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Dŵr Cymru Welsh Water

Menai Strait - Shellfish Waters Project

Hydrogeological Impact Assessment for Temporary Construction Dewatering

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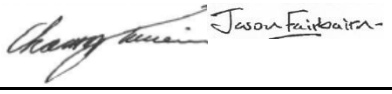
		Signature			
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1. Introduction

1.1 Purpose of this report

This report presents a Hydrogeological Impact Assessment (HIA) of temporary construction dewatering activities required for Menai Strait - Shellfish Waters Project in Bangor. This is furthermore known in this report as "The Site".

'Water Abstraction and Impounding (Exemptions) Regulations 2017' requires that certain temporary construction dewatering activities in England and Wales require an abstraction licence. This report presents an estimate of the expected abstraction quantities required to assess whether an abstraction license is required and also a hydrogeological assessment of those quantities on water features.

An abstraction license application has been submitted for abstraction of up to 200m^3/day. This is a conservative quantity based on a permeability of 1.5x10^{-5} m/s, to ensure that there is sufficient flexibility for the dewatering operation. The actual abstraction rate is likely to be lower based on the pumping test results (which abstracted at approximately 14m^3/d and indicated a ground permeability of 2.0x10^{-6} m/s).

The temporary construction dewatering requires drawdown beneath the formation level of the structure to a level of approximately 0.5mOD, with any variation in abstraction rate the result of different hydrogeological parameters (groundwater levels, permeabilities or zone of influence) than anticipated from the ground investigation. It is noted that the water table was drawndown to the target level in the vicinity of the pumping well, during the pumping test.

This report outlines a conceptual hydrogeological model of the construction site, summarises the findings of additional ground investigation, considers the potential connection and risk of impact on nearby sensitive environmental receptors. The conceptual model has then been used to inform a Tier-1 HIA following NRW guidelines [1].

1.2 Legislative background

The introduction of the 'Water Abstraction and Impounding (Exemptions) Regulations 2017' in England and Wales has introduced the need to licence temporary construction dewatering activities in certain situations.

All large-scale groundwater abstractions required for construction dewatering, as of January 2018, require a licence to carry out these operations. These regulations have been brought into motion to help create a fairer system for all abstractors as well as enable the Regulator to manage water resources more effectively.

The regulations are cited as the 'Water Abstraction and Impounding (Exemptions) Regulations 2017'[2]. Under Part 2, Section 5 (entitled 'Small scale dewatering in the course of building or engineering works') of these Regulations, the following exemptions to groundwater abstraction licencing are identified:

"Small scale dewatering in the course of building or engineering works"

- 5.(1) The restriction on abstraction does not apply to an abstraction or series of abstractions of water carried out in the course of building or engineering works for the purpose of dewatering from a sump or excavation if:
  - (a) the abstraction or series of abstractions are temporary and, in any event, carried out over a period of less than six consecutive months beginning with commencement of the first abstraction;
  - (b) each abstraction does not cause or is not likely to cause damage to a conservation site or specific features in such a site;
  - (c) each abstraction does not cause or is not likely to cause damage to protected species; and,
  - (d) either:
    - (i) the water abstracted is immediately discharged to a soakaway; or,
    - (ii) the volume of water abstracted is less than 100 cubic metres of water per day and there is no intervening use of that water before discharge.
- 5.(2) Where the abstraction is undertaken within 500 metres of a conservation site or within 250 metres of a spring, well or borehole used to supply water for any lawful use, paragraph (1)(d)(ii)

applies in respect of that abstraction as if the reference to 100 cubic metres of water per day were a reference to 50 cubic metres of water per day."

All of these provisions listed above must be satisfied to qualify for an abstraction licence exemption. All abstractions less than 20 m^3/d, for whatever use, will not need an abstraction licence.

1.3 Description of proposed construction activities

The Welsh Water Menai Shellfish Project aims to improve the storm overflow performance from the Bangor Beach Road Sewage Pumping Station (SPS). This pumping station is one of four assets that fall under the Asset Management Plan (AMP) 7 National Environmental Programme (NEP) to meet the Shellfish Water Directive of 10 No. spills per annum for the Menai Strait. The identified solution requires new infrastructure to be installed below ground level at a site located between the A5 Beach Road and the promenade along the Menai Strait (**Figure 1**).

The scheme proposals comprise a buried stormwater run-off tank with a volume of around 4,300m^3 and associated pipework to connect into the existing foul water network and Menai SPS. A below ground stormwater tank is approximately 60m by 40m and will be constructed to a maximum depth of 5.5m below existing ground level. Construction excavations are anticipated to reach 6.0m bgl at their deepest. The tank will be connected to the existing SPS through a new 500mm diameter raising main pipe and a 600mm gravity pipe which will connect the tank to an existing manhole within the car park to the north-west.

The proposed dewatering activities, including construction phases of excavation and installation will be temporary and are currently programmed to be completed over a period of 6 months, subject to site progress and receipt of relevant consenting.

Upon completion of the tank construction, the playing field will be reinstated and, at the time of writing of this report, is understood to remain in use as a football pitch.

1.4 Need for an abstraction licence

It is anticipated that an abstraction licence will be required to permit dewatering at the Site. The Site is within 500m of a number of conservation sites (Traeth Lafan SSSI, Menai Strait and Conwy Bay SAC, Traeth Lafan/Lavan Sands SPA and Coedydd Afon Menai) and therefore an abstraction licence would be necessary for discharge rates above 50m^3/d. Additionally, since the dewatering works are anticipated to potentially be more than six months duration, the abstraction would not fall into the exemption category, and so would require an abstraction licence for any groundwater abstraction above 20m^3/d.

Estimated discharge rates based on the results of the pumping test and an equivalent well analysis indicate that the flow rate from dewatering could be around 60m^3/d (0.7l/s). Accounting for the potentially higher estimated permeability of the Made Ground, conservative estimates of the dewatering rates could be as high as 200m^3/d (2.3l/s). As both estimated dewatering rates exceeds the 50m^3/d threshold as cited in the regulations, an abstraction licence will be required.

