on the sensitivity of the receptor and likelihood of impact occurring. Impacts assessed as moderate or high are considered to require further assessment or mitigation.

### 4.1.1 Potential Effects

Without appropriate design and controls, construction works have the potential to impair the local hydrology (water quality) and hydrogeology (groundwater levels, flow and quality), from the following:

- The use of machinery and the movement of soils has the potential to generate suspended solids in run-off and/ or introduce oils or hydrocarbons to the water environment;
- The use of bentonite drilling muds has the potential to impact on water quality;
- Existing groundwater flow paths could be disturbed or altered, impacting nearby groundwater abstractions.

Standard construction techniques and best practices will be used to avoid or reduce these potential impacts with outline control measures set out in the Outline Code of Construction Practice (CoCP) (application ref: 8.13.1). Details are given in the following section.

### 4.1.2 Receptor Sensitivity

Based on the review of the baseline conditions and the CSM as developed in the previous section it is considered that the primary receptor in the vicinity of the development site is the underlying Principal bedrock aquifer. The superficial deposits are also considered a potential receptor however given the limited groundwater potential these are not considered to be highly sensitive as there are no associated abstractions and are unlikely to provide flow to either surface water or ecological receptors.

For the purpose of this assessment the sensitivity of the bedrock aquifer is assessed as High whilst the superficial deposits are assessed as Low.

One groundwater abstraction has been recorded within 500 m of the site, given that this provides drinking water it is also considered to have a high sensitivity.

### 4.1.3 Embedded mitigation

As part of the design for the onshore works careful routing of the onshore ECC and design of key crossing points (sea defence structures, main rivers, non-main and ordinary watercourses, roads) has been undertaken to avoid key areas of sensitivity.

Best practice construction techniques and procedures will be followed during any works and these are outlined within the outline CoCP and accompanying appendices that provide a series of management plans which will be agreed with NRW and DCC prior to any development taking place. These include:

- A Pollution Prevention and Emergency Incident Response Plan (PPEIRP) is being developed for the works, an outline version of which is provided in the outline CoCP Appendix 6: Pollution Prevention and Emergency Incident Response Plan (application ref 8.13.6) that sets out the principles to be followed when the final PPEIRP is finalised. The outline PPEIRP sets out the pollution prevention measures, and emergency incident responses, which may be implemented by the Applicant and its contractors during construction;
- An Outline Soil Management Plan (SMP) is provided as Appendix 4 to the outline CoCP (application ref: 8.13.4). The SMP provides details of mitigation measures and best practice handling techniques to safeguard soil resources by ensuring their protection, conservation and appropriate reinstatement during the construction of the onshore works. These measures will include guidance on earthworks and stockpiling in order to minimise potential entrainment of sediments to surface water features or increase in nitrogen loading to groundwater through infiltration.

The construction works will also be undertaken in accordance with good practice guidance within the following documents:

- CIRIA SP156 Control of Water Pollution from Construction Sites – Guide to Good Practice, 2002;
- CIRIA C502 Environmental Good Practice on Site C741, CIRIA 2015;

The Pollution Prevention Guidelines (PPGs) (which are progressively being replaced with Guidance for Pollution Prevention (GPPs)) provide environmental good practice for the whole of the UK and environmental regulatory guidance for Wales. Relevant PPGs/GPPs will be followed, including:

- GPP01: Understanding your environmental responsibilities – good environmental practices (Oct 2020)
- GPP02: Above Ground Oil Storage Tanks (Jan 2018);
- GPP04: Treatment and Disposal of wastewater where there is no connection to the public sewer (Nov 2017);
- PPG6: Working at construction and demolition sites (2012);
- GPP08: Safe storage and disposal of used oils (July 2017);
- GPP13: Vehicle Washing and Cleansing (April 2017);
- PPG18: Managing fire water and major spillages (June 2000);
- GPP21: Pollution incident response planning (June 2021);
- GPP22: Dealing with Spills (Oct 2018).

### 4.1.4 Impact on groundwater quality from construction activities

Measures outlined within the outline CoCP, SMP and PPEIRP will minimise the potential for any contaminants to be generated or released as part of the works and therefore minimise the potential impact on water quality.

The embedded mitigation measures include the implementation of spill procedures and use of spill kits. These measures together with appropriate drainage systems and containment will minimise the potential for any reduction in water quality associated with spills or leaks of stored oils/ fuels/ chemicals or other polluting substances migrating into nearby groundwater.

Whilst there is the potential for the construction of an entry/ exit pit relating to the HDD cable installation to introduce a pathway for contaminants, the low permeability of the underlying strata is likely to limit the migration of potential contaminants.

In the event that groundwater within the Kinnerton sandstone is encountered this could be sensitive to accidental spillages and runoff from the HDD works as the drilling will create a preferential pathway to the underlying sandstone. Measures in the outline CoCP to control the storage and use of materials and chemicals would be implemented, which would limit the magnitude of impact.

The above embedded mitigation measures will ensure that the risk to both shallow perched groundwater within the superficial deposits and groundwater within the deeper Kinnerton sandstone aquifer is low.

### 4.1.5 Impact on groundwater quality from drilling mud

Drilling mud is used as part of the HDD process and is pumped into the works to stabilise the drilled bore, recover drilling cuttings and ensure it does not collapse. Bentonite is the most commonly used drilling mud.

Bentonite is a naturally occurring swelling clay with sodium bentonite and calcium bentonite the most widely used in industry. The primary water quality concerns from the use of bentonite drilling muds are related to increased turbidity of the aquifer, or the release of elevated pH, sodium or calcium concentrations.

Bentonite clays have very fine particle sizes which in certain conditions, such as within fissured aquifers, has the potential to migrate from the drilling hole where voids in the aquifer are connected via the drilling. Drilling will however primarily take place through the superficial tidal flat deposits and till deposits, both of which are dominated by clays and silts which will limit the potential for any migration of bentonite away from the drill hole.

The Kinnerton sandstone is described as a *'fine to medium grained sandstone'* therefore the potential for significant migration of bentonite drilling muds is considered to be very low. Any impact to water quality would therefore be highly localised to the immediate vicinity of the drilling works. As outlined above there are no sensitive abstractions or ecological sites within the immediate vicinity of the works which could be impacted. Given the significant aquifer thickness in comparison to the small diameter of the open hole and the small volume of bentonite used in the process, the potential for the bentonite to adversely impact water quality is considered to be very low.

It should also be noted that the use of bentonite as a drilling mud is a common approach in borehole drilling (both HDD and conventional well drilling) and is generally considered to be low risk to groundwaters. Good management and disposal practices of excess bentonite will apply to ensure further protection to superficial and bedrock aquifers.

The above assessment therefore indicates that the risk from the use of drilling muds is low. To ensure that the risk is controlled, careful monitoring of the drilling mud used will be undertaken to ensure that any losses to the aquifer which could indicate migration away from the drill hole are identified as early as possible and allow for appropriate mitigation to be put into place in the highly unlikely event of this occurring.

### 4.1.6 Impact on surface water quality

The CSM indicates that the watercourses within the vicinity of the proposed crossing are considered to receive very little or no groundwater baseflow due to the typically low permeability of the tidal flat deposits therefore it is considered highly unlikely that any impact from the HDD works would migrate to surface water. This along with the measures outlined above to protect groundwater will ensure that the potential impact on surface water quality is negligible.

### 4.1.7 Impact on Groundwater Levels and Flows

As outlined in Section 3.3.2, groundwater is considered to be present within the underlying bedrock at a depth up to 20 m below ground level (BGL) at the HDD crossing point (the potentiometric surface is approximately 10m below ground level but would not be encountered until the bedrock is reached at c.20m BGL). There is therefore the potential that the HDD crossing will encounter the underling bedrock aquifer, although it is noted that the majority of drilling will take place within the overlying superficial deposits.