1.5 The HIA methodology

NRW have stated that an application for an abstraction licence must be accompanied by a HIA. The HIA methodology is described in 'Hydrogeological Impact Appraisal for dewatering abstractions'[1]. The HIA methodology is composed of a series of 14 steps as follows:

1. Establish the regional water resource – see Section 2;
2. Develop a conceptual model for the dewatering operation and the surrounding area – see Section 3;
3. Identify all potential water features which are susceptible to flow impacts – see Section 4.1;
4. Apportion the likely flow impacts to the water features – see section 4.2;
5. Mitigate the flow impacts – see Section 4.3;
6. Assess the significance of the net flow impacts – see Section 4.4;

7. Define the search area for drawdown impacts – see Section 5.1;
8. Identify all potential water features which could be impacted by drawdown – see Section 5.2;
9. Predict the likely drawdown impacts – see Section 5.3;
10. Mitigate the drawdown impacts – see Section 5.4;
11. Assess the significance of net drawdown impacts – see Section 5.5;
12. Assess the water quality impacts – see Section 6;
13. Redesign the mitigation measures to minimise flow and drawdown impacts – see Section 7; and
14. Develop a monitoring strategy – see Section 8.

2. Regional Water Resource Status

The Site is located within the Lleyn and Eryri surface water catchment [3]. Surface water and groundwater availability for the location of the Site has not been assessed or set out in the 'Lleyn and Eryri Abstraction Management Strategy 2015'[3], so it is assumed that abstraction licences are determined on a case by case basis.

3. Conceptual Model

3.1 Site location and topography

The Site is in Bangor, North Wales (Grid Reference SH 58618 72847) and is located on a grassed recreation ground (used as a football pitch) bounded by Beach Road to the south and the seafront promenade to the north-east. To the west, the Site is bounded by a car park and a small building housing changing rooms. The Menai SPS is located to the north of the Site, discharging into the Menai Strait. The proposed dewatering activity will take place for the duration of construction of the stormwater run-off tank and associated infrastructure which is shown in the site plan in **Figure 1**.

The topography of the Site is generally level at approximately 6.5mAOD. The Site forms reclaimed land, built up circa 4-5m from the original beach level and was initially used as a recreational ground from 1929. It was subsequently landscaped which is assumed to have created the level recreation ground that is now present. The tidal range in the Menai at the nearest gauge (Llandudno) varies from -3.37mOD (mean low water spring tide) and 3.83mOD (mean high water spring tide).

3.2 Published Geology

3.2.1 Superficial geology

The published British Geological Survey (BGS) 1:50,000 scale mapping [6] indicates that the Site is directly underlain by Made Ground (Artificial Deposits) overlying Quaternary Coastal Zone Deposits (undifferentiated comprising sand, silt and clay). The mapping shows the Coastal deposits extend northeast of the Site below the Menai Strait. On the landward side beyond the A5 road, superficial deposits comprising of Quaternary tidal flat deposits (silt and clay) and Glacial Till (Devensian Diamicton) are present. **Figure 2** shows the BGS 1:50,000 scale mapping Superficial Geology [4].

3.2.2 Bedrock geology

The published British Geological Survey (BGS) 1:50,000 scale mapping [5] shows that below the superficial deposits are the Ordovician bedrock strata of the Nant Ffrancon subgroup - siltstone comprising of mudstones, silty mudstones and sandstones. There are no mapped faults located below the Site however the bedrock within the Bangor area is highly faulted comprising of northwest-southeast and southwest-northeast

oriented features. **Figure 2** shows the BGS 1:50,000 scale mapping Bedrock Geology and location of faults [4].

3.3 Ground investigation

Two phases of ground investigation have been undertaken at the Site in 2023 to inform the design of the Menai Strait stormwater tank. The first phase of ground investigation [7] which took place between 17th April and 27th April 2023 comprised of three cable percussive boreholes with rotary follow-on, two dynamic probe test holes, and three trial pits. The exploratory hole locations are presented in **Figure 1** and the scope of the investigation is presented in **Table 1**.

Table 1: Scope of ground investigation

Type	Number	Final depth (m bgl)	Purpose
Dynamically sampled borehole rotary cored follow on	3	14.95 to 23.95	To investigate the deeper ground conditions, take soil samples for chemical and geotechnical laboratory testing, take SPT tests, allow for installation of standpipes, monitor and sample groundwater, and allow for variable head infiltration tests to be conducted
Dynamic Sample Boreholes with Dynamic Probe Test Follow-on	2	3.00 to 3.73	To gather information on the shallow ground conditions, take soil samples for chemical and geotechnical laboratory testing
Machine excavated trial pit	3	2.40 to 2.80	To gather information on the shallow ground conditions, take soil samples for chemical and geotechnical laboratory testing

Groundwater standpipes were installed in BH01 (2.0 to 5.0m – Made Ground) and BH02 (2.5 to 7.0m – Made Ground & upper Coastal Zone Deposits) within the superficial deposits, to enable gas and groundwater monitoring. Three permeability tests were undertaken within the ground investigation boreholes; two within the Made Ground and one within the deeper Coastal Zone Deposits (Silt). The tests in BH01 and BH02 were undertaken within the standpipes following completion of the borehole, whilst the test in BH03 was conducted during a pause in drilling (no standpipe installed in BH03). A summary of the ground conditions encountered is provided in **Table 2**.

Table 2: Summary of stratigraphy encountered during the GI

Stratum	Depth to top of stratum (mbgl)	Thickness (m)	Description / Remarks
Made Ground	Surface (approx. 5.7 to 6.3mOD)	5 to 6	0.2 to 0.4m of topsoil encountered in all exploratory holes. Gravelly clayey SAND or a gravelly sandy CLAY / SILT. Gravels comprised of include siltstone, slate, clinker, wood, glass, brick fragments, mudstone, sandstone, granite, ceramic tiles, limestone, slag, metal and quartz. Some soils samples contain medium to high cobble content made up of predominantly slate.
Coastal Zone deposits	5 to 6 (where present)	2 to 2.4 (where present)	Very sandy clayey GRAVEL with high cobble content. Not identified in BH03.
Coastal Zone deposits (Clays / Silts)	6 to 8	2 to 5	Very soft to firm dark grey or grey mottled brown or occasionally black silty gravelly CLAY. Gravel is subangular to subrounded fine to medium of siltstone, mudstone and quartz. Occasionally described as laminated, water softened, containing wood fragments and plant matter, with an organic odour, and with white shell fragments.
Coastal Zone deposits (Basal Sands and Gravels)	10 to 11 (where present)	1.5 to 2 (where present)	Identified in BH03 as GRAVEL (driller's description, rotary open-hole technique). Not identified in BH01.

Highly weathered Nant Ffrancon Siltstone (Firm to Very Stiff Clays)	11 to 13	Unproven	Firm to very stiff grey slightly sandy slightly gravelly CLAY. Gravel is fine to coarse and subangular to subrounded fine to coarse of mudstone, siltstone and quartz.

A second phase of ground investigation [8] was undertaken between 21st November and 14th December 2023. This investigation comprised of the drilling of a pumping well (PW01) and three monitoring standpipes (MW01, 02 and 03) to undertake groundwater pumping testing. The pumping tests comprised of a 72-hour constant rate test with recovery and a 24-hour pumping and recharge trial. Groundwater monitoring during the pumping tests was undertaken at each of the monitoring boreholes including those installed during the first phase of investigation. The factual pumping test report is provided in **Appendix A**.

3.4 Hydrogeology

3.4.1 Groundwater levels

During the first phase of ground investigation, the groundwater elevation in BH01 varied between 1.6m AOD and 2.2m AOD (4.1m bgl and 3.5m bgl), whilst in BH02 varied between 1.8m AOD and 2.1m AOD (4.44m bgl and 4.14m bgl). The borehole location plan is shown in **Figure 1**. Groundwater monitoring data indicated a slight tidal influence on groundwater levels with the response more pronounced in BH01 which is expected given its closer proximity to the seafront. In BH01, groundwater levels showed 0.6m variance between spring and neap tides, whilst 0.2m difference was observed in groundwater levels between high and low tides.

During the pumping test investigations, groundwater monitoring was undertaken at each borehole standpipe. However, due to the testing undertaken, the only period with no pumping or recovery being undertaken was between the 3rd and 4th December 2023. During this period, groundwater levels at the Site were broadly stable however the groundwater levels varied from around 2.05mOD at MW02 to 2.4mOD at BH02. MW01, MW02, MW03, PW01 and BH02 generally showed similar variation in groundwater level (and response to pumping) with very little tidal influence observed. BH01 (screened only in the Made Ground) did not respond to pumping during the test and showed variation in groundwater levels in response to tidal effects.

During the 72-hour pumping test, at a rate of approximately 0.17l/s (14.7m^3/d), groundwater levels at the pumping well were lowered by a maximum of 6.1m. Groundwater levels at the observation standpipes were lowered by 2.5m at MW01 (5m from the pumping well), 2.3m at MW02 (10m from the pumping well), 2.4m at BH02 (21m from the pumping well) and 0.5m at MW03 (35m from the pumping well). No response to pumping was observed at BH01 located approximately 17m from the pumping well.

3.4.2 Aquifer properties

Three permeability tests were undertaken within the first ground investigation boreholes; two within the Made Ground and one within the deeper Coastal Zone Deposits (Silt). The tests in BH01 and BH02 were undertaken within the standpipes following completion of the borehole, whilst the test in BH03 was conducted during a pause in drilling (no standpipe installed in BH03).

The rising head tests undertaken within the Made Ground in BH01 and BH02 provided estimated hydraulic conductivity values of 6.3 x 10^{-5} m/s (soil described as gravelly sand) and 3.0 x 10^{-6} m/s (described as sandy clayey gravel) respectively. The falling head test undertaken in the Coastal Zone Deposits (soil in the test interval described as very soft to soft silt) provided an estimated hydraulic conductivity value of 4.4 x 10^{-8} m/s.

A 72-hour constant rate pumping test was carried out on Site between 4th December and 7th December 2023 to evaluate the hydraulic properties of the Superficial deposits at the Site and establish the potential radius of influence from pumping during dewatering. The pumping well was screened from 3mOD to -6mOD, across both the Made Ground and Coastal Zone Deposits and only a bulk permeability of the Made Ground and Coastal Zone Deposits could be established. The results indicated a bulk permeability of around 2x10^{-6} to 4x10^{-6} m/s. The results and analysis of the testing is provided in **Appendix B**.

3.4.3 Groundwater quality

Groundwater quality samples collected during the first phase of investigation found that there were some minor exceedances of cadmium, nickel, and zinc compared to the saltwater environmental quality standards (SEQS). Manganese was also found to exceed the SEQS for all samples. Cyanide exceeded the freshwater EQS for all samples.

Two water quality samples from the pumping well were taken during the constant rate pumping test. The groundwater quality of the pumped water was found to be brackish, with a total dissolved solids concentration of between 2,700 and 2,900mg/l. This is likely to be as a result of mixing of water from the Menai Strait. The pumped water showed exceedances of Copper, Zinc and Manganese compared to the SEQS.

3.5 Water features

A water features survey was carried out as part of the consent to pumping test. The surveys were undertaken between the 20th and 21st of July 2023 to establish potential water features within 1km of the pump test location. A 1km buffer was chosen as a very conservative search radius to ensure all features were captured in the survey. The water features survey is provided in **Appendix C**.

The closest water body to the proposed stormwater tank is the Menai Strait, the mean high-water level of which is located approximately 10m from the northern most part of the storage tank. This is located beyond the Bangor promenade and forms Bangor Flats beach during low tide, The Menai Strait is both a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC). However, the areas adjacent to the Site and around Bangor harbour are not designated. The closest designated area is approximately 475m from the Site.

The nearest other water features proximal to the Site include two surface water discharges onto Bangor Flats beach from a culvert and the outlet into the Menai Strait from a disused dock. Other water features were observed within the 1km search radius and are included in **Appendix B**. It is unlikely that these will be impacted by the temporary dewatering given the limited drawdown required and low to moderate permeability observed during the investigations.

3.6 Construction activities associated with removal of groundwater

The proposed construction programme at the Site includes excavation and dewatering to aid safe excavation and construction of the stormwater tank. The dewatering will be temporary however the anticipated duration is currently around or greater than six months. This applies to the proposed dewatering to facilitate construction of the stormwater tank and associated infrastructure which has approximate dimensions of around 24m by 60m and will be constructed to a minimum elevation of around 1mOD (5mbgl). The location of the proposed works are provided in **Figure 1**.