Some perched groundwater is potentially present within the superficial deposits however given typical low permeability of the tidal flat deposits and till deposits mean that these are unlikely to provide a significant resource.

The method of working will minimise the size of the opening and therefore ensure that any dewatering which does occur as a result of the tunnelling is kept to a minimum. This could have a moderate impact on any groundwater encountered within the superficial deposits as it will likely locally alter the flows, however given the lack of any associated receptors and the low sensitivity of the aquifer, the magnitude of impact is considered to be low and acceptable.

In the event that the HDD works encounter the bedrock aquifer the overall impact on flows is likely to be low owing to the very small size of the opening in relation to the significant aquifer thickness (in excess of 200 m) and the lack of any nearby significant receptors which could be impacted by what would be a very localised radius of influence. Following installation, the presence of the cables within the aquifer will potentially result in a very minor alteration in flows but given the minor development extent in relation to the aquifer the overall significance of impact is assessed as minor and no further mitigation above that embedded in the design is considered necessary.

### 4.1.8 Impact on Groundwater Abstractions

One groundwater abstraction has been recorded approximately 500 m to the south-west of the development area. This abstracts groundwater from the bedrock aquifer as a potable source. Given the pollution prevention measures which will be put into place the potential for adversely impacting the abstraction is assessed as very low.

The release of bentonite into the aquifer has the potential to impact the turbidity of drinking water however given the distance of the abstraction from the HDD works and the low likelihood of bentonite migrating within the sandstone aquifer there is considered to be a very low risk to this abstraction.

It is also noted that groundwater flow within the sandstone is likely to be in a northerly direction towards the coast and therefore the abstraction is likely to be up-gradient of the site and any impact which did occur to the bedrock aquifer would not affect the groundwater abstraction.

# 5.0 Conclusions

A groundwater risk assessment has been undertaken to assess the potential impact of the proposed Landfall HDD Crossing Works on groundwater receptors.

The assessment has indicated that the primary potential receptor of concern relates to groundwater within the underlying Kinnerton sandstone aquifer and an associated licensed groundwater abstraction located approximately 500 m to the south-west.

The various watercourses in the vicinity of the development area are not considered to be groundwater dependent due to the low permeability of the overlying superficial deposits which act as a confining layer above the sandstone aquifer.

An assessment of the potential impact of the works on groundwater levels, flow and quality and surface water quality has been undertaken and confirms that the potential impact on levels and flows is considered to be

negligible or low. The risk to both groundwater and surface water quality will be managed through the implementation of best practice measures in accordance within a series of management plans developed for the works and ensure that the risk to groundwater quality is low. The lack of any hydraulic continuity between groundwater and surface water ensures that the risk to surface water quality is negligible.

# 6.0 References

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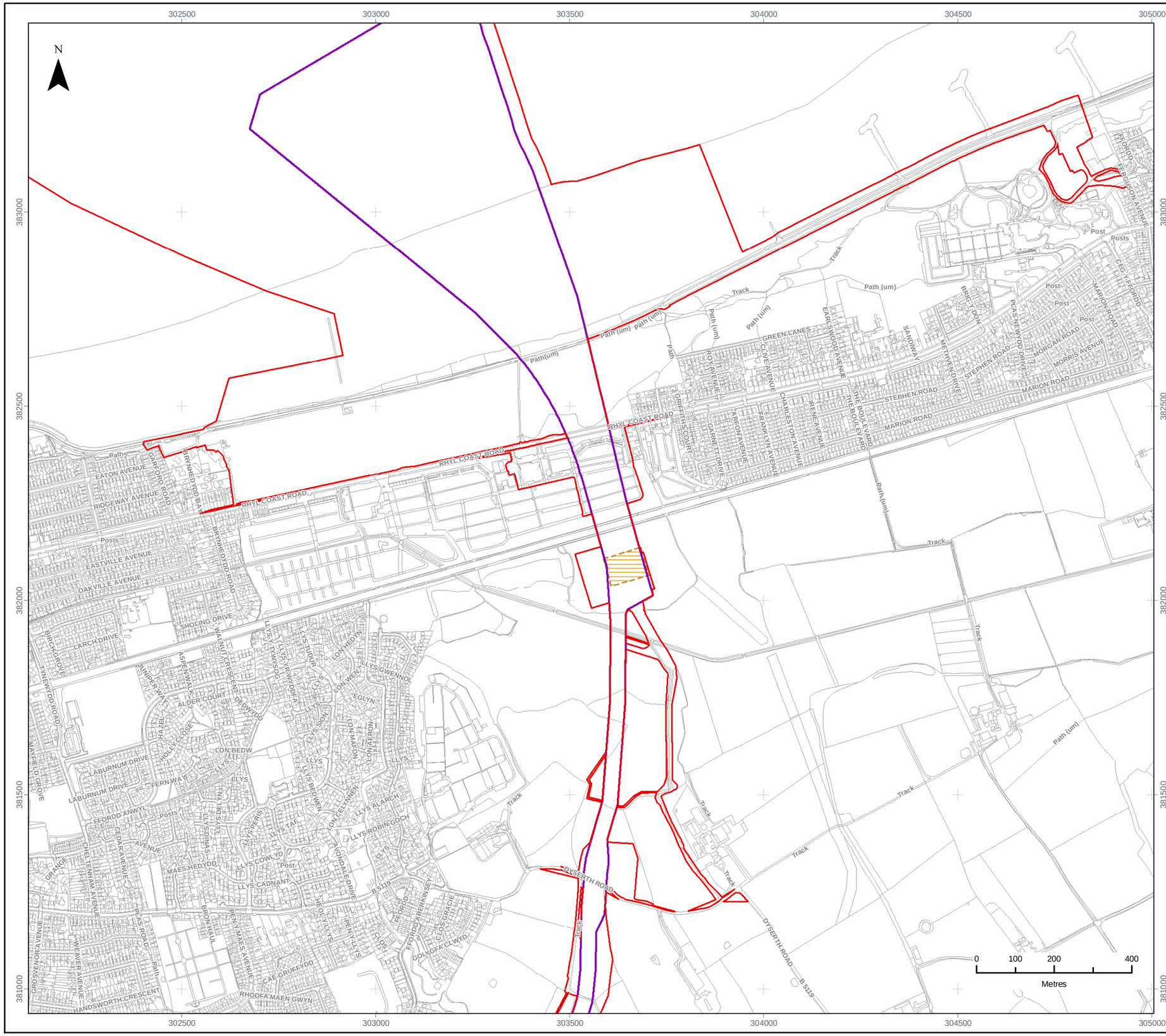
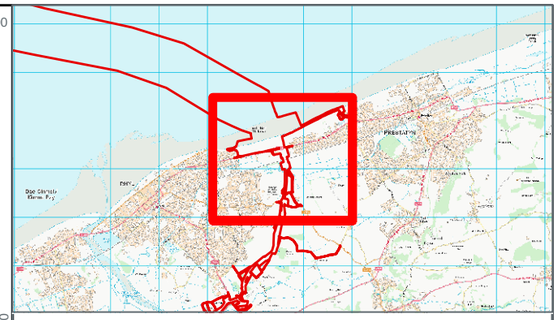


LEGEND

- Order Limits
- Proposed Onshore Export Cable Corridor
- Proposed Trenchless Crossing Compound

Data Source:
© Crown copyright [and database rights] (2022) OS OpenData.