Figure 1 Site layout including ground investigation and pumping test locations

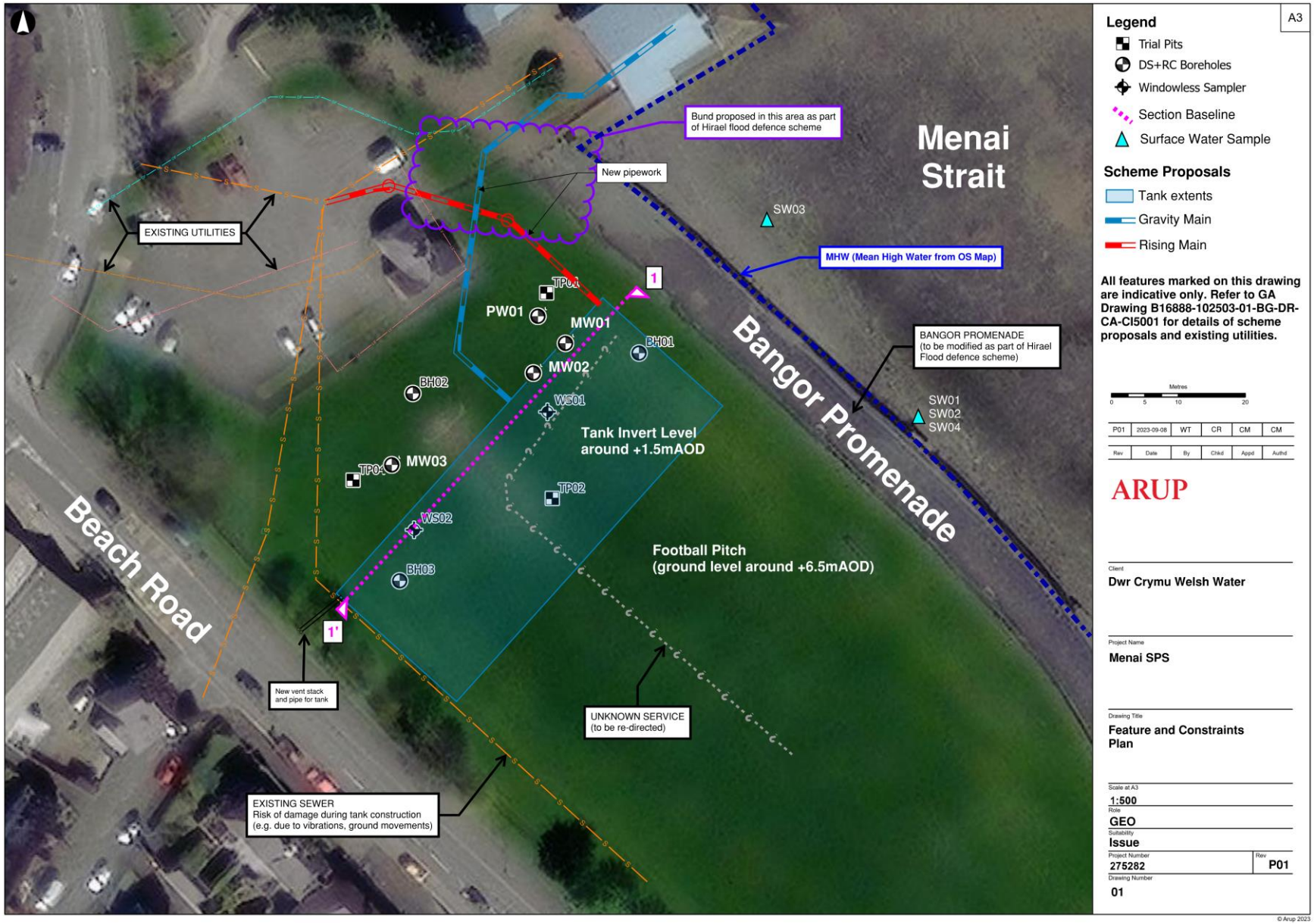
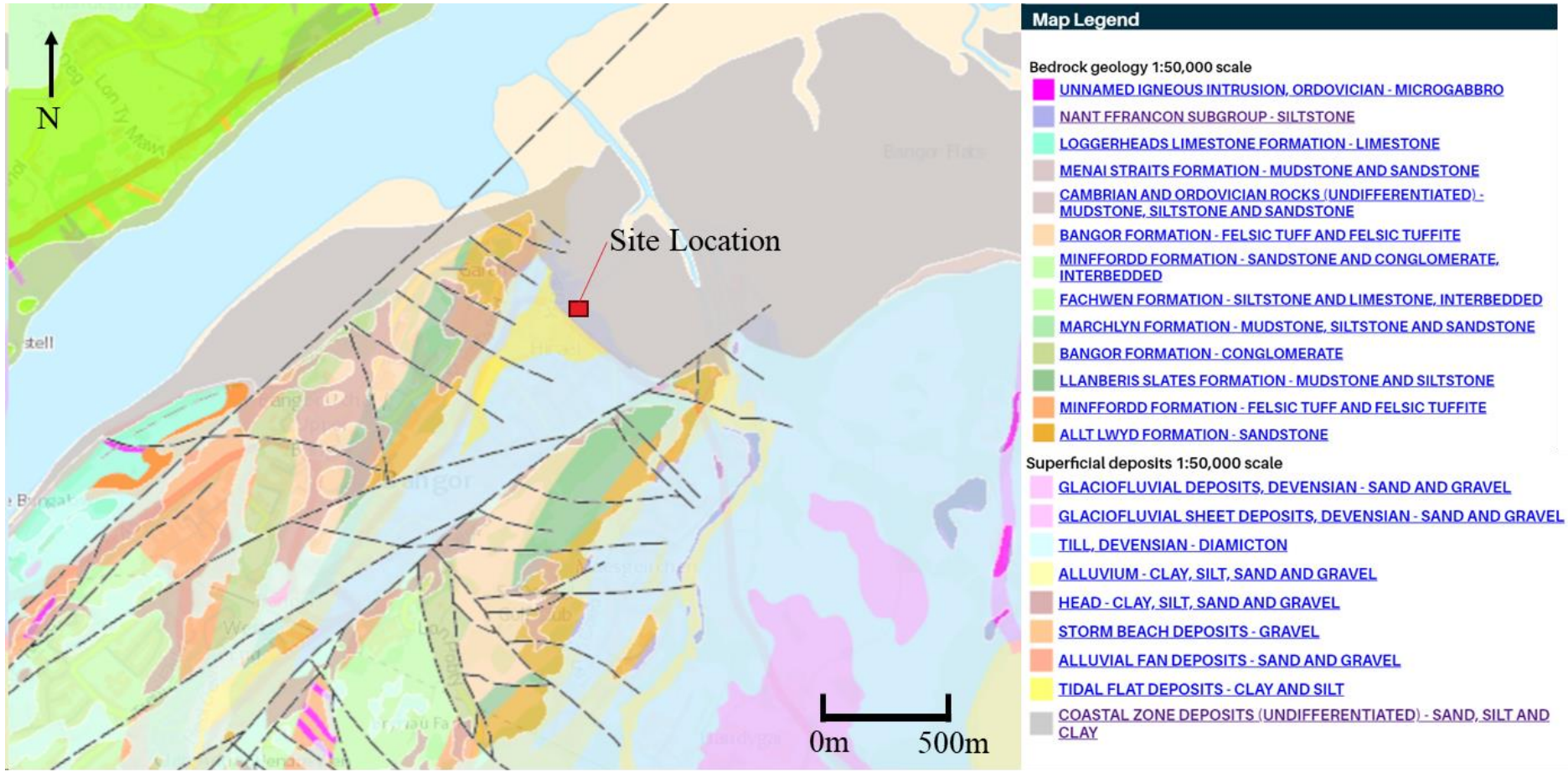