PROJECT TITLE:

*AWEL Y MÔR OFFSHORE WINDFARM*

North Wales Mainline Railway Trenchless Crossing Works (HDD):
Hydrogeological Risk Assessment

FIGURE TITLE:

## SITE CONTEXT

| VER | DATE | REMARKS | Drawn | Checked |
|---|---|---|---|---|
| 1 | 08/02/2022 | First Issue | PW | SM |
| | | | | |
| | | | | |

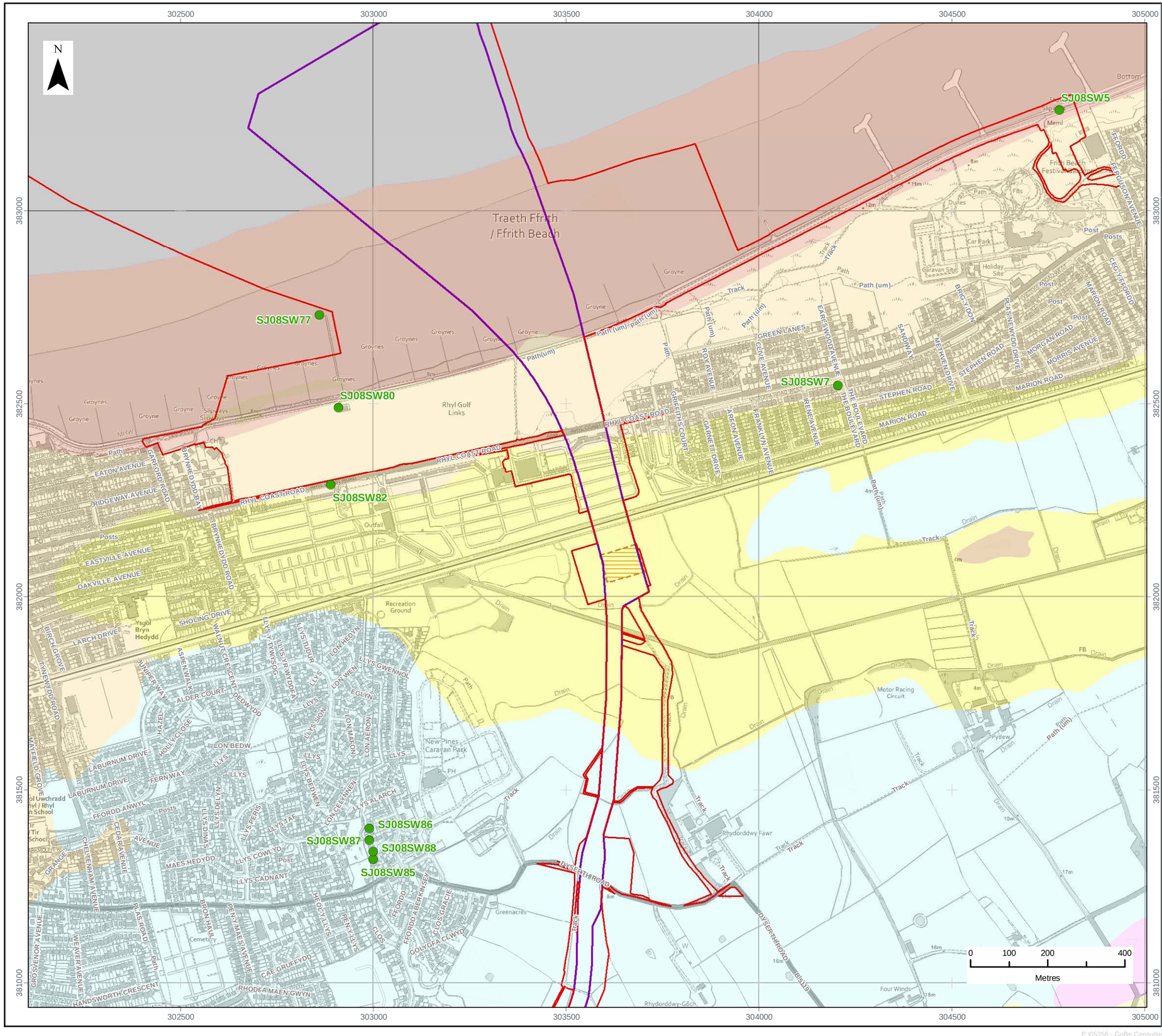
FIGURE NUMBER:

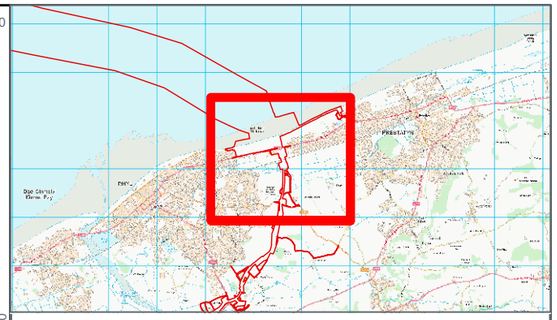
FIGURE 1

| SCALE: | PLOT SIZE: | DATUM: | COORDINATE SYSTEM: |
|---|---|---|---|
| 1:10,000 | A3 | ODN | British National Grid |

Fferm Wynt Alltraeth
AWEL Y MÔR
Offshore Wind Farm

P:\05356 - GoBe Consultants Ltd\00009 Awel y Mor\Tech\GIS\Dwgs\Wking\202201 HRA\05356.00009.0294.0 HDD Site Context.mxd



LEGEND

- Order Limits
- Proposed Onshore Export Cable Corridor
- Proposed Trenchless Crossing Compound

Superficial Geology

- Alluvium - Clay, Silt, Sand And Gravel
- Blown Sand - Sand
- Marine Beach Deposits
- Peat
- Tidal Flat Deposits - Clay, Silt And Sand
- Till, Devensian - Diamicton
- Glaciofluvial Sheet Deposits, Devensian - Sand And Gravel
- Historic BGS Borehole



PROJECT TITLE:

*AWEL Y MÔR OFFSHORE WINDFARM*

North Wales Mainline Railway Trenchless Crossing Works (HDD): Hydrogeological Risk Assessment

FIGURE TITLE:

# SUPERFICIAL DEPOSITS

| VER | DATE | REMARKS | Drawn | Checked |
|---|---|---|---|---|
| 1 | 08/02/2022 | First Issue | PW | SM |
| | | | | |
| | | | | |

FIGURE NUMBER:

FIGURE 2

| SCALE: | PLOT SIZE: | DATUM: | COORDINATE SYSTEM: |
|---|---|---|---|
| 1:10,000 | A3 | ODN | British National Grid |