Figure 2 BGS 1:50,000 scale mapping (Superfiial and Bedrock Geology [4]



4. Flow impacts

4.1 Water features susceptible to flow impacts

The location of water features are show in **Appendix C**.

- **Menai Strait:** The Menai Strait and Bangor Flats beach are located adjacent (approximately 10m) from the proposed stormwater tank. The Menai Strait is likely to be hydraulicly connected with the shallow Made Ground and underlying superficial deposits. However, the groundwater monitoring data indicates that there is limited tidal influence of the groundwater levels at the Site. This suggests that the actual hydraulic connection may be limited, possibly as a result of lower permeability material being present, which was observed in one of the falling head tests undertaken in the first ground investigation. That brackish water was observed during the pumping test indicates that the groundwater and Menai Strait are hydraulically connected however the connection is not immediate. The contribution of groundwater to the Menai Strait is likely to be negligible compared to the volume of water within the water body.
- **Surface watercourses:** An unnamed watercourse is shown on mapping located approximately 50m to the west of the stormwater tank. However, the water feature appears to be culverted below ground and outfalls to the Menai Strait to the north of the Site (confirmed during the water features survey). As the watercourse is culverted, it is unlikely that there will be a hydraulic connection to groundwater. The water features survey also showed other surface watercourses within 1km of the Site but none within 500m.
- **Local springs:** The water features survey indicated that there are 3 sites with potential springs within the 1km search radius however none of these are within 500m of the Site. During the water features survey (Appendix C) no spring was observed at feature 13 whilst potential springs were observed at features 6 and 7 at approximately 800-900m distance.
- **Licenced and unlicenced groundwater abstractions:** There are no licenced groundwater abstractions within 1km of the Site. During the water features survey, two unlicenced abstraction wells (feature 12) were found to the northwest of Bangor, close to the Menai Strait. The wells are approximately 400m-500m distance from the Site and are understood to supply a local resident. No information is available on the depth of the wells or which strata they are pumping from. Given the proximity to the Menai Strait it is likely that the wells extract water from deeper bedrock strata.

4.2 Flow impacts

Based on the results of the site investigation and assessment of the nearby water features, there are considered to be no receptors that will be impacted by changes in flow caused by the temporary dewatering at rates of 60m^3/d (estimate based on pumping test results) or 200m^3/d (conservative maximum estimate).

Although dewatering at up to 200m^3/d (2.3 lit/sec) may temporarily reduce the rate of groundwater flow to the Menai near to the Site, it is unlikely to have a discernible impact on baseflow to the Menai. This is due to the relatively insignificant abstraction volume compared to the volume of water in the Menai Strait water body. Furthermore, the limited observation of tidal groundwater behaviour on the site indicates that connection between the groundwater and the Menai Strait is limited. It is also noted that during low tide, the water level in the Menai Strait will be below the target dewatering level. The loss of a minor quantity of groundwater flow within the Made Ground and Superficial Geology is considered unlikely to have any discernible effect on flow within the Menai Strait.

Furthermore, the Menai is not classified as a SSSI in the area adjacent to the stormwater tank although the Site is within 500m of the SSSI; the nearest boundary to the SSSI is on the other side of the harbour.

Flow impacts on the culverted watercourse are not expected due to the assumed lack of hydraulic continuity between the water bodies.

All other water features are more than 400m from the site. With drawdown limited at the site to 1-2m, impacts on baseflows at these distances is anticipated to be negligible. This is particularly the case, with the

dominant Menai Strait head boundary being adjacent to the site which will limit the zone of influence to the northwest and southeast (along the coastline).

4.3 Mitigation of flow impacts

Based on the assessment of flow impacts, no mitigation is deemed necessary. The Menai will be observed throughout the works to ensure no unforeseen impacts occur from the temporary dewatering operation.

4.4 Significance of flow impacts

No significant flow impacts are anticipated as a result of temporary dewatering.

5. Drawdown Impacts

5.1 Search area for drawdown impacts

Groundwater levels at the Site are likely to require lowering by between 1.5m to 2m, assuming a baseline groundwater level of between 2mOD and 2.5mOD, and a target drawdown to around 0.5mOD to 1mOD. Drawdown will principally be required within the Made Ground deposits in which the excavation will take place. However, it is likely that drawdown in the underlying Coastal Zone Deposits will also occur.

Based on the results of the pumping test, which abstracted groundwater at a rate of approximately 14m^3/d, over 72 hours, the estimated distance of influence (using the distance drawdown data once groundwater levels had stabilised) was conservatively estimated to be approximately 150m. Drawdown locally around the pumping test exceeded the required drawdown required for the construction of the stormwater tank (pumping at a rate of 0.17l/s).

The main dewatering operation will not aim to lower the groundwater table further than the pumping test, but will draw down the water table over a larger footprint and for a longer period of time. As such, the zone of influence of the main dewatering operation could theoretically be greater than observed during the test. However, this is likely to be limited by the dominance of the Menai Strait water body acting as a source of recharge and the limited spatial extent of the Made Ground. The drawdown data from the pumping test indicates a barrier boundary (see Figure 6) was observed during the pumping test which supports the assumed limited spatial extent of the groundwater body and associated zone of influence.

The abstraction values of 60m^3/d and 200m^3/d applied for in the license are calculated in Table 7 (using the Dupuit-Forcheimer equation for steady state flow in an unconfined aquifer). The 60m^3/d value is based on a 2.0m drawdown, a permeability of 2x10^{-6} m/s (from the pumping test) and a zone of influence of 8.5m. The 200m^3/d value is based on a 2.0m drawdown, a permeability of 1.5x10^{-5} and a zone of influence 23.0m. The calculations use small zones of influence (as may be experienced in the early stages of the dewatering) to provide conservative estimations of abstraction rates. If the pumping test zone of influence of 150m is used within the equations this results in calculated steady state abstraction rates of 9m^3/d and 65m^3/d respectively.

Table 1 shows the estimated radius of influence based on different hydraulic conductivity assumptions. The Sichardt equation used in these estimates is generally advised against in HIA guidance given its empirical nature, however, they have been included as a comparison against the distance interpreted from the pumping test extrapolation of data. The estimated distance of influence in Table 1 is significantly lower than that estimated from the pumping test results. For estimating drawdown impacts, a minimum value of 150m has been used.

Table 3: Scope of ground investigation

Hydraulic conductivity (m/s)	Source	Distance of influence (m)
6x10^{-5}	Maximum falling head test value	47
1.5x10^{-5}	Weighted average K value based on variable head and pumping test data (Appendix D)	23

Hydraulic conductivity (m/s)	Source	Distance of influence (m)
$2x10^{-6}$	Average estimated value from pumping test	8.5
- Assumes 2m drawdown, radial flow		

Further information relating to the estimation of the radius of influence and the estimated dewatering volumes is provided in **Appendix D**.

5.2 Water features susceptible to drawdown

- **Menai Strait:** The Menai Strait and Bangor Flats beach are located adjacent (approximately 10m) from the proposed stormwater tank. As noted above, the Menai Strait is likely to have some hydraulic connection with groundwater however the water body is likely to act as a constant source of water and groundwater drawdown is unlikely to extend beyond the water body boundary. During low tide, the water level in the Menai Strait will be below the target dewatering level.
- **Surface watercourses:** An unnamed watercourse is shown on mapping located approximately 50m to the west of the stormwater tank. As the watercourse is culverted, it is unlikely that there will be a hydraulic connection to groundwater.
- **Local springs:** The water features survey indicated that there are 3 sites with potential springs within the 1km search radius however none of these are within 500m of the Site. During the water features survey (Appendix C) no spring was observed at feature 13 whilst potential springs were observed at features 6 and 7 at approximately 800-900m distance.
- **Licenced and unlicenced groundwater abstractions:** There are no licenced groundwater abstractions within 1km of the Site. During the water features survey, two unlicenced abstraction wells (feature 12) were found to the northwest of Bangor, close to the Menai Strait. The wells are approximately 400m-500m distance from the Site and are understood to supply a local resident. No information is available on the depth of the wells or which strata they are pumping from. Given the proximity to the Menai Strait it is likely that the wells extract water from deeper bedrock strata.

5.3 Drawdown impacts

The zone of influence assessed by the pumping test (which drew down the water table below the dewatering target level) was 150m (see Figure 5 in Appendix B). The main dewatering operation will not aim to reduce the water table deeper than the pumping test, but draw down of the water table will occur over a larger footprint and for a longer period. As such, the zone of influence of the main dewatering operation could theoretically be greater. However, this is likely to be limited by the dominance of the Menai Strait water body acting as a source of recharge and limited spatial extent of the Made Ground.

Although there are a few water features (such as the Menai and culverted surface water courses) within the anticipated zone of drawdown, these are not anticipated to be impacted from any change in groundwater level due to their dominance as a head boundary (the Menai), the relatively limited drawdown required at the site (1-2m) and the limited hydraulic continuity to those receptors (such as the culverted water courses).

The identified springs and groundwater abstractions are over 800m and 400m respectively from the dewatering and as such any drawdown at these locations is considered to be limited and have negligible impact.

5.4 Mitigation of drawdown impacts

Based on the assessment of drawdown impacts, no mitigation is deemed necessary.

5.5 Significance of flow impacts

No significant drawdown impacts are anticipated as a result of temporary dewatering.

6. Water Quality impacts

Abstracted groundwater is currently anticipated to be discharged directly to the Welsh Water sewer network. The Contractor will adhere to the conditions of any consents from Welsh Water. Contamination of water bodies is to be prevented by utilising best practice measures (following Guidance for Pollution Prevention [9]).

A settlement tank will be used to allow settling of the abstracted water to limit levels of silt that might be released to the combined sewer. In addition, the use of a filter pack within each wellpoint (where used) will act as an additional treatment barrier by allowing the filtration of the groundwater prior to it reaching the surface.

7. Redesign mitigation methods

Currently it is proposed to discharge all of the abstracted water directly to the Welsh Water combined sewer. Discharge will be via a settlement tank to prevent excess siltation, and no negative impacts on water quality of proximal surface water courses is anticipated. Best practice pollution prevention measures will be used to prevent adverse effects to the wider environment from the construction works.

8. Monitoring and reporting plan

Regular monitoring of abstraction volumes will be undertaken throughout the duration of the dewatering works. The discharge quality will also be monitored visually to check that quality and turbidity is suitable for discharge to the combined sewer, with additional monitoring undertaken as required in line with any licenses, permits or consents.

9. Conclusions

This report presents an HIA that follows the methodology outlined in NRW guidelines. The assessment concludes that an abstraction licence will be required for the proposed construction dewatering activities at Menai SPS. This is because the estimated abstraction volume may exceed 20m^3/d, the maximum permitted abstraction volume when works could exceed 6 months.

Estimated groundwater abstraction rates based on the results of the pumping test and analytical equivalent well analysis indicate that the abstraction flow rates may be between 60m^3/d and 200m^3/d, depending on the hydraulic conductivity of the heterogenous materials at the Site. These values are conservative, and the actual abstraction rate may be lower (i.e. the pumping test reduced the water table around the pumping well to the target drawdown level at a rate of only 14m^3/d).

Based on the results of the pumping test, and the relatively limited drawdown required for the dewatering, a conservative zone of influence in the order of 150m has been assumed during the works. The localised mapped extent of the Made Ground deposits and dominance of the Menai Strait water body acting as a source of recharge will limit impacts at distance.

The assessment has reviewed possible impacts to any local water features within 1km of the site and concluded that any impacts will be negligible or non-existent. This is due to most features being more than 400m from the dewatering activity or having limited hydrogeological connectivity (culverted watercourses).

The closest receptor is the Menai Water Body where impacts are considered to be negligible due to the relatively small drawdown requirements and abstraction volumes compared to the volume of the water body.