Fferm Wynt Alltraeth
AWEL Y MÔR
Offshore Wind Farm

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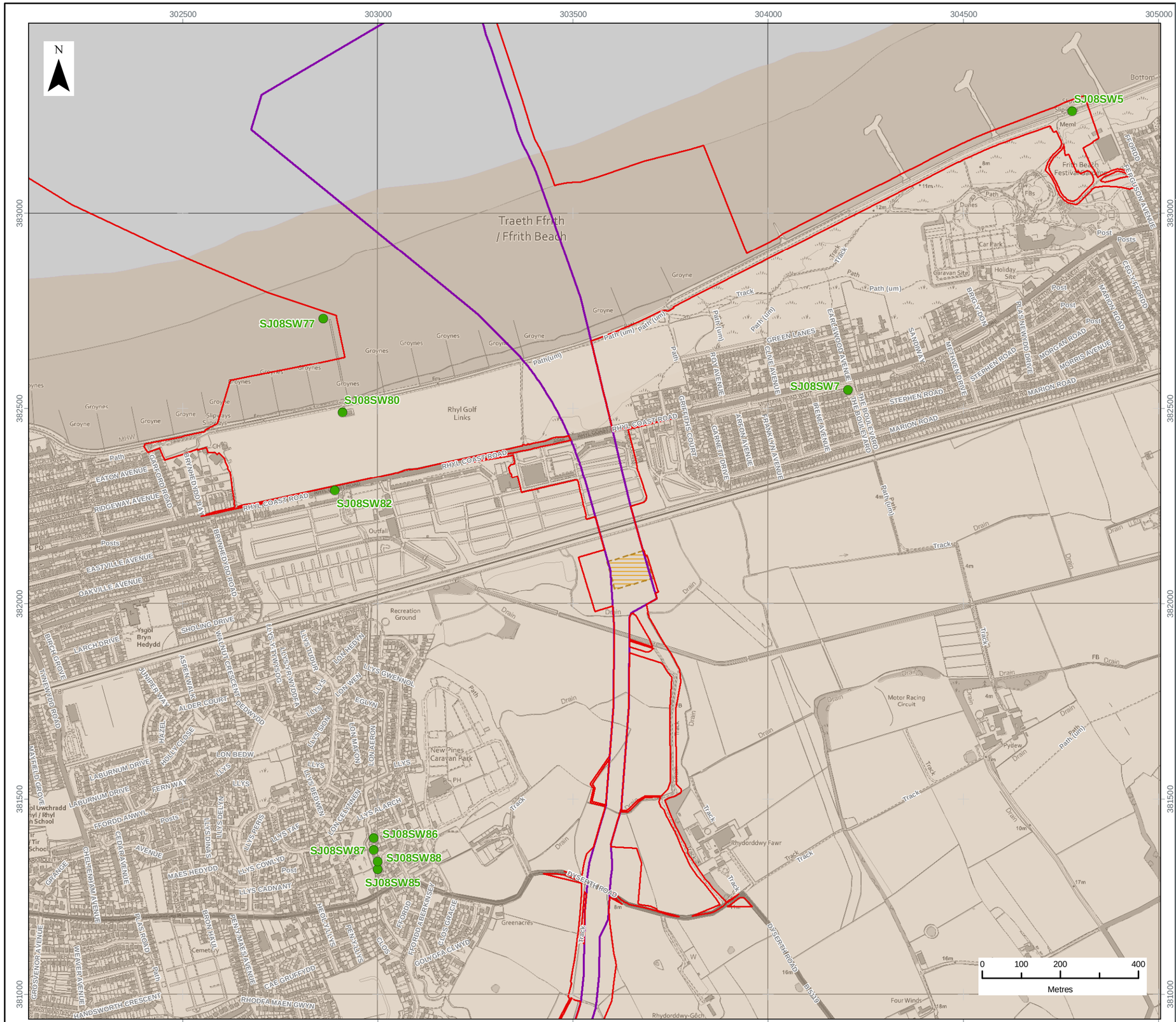


LEGEND

- Order Limits
- Proposed Onshore Export Cable Corridor
- Proposed Trenchless Crossing Compound

Bedrock Geology

- Kinnerton Sandstone Formation - Sandstone (Triassic)
- Historic BGS Borehole

Data Source:
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Contains British Geological Survey Materials © NERC 2019
Historic BGS Boreholes based upon records provided by British Geological Survey (UKRI)

PROJECT TITLE:

*AWEL Y MÔR OFFSHORE WINDFARM*

North Wales Mainline Railway Trenchless Crossing Works (HDD):
Hydrogeological Risk Assessment

FIGURE TITLE:

# BEDROCK GEOLOGY

| VER | DATE | REMARKS | Drawn | Checked |
|---|---|---|---|---|
| 1 | 08/02/2022 | First Issue | PW | SM |
| | | | | |
| | | | | |

FIGURE NUMBER:

FIGURE 3

| SCALE: | PLOT SIZE: | DATUM: | COORDINATE SYSTEM: |
|---|---|---|---|
| 1:10,000 | A3 | ODN | British National Grid |

Fferm Wynt Alltraeth
AWEL Y MÔR
Offshore Wind Farm

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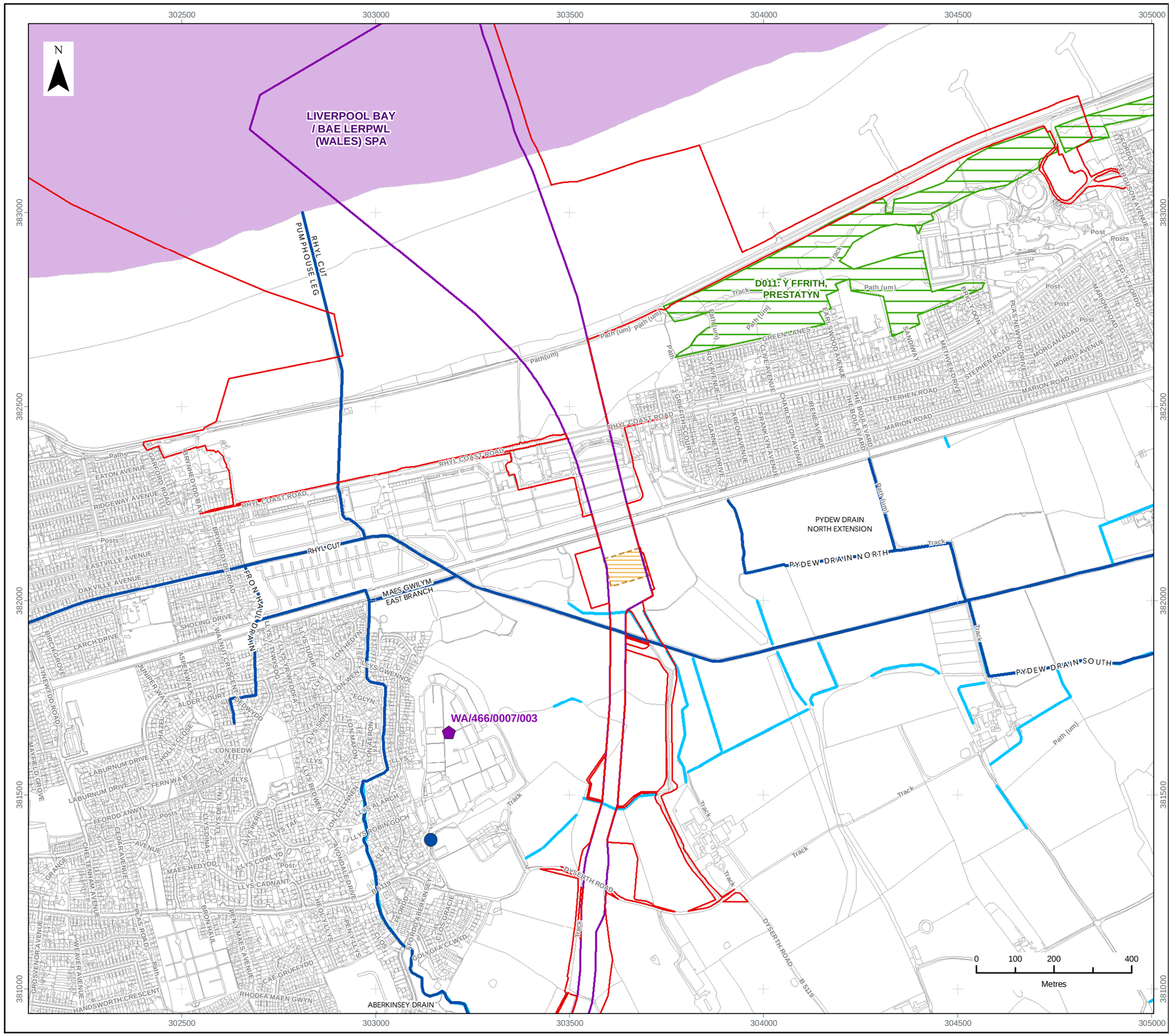


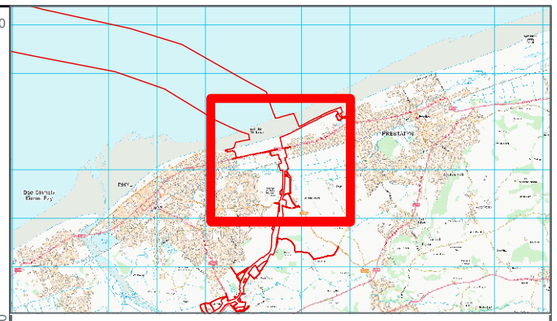

LEGEND

- Order Limits
- Proposed Onshore Export Cable Corridor
- Proposed Trenchless Crossing Compound
- Local Wildlife Site
- Special Protection Area (SPA)
- NRW Main River
- Ordinary Watercourse
- Licensed Private Water Supply (PWS)
- Private Water Abstraction