At low tide, water levels in the Menai will be below the target dewatering level and the limited groundwater tidal response observed during monitoring indicates that there is limited hydraulic continuity between the groundwater and Menai.

In addition, no changes to the existing hydrological regime are anticipated post-construction to any water-dependent habitats as a result of the construction works. As a result, no further tiers of investigation are considered necessary, given the temporary nature of the abstraction.

10. References

[1] Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report - SC040020/SR1

[2] The Water Abstraction and Impounding (Exemptions) Regulations 2017. 2017 No. 1044, PART 2, Regulation 5. https://www.legislation.gov.uk/uksi/2017/1044/regulation/5/made Accessed 29/20/2018

[3] Lleyn and Eryri Abstraction Management Strategy 2015 https://cdn.cyfoethnaturiol.cymru/media/674761/llyn-eryri_cams_2015_english.pdf?mode=pad&rnd=131596369487270000#:~:text=We%20use%20Catchment%20Abstraction%20Management,round%20of%20CAMS%20licensing%20strategies.

[4] BGS Geoindex webmap http://mapapps2.bgs.ac.uk/geoindex/home.html.

[5] BGS :50,000 scale mapping Sheet 104: Bangor– Solid

[6] BGS scale mapping Sheet 104: Bangor - Drift

[7] Geotechnics, 2023. Ground Investigation Factual Report – Menai SPS

[8] Stuart Wells, 2024. Menai Strait pumping test factual report

Guidance for Pollution Prevention http://www.netregs.org.uk/environmental-topics/pollution-prevention-guidelines-ppgs-and-replacement-series/guidance-for-pollution-prevention-gpps-full-list/. Accessed 30/05/2018

Appendix A

Pumping test Factual Report

Menai Strait

Pumping Test Factual Report

Contract Name:	Menai Strait - Pumping Test
Client Name:	Morgan Sindall
Groundwater & Dewatering Specialist:	Stuart Wells Limited (SWL)
Report No:	SWL23-195-01-PT-01

Revision	Date	Description	Prepared By (SWL)	Checked By (SWL)
01	09 January 2023	Submission	Philip Price	Mark Pickett

For: Morgan Sindall Construction & Infrastructure Ltd. Welsh Water Capital Delivery Alliance Ty Awen Spooner Close Coedkernew Newport NP10 8FZ	Contact: Name: Steven Clarke Telephone: 07890 318641 Email : steven.clarke@morgansindall.com
By: Stuart Wells Ltd Hargham Road Shropham Norfolk NR17 1DT	Contact: Dr Mark Pickett Technical Director Telephone: 01953 458 985 Email: mark.pickett@stuartwells.co.uk

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Appendix A: Borehole Logs

Appendix B: Laboratory Test Results

1. Introduction

The project known as Menai Strait, involves an upgrade to the existing storm water network, which will include the construction of a new Storm Storage Tank. It is understood that during construction works there is a requirement to control and temporarily lower groundwater levels. As a result, a pumping test and recharge trial was proposed to be completed. The purpose of the pumping test was to provide additional data on the hydrogeological properties of the relatively shallow Coastal Zone Deposits. This information is essential to inform the design of a temporary dewatering system, identify the likely abstracted flows required, and support permit applications.

Stuart Wells Limited (hereafter referred to as SWL) were appointed by Morgan Sindall Construction & Infrastructure Ltd. (hereafter referred to as Morgan Sindall) to undertake a pumping test. As part of our works, we installed 1 no. pumping (abstraction) well (PW01) and 3 no. groundwater monitoring wells (MW01, MW02 and MW03).

In addition, 2 no. pre-existing monitoring wells (BH01 and BH2) were adopted into the groundwater monitoring network.

Our works were completed in general accordance with the Consent to Investigate a Groundwater Source, issued by Natural Resources Wales (NRW), consent no. WA/065/0017/0003, dated 14 September 2023 (herein referred to as the GIC).

Following the introduction, this Pumping Test Factual Report is structured as follows:

- Section 2: A summary of Ground Conditions encountered.
- Section 3: Scope of works.
- Section 4: Fieldwork completed.
- Section 5: Test Results.
- Section 6: Groundwater Quality.
- Section 7: Discussion.
- Section 8: References.

2. Ground Conditions

The site investigation (Geotechnics, 2023) indicates that the typical ground conditions sequence encountered at the site will comprise Made Ground overlying the Coastal Zone Deposits with the Nant Ffrancon Subgroup at depth.

The ground conditions, as encountered during our drilling phase concurred with those presented in the ground investigation. A summary of the ground conditions is presented in Table 1. Please find individual borehole logs as drilled during this ground investigation presented in Appendix A.

Table 1: Summary of ground conditions encountered

Geotechnical Unit	Thickness (m)	Depth (m BGL)	Description
Made Ground	5.2	0.0 to 5.2	Variable rubble ash fill
Coastal Zone Deposits	2.6	5.2 to 7.8	Silt
Coastal Zone Deposits	4.2	7.8 to 12.0	Silty sandy GRAVEL

Standing groundwater levels at the site were recorded during pre-test monitoring to vary at the site between 3.3 to 3.9 m depth (2.1 to 2.4 mAOD).

3. Scope of Works

The site works comprised the drilling and installation of 1 no. pumping (abstraction) well (PW01) and 3 no. groundwater monitoring wells (MW01, MW02 and MW03), using a Beretta T51 rotary drilling rig. An electric submersible pump with a capacity of up to 3 l/s was installed on a rigid PVC riser into the pumped well. The pump was powered by a 40 kVA generator.

In addition, 2 no. pre-existing monitoring wells (BH01 and BH02) were adopted as monitoring wells.

The investigation consisted of the following testing requirements:

- 1 no. Pumping Test.
  - Pre-test monitoring.
  - Equipment installation and equipment test.
  - Constant Rate Testing.
  - Recharge Trial.
  - Groundwater sampling and analysis.
  - Recovery monitoring.

A summary of each well installation is presented in Table 2. The test configuration is also shown in the layout drawing Figure 1.