Note: There are no Source Protection Zones within the Displayed Area



PROJECT TITLE:

*AWEL Y MÔR OFFSHORE WINDFARM*

North Wales Mainline Railway Trenchless Crossing Works (HDD): Hydrogeological Risk Assessment

FIGURE TITLE:

# GROUNDWATER SPZs, WATERCOURSES, ABSTRACTIONS AND ECOLOGICAL SITES

| VER | DATE | REMARKS | Drawn | Checked |
|---|---|---|---|---|
| 1 | 08/02/2022 | First Issue | PW | SM |
| | | | | |
| | | | | |

FIGURE NUMBER:

FIGURE 4

| SCALE: | PLOT SIZE: | DATUM: | COORDINATE SYSTEM: |
|---|---|---|---|
| 1:10,000 | A3 | ODN | British National Grid |

Fferm Wynt Alltraeth
AWEL Y MÔR
Offshore Wind Farm

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## BGS BOREHOLE REFERENCE: SJ08SE23

Easting: 305480
Northing: 382700
Date: -
Length: 205.74m

SJ 08 SE/3 23

**Prestatyn Borehole, Prestatyn** Grid Ref: SJ 0548 8270

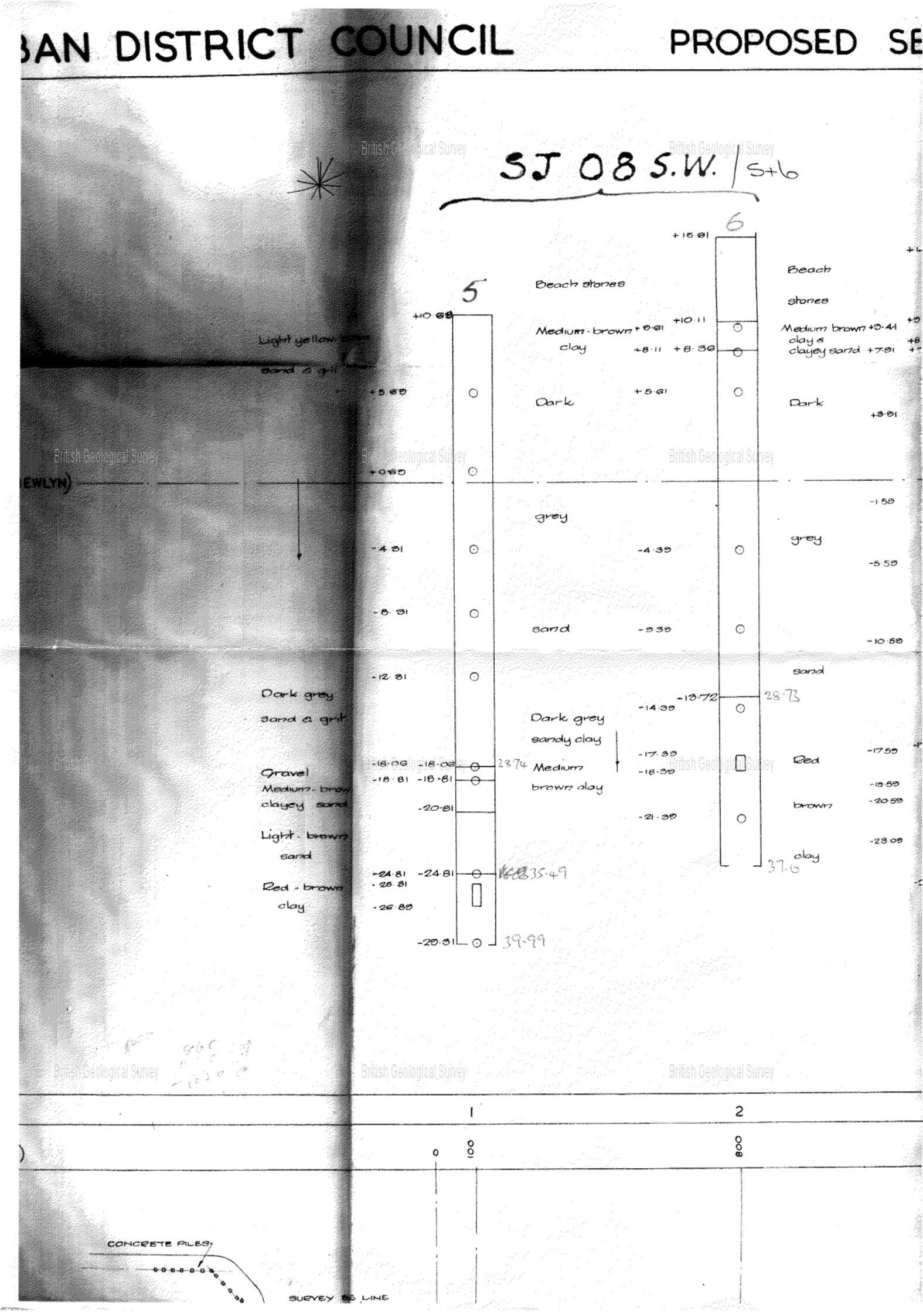
| | Ft | in | Ft | in |
|---|---|---|---|---|
| Drift | 70 | 0 (21.33m) | 70 | 0 (21.33m) |
| Red and white sandstone and marl and ? a thin coal | 605 | 0 (184.40m) | 675 | 0 (205.74m) |

From Rhyl memoir O.S 79 N.W. pp. 27 and 30?

## BGS BOREHOLE REFERENCE: SJ08SW5

Easting: 304779
Northing: 383261
Date: -
Length: 12.19m

SJ 08 S.W. / 5+6


5
+10·68
Beach stones
+9·61
Medium-brown clay
+8·11
Light yellow sand & grit
+5·68
+5·61
Dark grey sand
+0·69
-0·39
-4·31
-4·39
-8·31
-9·39
-12·31
Dark grey sand & grit
-14·39
Dark grey sandy clay
-17·39
-18·02
-18·02
2874
Medium brown clay
-18·81
-18·81
-18·39
Gravel
Medium-brown clayey sand
-20·81
-21·39
Light-brown sand
-24·81
-24·81
35·49
Red-brown clay
-25·81
-26·89
-29·81
39·99
6
+15·81
Beach stones
+10·11
+10·41
Medium brown clay & clayey sand
+8·36
+7·91
Dark grey
+5·91
+3·91
-1·59
grey
-4·39
-5·59
sand
-9·39
-10·59
sand
-13·72
28·73
-14·39
-17·59
Red brown clay
-17·39
-18·39
-19·59
-20·59
-21·39
-23·09
37·6
1
2
0
CONCRETE PILES
SURVEY BASE LINE

## BGS BOREHOLE REFERENCE: SJ08SW7

Easting: 304205
Northing: 382547
Date: -
Length: 4.57m

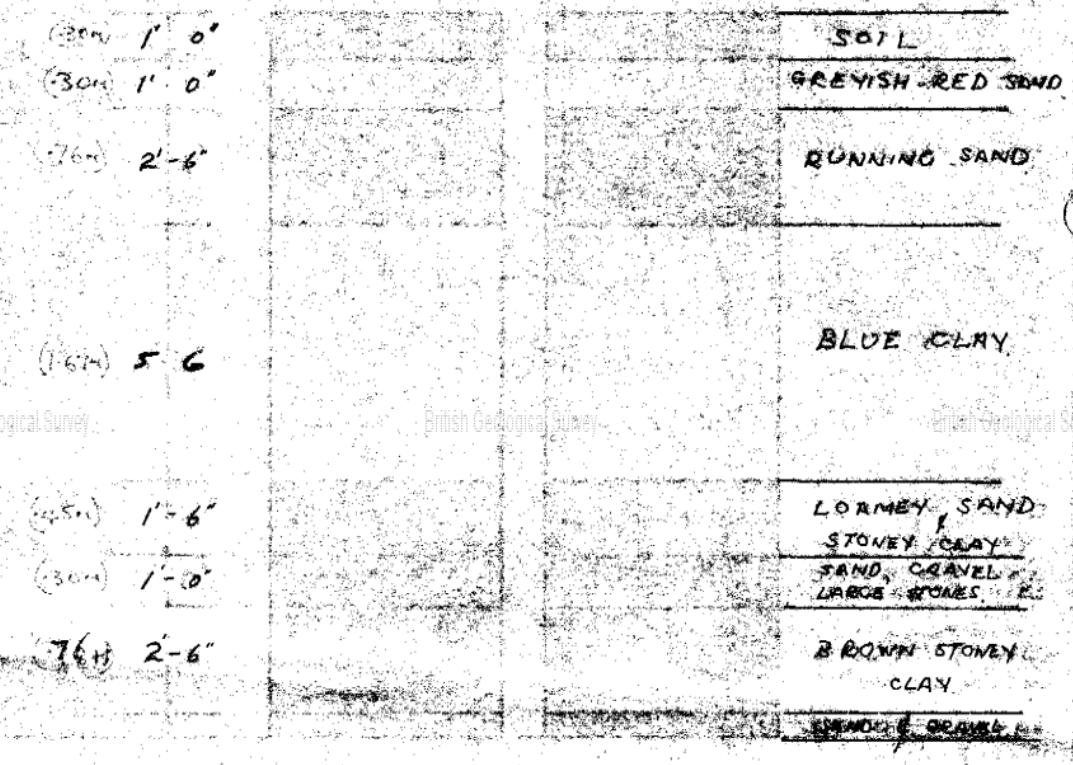
F 26
16"

5508SW/7

7

Earlswood Avenue

Victoria Road West




Water commenced at 2'-0" and the hole made water throughout the boring and was not shut out. Water level at finish 3'-0"

NO 1

## BGS BOREHOLE REFERENCE: SJ08SW77

Easting: 302860
Northing: 382730
Date: 1963
Length: 4.88m

14a-f_1.TIF

95/35 A-F

# WELSH NATIONAL WATER DEVELOPMENT AUTHORITY

## DEE AND CLWYD RIVER DIVISION

SJ08/14 A-F

SJ08/14



DETAILED HYDROGEOLOGICAL RECORD SHEET : INDIVIDUAL SITE RECORD

D.C.R.D. REF. No. ~~95/35~~

NAME Rhyl Cut Improvement Scheme FLINTSHIRE

N.G.R. various : see b/h logs SJ08SW

EXACT SITE KNOWN YES/~~NO~~

LOCATION SKETCH YES/NO/MAP

HEIGHT A.O.D. -1 → 5 ..... METRES

ESTIMATED FROM ~~MAP~~/SURVEY/~~OTHER~~

REFERENCE POINT NONE/~~DETAILS~~/~~SKETCH~~

LOG YES/~~NO~~

LOCATION OF LOG HERE/~~I.G.S.~~

SUMMARY OF LOG

i) THICKNESS OF DRIFT > 12·2 ..... METRES

ii) TOTAL DEPTH Max 12·2 ..... METRES

iii) O.D. LEVEL OF ROCKHEAD ..... METRES

WATER QUALITY INFORMATION ~~YES~~/NO

WATER QUANTITY INFORMATION

ABSTRACTION ~~YES~~/NO/~~OCCASIONALLY~~/~~NOT KNOWN~~ LICENSED ABSTRACTION /HOUR /DAY /YEAR

LICENCE NO.

WATER LEVEL INFORMATION ~~YES~~/NO

DETAILS :

PUMPING TEST ~~YES~~/NO DATE

LOCATION OF DATA

WATER LEVELS RECORDED NONE/~~ISOLATED~~ READINGS/~~MONTHLY~~/~~AUTOGRAPHIC~~

LOCATION OF RECORDS

ACCESS Boreholes filled in.

DEE AND CLWYD RIVER AUTHORITY SJ08/14A

14a_2.TIF

SJ08/14 A

95/35A

# BOREHOLE RECORD.

JOB RHYL CUT IMPROVEMENT SCHEME JOB No. 223

N. G. REF SJ0286 8273 DATE April 1963 B.H. No. 1 GROUND LEVEL -4·0 O.D.N.

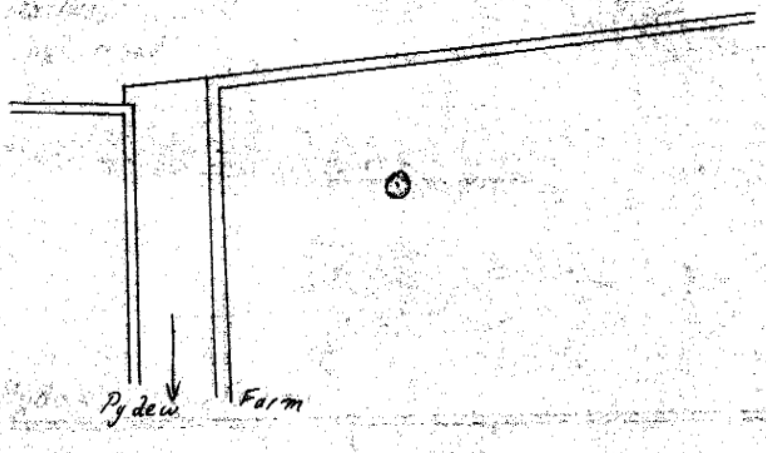
| Description of Strata | Depth | Log | O.D.N. | Remarks |
|---|---|---|---|---|
| | 0 | | -4·0 | |
| Sand & gravel | | | | |
| | 3·0 | | -7·0 | These levels are in feet |
| Soft dark grey silty clay | 3·5 | | -7·5 | |
| Sand & gravel | | | | |
| | 16·0 | | -20·0 | |

## BGS BOREHOLE REFERENCE: SJ08SW8

Easting: 303686
Northing: 380835
Date: -
Length: 6.10m

F. 26
13.

SS08SW/8




| | | |
|---|---|---|
| (.91m) | 3'-0" | BLUE CLAY |
| (.30m) | 1' 0" | GREY SAND & STONES (22) |
| (1.83m) | 6'-6" | RED CLAY |
| (.76m) | 2'-6" | BROWN CLAY |
| (.60m) | 2'-0" | RUNNING SAND |
| (1.52m) | 5' 0" | STIFF BROWN CLAY |

(61)

Made water to 10'-0". Water shut out at 10'-0" and borehole dry below this depth.

NO 3

## BGS BOREHOLE REFERENCE: SJ08SW80

Easting: 302910
Northing: 382490
Date: 1963
Length: 12.19m

14a-f_1.TIF

95/35 A-F

# WELSH NATIONAL WATER DEVELOPMENT AUTHORITY

## DEE AND CLWYD RIVER DIVISION

SJ08/14 A-F

SJ08/14



DETAILED HYDROGEOLOGICAL RECORD SHEET : INDIVIDUAL SITE RECORD

D.C.R.D. REF. No. ~~95/35~~

NAME Rhyl Cut Improvement Scheme FLINTSHIRE

N.G.R. various : see b/h logs SJ08SW

EXACT SITE KNOWN YES/~~NO~~

LOCATION SKETCH YES/NO/MAP

HEIGHT A.O.D. -1 → 5 ..... METRES

ESTIMATED FROM ~~MAP~~/SURVEY/~~OTHER~~

REFERENCE POINT NONE/~~DETAILS~~/~~SKETCH~~

LOG YES/~~NO~~

LOCATION OF LOG HERE/~~I.G.S.~~

SUMMARY OF LOG

i) THICKNESS OF DRIFT > 12·2 ..... METRES

ii) TOTAL DEPTH Max 12·2 ..... METRES

iii) O.D. LEVEL OF ROCKHEAD ..... METRES

WATER QUALITY INFORMATION ~~YES~~/NO

WATER QUANTITY INFORMATION

ABSTRACTION ~~YES~~/NO/~~OCCASIONALLY~~/~~NOT KNOWN~~ LICENSED ABSTRACTION /HOUR /DAY /YEAR

LICENCE NO.

WATER LEVEL INFORMATION ~~YES~~/NO

DETAILS :

PUMPING TEST ~~YES~~/NO DATE

LOCATION OF DATA

WATER LEVELS RECORDED NONE/~~ISOLATED~~ READINGS/~~MONTHLY~~/~~AUTOGRAPHIC~~

LOCATION OF RECORDS

ACCESS Boreholes filled in.

DEE AND CLWYD RIVER AUTHORITY

95/35D

14d-5.TIF

SJ08/14 D
SJ08/14D

# BOREHOLE RECORD.

JOB RHYL CUT IMPROVEMENT SCHEME ... JOB No. 223 61

N. G. REF. SJ 0291 8249 DATE April 1963 B.H. No: 4 & 5 .. GROUND LEVEL 18·0 O.D.N.

| Description of Strata | Depth | Log | O.D.N. | Remarks |
|---|---|---|---|---|
| Topsoil | 0 | | 18·0 | |
| Brown sand with some gravel | 3·5 | | 14·5 | |
| Soft grey organic clay | 7·0 | | 11·0 | |
| Black peat | 8·5 | | 9·5 | |
| Soft grey silty clay | 9·5 | | 8·5 | These levels are in feet |
| | 11·5 | | 6·5 | |
| Grey sand with some gravel | 22·0 | | -4·0 | |
| Stiff brown boulder clay | 40·0 | | -22·0 | |

## BGS BOREHOLE REFERENCE: SJ08SW82

Easting: 302890
Northing: 382290
Date: 1963
Length: 5.97m

14a-f_1.TIF

95/35 A-F

# WELSH NATIONAL WATER DEVELOPMENT AUTHORITY

## DEE AND CLWYD RIVER DIVISION

SJ08/14 A-F

SJ08/14



DETAILED HYDROGEOLOGICAL RECORD SHEET : INDIVIDUAL SITE RECORD

D.C.R.D. REF. No. ~~95/35~~

NAME Rhyl Cut Improvement Scheme FLINTSHIRE

N.G.R. various : see b/h logs SJ08SW

EXACT SITE KNOWN YES/~~NO~~

LOCATION SKETCH YES/NO/MAP

HEIGHT A.O.D. -1 → 5 ..... METRES

ESTIMATED FROM ~~MAP~~/SURVEY/~~OTHER~~

REFERENCE POINT NONE/~~DETAILS~~/~~SKETCH~~

LOG YES/~~NO~~

LOCATION OF LOG HERE/~~I.G.S.~~

SUMMARY OF LOG

i) THICKNESS OF DRIFT > 12·2 ..... METRES

ii) TOTAL DEPTH Max 12·2 ..... METRES

iii) O.D. LEVEL OF ROCKHEAD ..... METRES

WATER QUALITY INFORMATION ~~YES~~/NO

WATER QUANTITY INFORMATION

ABSTRACTION ~~YES~~/NO/~~OCCASIONALLY~~/~~NOT KNOWN~~ LICENSED ABSTRACTION /HOUR /DAY /YEAR

LICENCE NO.

WATER LEVEL INFORMATION ~~YES~~/NO

DETAILS :

PUMPING TEST ~~YES~~/NO DATE

LOCATION OF DATA

WATER LEVELS RECORDED NONE/~~ISOLATED~~ READINGS/~~MONTHLY~~/~~AUTOGRAPHIC~~

LOCATION OF RECORDS

ACCESS Boreholes filled in.

DEE AND CLWYD RIVER AUTHORITY

14f_7.TIF

98/35F

# BOREHOLE RECORD.

SJ 08/14 F

SJ08/14F

JOB RHYL CUT IMPROVEMENT SCHEME JOB No. 223

N. G. REF SJ0289 8229 DATE April 1963 B.H. No. 7 GROUND LEVEL 15.0 O.D.N.

| Description of Strata | Depth | Log | O.D.N. | Remarks |
|---|---|---|---|---|
| Topsoil | 0 | | 15·0 | |
| | 1·5 | | 13·5 | |
| Firm grey/brown silty clay | | | | These levels are in feet. |
| Black peat with bands of grey silty clay | 5·5 | | 9·5 | |
| | 6·5 | | 8·5 | |
| Grey silty sand & gravel | | | | |
| | 16·5 | | -1·5 | |
| Stiff brown boulder clay | | | | |
| | 19·5 | | -4·5 | |

## BGS BOREHOLE REFERENCE: SJ08SW85

Easting: 303000
Northing: 381320
Date: 1991
Length: 10.00m

STRATA SURVEYS LTD.,
Telephone: 0606 84 4637 Fax: 0606 84 6657

Borehole Number : 1
Sheet 1 of 1.

Job Number : 6034 Location : Maes Gwilym, Rhyl.

Client : Whelmar, Chester.

Dia. & Drilling Methods
light cable percussion
150mm diameter

303004
381322

| Description of Strata | Red. Level | Legend | Thick -ness | Depth m | Sample Depths | Sample Types | N Value | Cu | ø | Water Level | Pie -zo | Daily Prog. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.00 | | | | | | | | |
| TOPSOIL. | | | (0.20) | 0.20 | | | | | | | | |
| Firm brown slightly gravelly sandy CLAY (Boulder Clay), firm/stiff from 2.00m, very sandy very gravelly clay from 3.30m. | | | (4.40) | | 0.50 - 0.95 | U 1 | | | | | | |
| | | | | | 1.00 | D 1 | | | | | | |
| | | | | | 1.50 - 1.95 | U 2 | | | | | | |
| | | | | | 2.00 | D 2 | | 26 | 13 | | | |
| | | | | | 2.60 - 3.03 | U 3 | | | | | | |
| | | | | | 3.10 | D 3 | | 49 | 16 | | | |
| | | | | | 3.60 - 3.90 | U 4 | | | | | | |
| | | | | | 3.90 | W 1 | | | | ▽ 25/6 | | |
| | | | | | 4.10 | D 4 | | | | tsl | | |
| Loose brown clayey fine/medium grained SAND. | | | (0.60) | 4.60 | 4.50 - 4.70 | U 5 | | | | | | |
| | | | | | 4.70 | D 5 | | | | ▽ med | | |
| | | | | 5.20 | | | | | | | | |
| Very stiff brown slightly gravelly sandy CLAY (Boulder Clay). | | | (4.80) | | 5.40 - 5.63 | S 1 | N 70 /225 | | | | | |
| | | | | | 6.90 - 7.13 | S 2 | N 50 /225 | | | | | |
| | | | | | 8.40 - 8.78 | S 3 | N 82 /375 | | | | | |
| | | | | | 9.30 - 9.70 | U 6 | | | | | | |
| | | | | 10.00 | | | | | | | | 25/6 |
| Borehole Completed | | | | | | | | | | | | |

General Remarks :
Water strike 4.70m rising to 3.90m in 20 minutes.
Chiselling: 1hr 30mins very stiff clay.

Dates : 25/6/91
Driller : T.B.
Engineer: REB

## BGS BOREHOLE REFERENCE: SJ08SW86

Easting: 302990
Northing: 381400
Date: 1991
Length: 10.00m

STRATA SURVEYS LTD.,
Telephone: 0606 84 4637 Fax: 0606 84 6657

Borehole Number : 2
Sheet 1 of 1.

Job Number : 6034 Location : Naes Gwilym, Rhyl.
Client : Whelmar, Chester.

Dia. & Drilling Methods
light cable percussion
150mm diameter

302996
381406

| Description of Strata | Red. Level | Legend | Thick -ness | Depth m | Sample Depths | Sample Types | N Value | Cu | ø | Water Level | Pie -zo | Daily Prog. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.00 | | | | | | | | |
| TOPSOIL. | | | (0.40) | 0.40 | | | | | | | | |
| Stiff brown slightly gravelly sandy CLAY (Boulder Clay), sandy very silty clay from 1.60m. | | | (1.70) | | 0.60 - 0.96 | U 1 | | 25 | 27 | | | |
| | | | | | 1.10 | D 1 | | | | | | |
| | | | | | 1.60 - 2.03 | U 2 | | | | | | |
| | | | | 2.10 | 2.10 | D 2 | | 40 | 22 | | | |
| Brown slightly gravelly very clayey fine grained SAND. | | | (0.90) | | 2.50 - 2.83 | U 3 | | | | | | |
| | | | | | | | | 28 | 0 | | | |
| | | | (0.10) | 3.00 | 3.00 | D 3 | | | | | | |
| Firm/stiff brown slightly gravelly sandy CLAY (Boulder Clay), with sand bands. | | | (1.00) | 3.10 | 3.20 - 3.60 | U 4 | | | | | | 26/6 |
| Brown silty very clayey fine grained SAND. | | | | | | | | | | | | |
| | | | | 4.10 | | | | | | | | |
| Medium dense brown fine/medium grained SAND, becoming very dense medium/coarse grained Sand from 5.50m. | | | (3.10) | | 4.60 - 5.05 | S 1 | N 26 | | | | | |
| | | | | | 4.90 | W 1 | | | | ▼ 27/6 ts) | | |
| | | | | | | | | | | ▼ med | | |
| | | | | | 6.20 - 6.65 | S 2 | N 75 | | | | | |
| | | | | 7.20 | | | | | | | | |
| Medium dense brown clayey medium/coarse grained SAND, with some fine grained gravel. Dense from 9.00m with coarser gravel. | | | (2.80) | | 7.50 - 7.95 | S 3 | N 15 | | | | | |
| | | | | | 9.00 - 9.45 | S 4 | N 38 | | | | | |
| | | | | 10.00 | | | | | | | | 27/6 |
| Borehole Completed | | | | | | | | | | | | |

General Remarks :
Small seepage of water @ 3.00m. Water strike 5.70m rising to 4.90m in 20 minutes.

Dates : 26/6/91-27/6/91
Driller : T.B.
Engineer: REB

## BGS BOREHOLE REFERENCE: SJ08SW87

Easting: 302990
Northing: 381370
Date: 1991
Length: 10.00m

STRATA SURVEYS LTD.,
Telephone: 0606 84 4637 Fax: 0606 84 6657

Borehole Number : 3
Sheet 1 of 1.

Job Number : 6034 Location : Maes Gwilym, Rhyl.
Client : Whelmar, Chester.

Dia. & Drilling Methods
light cable percussion
150mm diameter

302997
381373

| Description of Strata | Red. Level | Legend | Thick -ness | Depth m | Sample Depths | Sample Types | N Value | Cu | φ | Water Level | Pie -zo | Daily Prog. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.00 | | | | | | | | |
| TOPSOIL. | | | (0.30) | 0.30 | | | | | | | | |
| Firm/stiff brown slightly gravelly sandy CLAY (Boulder Clay). | | | | | 0.70 - 1.05 | U 1 | | | | | | |
| | | | | | 1.20 | D 1 | | | | | | |
| | | | | | 1.70 - 2.08 | U 2 | | | | | | |
| | | | (3.10) | | 2.20 | D 2 | | 40 | 14 | | | |
| | | | | | 2.60 - 3.05 | U 3 | | | | | | |
| | | | | | 3.10 | D 3 | | | | | | |
| Loose brown silty very clayey fine grained SAND. | | | | 3.40 | 3.60 - 3.91 | U 4 | | | | | | |
| | | | (0.90) | | | | | 17 | 0 | | | |
| Medium dense brown clayey fine/medium grained SAND. | | | | 4.30 | 4.40 - 4.65 | S 1 | N 20 | | | | | |
| | | | (1.00) | | | | | | | | | |
| Medium dense brown gravelly very clayey fine/medium grained SAND, becoming Clay @ 6.40m, dense very clayey fine/medium grained Sand from 7.30m. | | | | 5.30 | 5.90 | W 1 | N 15 | | | 9.25/6 | | |
| | | | | | 5.90 - 6.35 | S 2 | | | | tsl | | |
| | | | (2.20) | | 6.40 | D 4 | | | | | | |
| | | | | | 7.30 - 7.75 | S 3 | N 44 | | | V fast | | |
| Very stiff brown slightly gravelly sandy CLAY (Boulder Clay). | | | | 7.50 | | | | | | | | |
| | | | | | 8.00 - 8.30 | S 4 | N 63 /300 | | | | | |
| | | | (2.50) | | | | | | | | | |
| | | | | | 9.50 - 9.80 | S 5 | N 73 /300 | | | | | |
| Borehole Completed | | | | 10.00 | | | | | | | | 25/6 |

General Remarks :
Water strike 7.30m rising to 5.90m in 30 minutes.
Chiselling: 1hr 7.50m-10.00m.

Dates : 26/6/91
Driller : T.B.
Engineer: REB

## BGS BOREHOLE REFERENCE: SJ08SW88

Easting: 303000
Northing: 381340
Date: 1991
Length: 10.00m

STRATA SURVEYS LTD.,
Telephone: 0606 84 4637 Fax: 0606 84 6657

Borehole Number : 4
Sheet 1 of 1.

Job Number : 6034 Location : Maes Gwilym, Rhyl.
Client : Whelmar, Chesster.

Dia. & Drilling Methods
light cable percussion
150mm diameter

303004
381341

| Description of Strata | Red. Level | Legend | Thick -ness | Depth m | Sample Depths | Sample Types | N Value | Cu | a | Water Level | Pie -zo | Daily Prog. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.00 | | | | | | | | |
| TOPSOIL. | | | (0.20) | 0.20 | | | | | | | | |
| Stiff brown slightly gravelly sandy CLAY (Boulder Clay), hard from 1.60m. | | | | | 0.60 - 0.93 | U 1 | | 62 | 16 | | | |
| | | | | | 1.20 | D 1 | | | | | | |
| | | | | | 1.60 - 2.05 | U 2 | | | | | | |
| | | | (3.30) | | | | | 111 | 35 | | | |
| | | | | | 2.20 | D 2 | | | | | | |
| | | | | | 2.60 - 3.05 | U 3 | | | | | | |
| | | | | | 3.10 | D 3 | | 120 | 33 | | | |
| | | | | 3.50 | | | | | | | | |
| Medium dense brown clayey fine grained SAND. | | | (0.70) | | 3.60 - 4.05 | S 1 | N 24 | | | | | |
| | | | | 4.20 | | | | | | | | |
| Very dense brown very clayey very gravelly fine/medium grained SAND. with cobble from 6.20m-6.90m. | | | | | 4.50 - 4.95 | S 2 | N 58 | | | | | 27/5 |
| | | | (2.80) | | | | | | | | | |
| | | | | | 6.00 - 6.30 | S 3 | N 64 /300 | | | | | |
| | | | | 7.00 | | | | | | | | |
| Very stiff brown slightly gravelly sandy CLAY (Boulder Clay). | | | | | 7.20 - 7.60 | U 4 | | | | | | |
| | | | | | 7.70 | D 4 | | | | | | |
| | | | (3.00) | | | | | | | | | |
| | | | | | 9.00 - 9.40 | U 5 | | | | | | |
| | | | | 10.00 | 10.00 | D 5 | | | | | | 28/5 |
| Borehole Completed | | | | | | | | | | | | |

General Remarks :
No water encountered during boring.
Chiselling: 45mins 6.20m-6.90m; 1hr 7.00m-10.00m.

Dates : 27/6/91-28/6/91
Driller : T.B.
Engineer: REB

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