TABLE 2: Well Installation Details

Well ID	Proposed Location		Ground Elevation*1 (mAOD)	Toe Depth (mBGL)	Bore dia. (mm)	liner dia. (mm)	Response (mBGL))	Target Geology*2
	Easting*1	Northing*1						
PW01 (Abstraction Well)	258635	372860	6.0	12.0	300	140	3.0 to 12.0	MG & CZD
MW01 (Monitoring Well)	258639	372857	6.0	9.0	150	50	3.0 to 9.0	MG & CZD
MW02 (Monitoring Well)	258635	372850	6.0	9.0	150	50	3.0 to 9.0	MG & CZD
MW03 (Monitoring Well)	258610	372836	6.0	9.0	150	50	3.0 to 9.0	MG & CZD
BH01 (Existing Monitoring Well)	258651	372854	5.70	15.41	102	50	2.0 to 4.9	MG
BH02 (Existing Monitoring Well)	258618	372847	6.24	23.95	102	50	2.5 to 7.0	MG & CZD

Notes: (1) All new locations and elevations are indicative only. At the time of preparing this report survey information of each location was not available.
(2) MG = Made Ground, CZD = Coastal Zone Deposits.

Figure 1: Indicative Pumping Test Layout.

4. Field Work

The programme of works undertaken at site is summarised in Table 3 below:

TABLE 3: Programme of Works

Date	Activity
21 November 2023	Drill and install PW01
22 November 2023	Drill and install MW01
22 November 2023	Drill and install MW02
23 November 2023	Drill and install MW02
30 November 2023	Equipment Installation and equipment test
01 to 04 December 2023	Pre-test monitoring
04 to 07 December 2023	Pumping Test - Constant Rate Test
04 December 2023	Groundwater sample obtained (1)
07 December 2023	Groundwater sample obtained (2)
11 to 12 December 2023	Pumping Test – Recharge Trial
12 to 14 December 2023	Recovery Monitoring

Equipment used during testing is summarised as follows:

- Submersible Borehole Pump.
- A duty 40kVA silenced generator was used to power the borehole pump, with bunded fuel tank, auto-mains failure (AMF) panel and standby generator.
- 5 no. electronic level-loggers were used at the pumping and monitoring wells to record continuous water level readings for the duration of the testing period.
- Manual water level readings were recorded using a Manual Dip Tape.
- Flow rate was monitored using 2 no. flowmeters.

5. Results

The following section presents the results obtained during the pumping test and recharge trial. The tests involved pre-test monitoring of groundwater levels, the installation of pumping test equipment, which was followed by a Constant Rate (pumping) Test (CRT), with subsequent recovery monitoring. After completion of the CRT a Recharge Trial was completed with another period of recovery monitoring.

During the Constant Rate (pumping) test a submersible pump was installed into the abstraction well (PW01) and pipework set-up to discharge groundwater, via a v-notch tank, to the local sewer (DP02). Whilst, during the Recharge Trial abstracted groundwater from PW01 was diverted to monitoring well MW03 where it was recharged directly back to the aquifer.

5.1 Pre-test Monitoring

Pre-test monitoring of the groundwater levels was completed from the 04 to 07 December 2023 at the abstraction and monitoring wells. The recorded telemetry is shown in Figure 2.

5.2 Equipment Test

An equipment test was undertaken on 30 November 2023. After the equipment testing, groundwater levels were left to recover prior to the commencement of the Constant Rate Test (CRT).

5.3 Constant Rate (pumping) Test (CRT)

The CRT was started at 10:05 on 04 December 2023 and conducted for a period of 72 hours, finishing at 10:05 on the 07 December 2023. A flow rate of 0.18 l/s was maintained during the pumping test.

A summary of water depths and drawdown achieved during the CRT is presented in Table 4. The results of the pumping test are presented in the hydrograph, Figure 3 (time-water level), whilst Figure 4 presents a semi-log plot of the distance drawdown in groundwater level.

5.4 Recovery Monitoring (1)

Upon completion of the CRT, recovery monitoring was completed until the morning of the 11 December 2023.

5.5 Recharge Trial

The Recharge Trial was started at 10:30 on 11 December 2023 and conducted for a period of 24 hours, finishing at 10:30 on 12 December 2023. A flow rate of 0.15 l/s was initially pumped, and reduced to 0.12 l/s at 15:50 on the 11 December 2023. The reduced flow rate, 0.12 l/s was maintained for the remainder of the recharge trial.

A summary of water depths and change in head achieved during the recharge trial is presented in Table 5. The results of the recharge trial are presented in the hydrograph, Figure 5 (time-water level).

5.6 Recovery Monitoring (2)

Upon completion of the Recharge Trial, recovery monitoring was completed until the loggers were removed on the 13 and 14 December 2023.

TABLE 4: Results of Pumping Test Constant Rate Test

					Pumping Test CRT @ 0.18 l/s (Tele' Data)				
Well No.	**Distance from pumped well (m)**	**Easting**	**Northing**	**Ground Elevation (mAOD)**	**Starting Water Level (mAOD)**	**Starting Water Depth (mbgl)**	**Lowest Water Level (mAOD)**	**Lowest Water Depth (mbgl)**	**Drawdown (m)**
Pumping Well (PW01)	0.10	258635.00	372860.00	6.00	3.84	2.16	9.93	-3.93	6.09
MW01	5.00	258639.00	372857.00	6.00	3.83	2.17	6.31	-0.31	2.48
MW02	10.00	258635.00	372850.00	6.00	3.95	2.05	6.21	-0.21	2.26
MW03	34.66	258610.00	372836.00	6.00	3.90	2.10	4.46	1.54	0.56
BH01	17.09	258651.00	372854.00	5.70	3.46	2.24	3.48	2.22	0.02
BH02	21.40	258618.00	372847.00	6.24	3.85	2.39	6.22	0.03	2.37

TABLE 5: Results of Recharge Tria

					Recharge Trial CRT @ 0.12 l/s (Tele' Data)				
Well No.	**Distance from pumped well (m)**	**Easting**	**Northing**	**Ground Elevation (mAOD)**	**Starting Water Level (mAOD)**	**Starting Water Depth (mbgl)**	**Lowest Water Level (mAOD)**	**Lowest Water Depth (mbgl)**	**Change (m)**
Pumping Well (PW01)	0.10	258635.00	372860.00	6.00	3.83	2.17	6.79	-0.79	2.95
MW01	5.00	258639.00	372857.00	6.00	3.83	2.17	5.31	0.69	1.47
MW02	10.00	258635.00	372850.00	6.00	3.98	2.02	5.17	0.83	1.19
MW03	34.66	258610.00	372836.00	6.00	3.94	2.06	2.51	3.49	-1.43
BH01	17.09	258651.00	372854.00	5.70	3.41	2.29	3.43	2.27	0.01
BH02	21.40	258618.00	372847.00	6.24	3.84	2.40	5.07	1.17	1.24

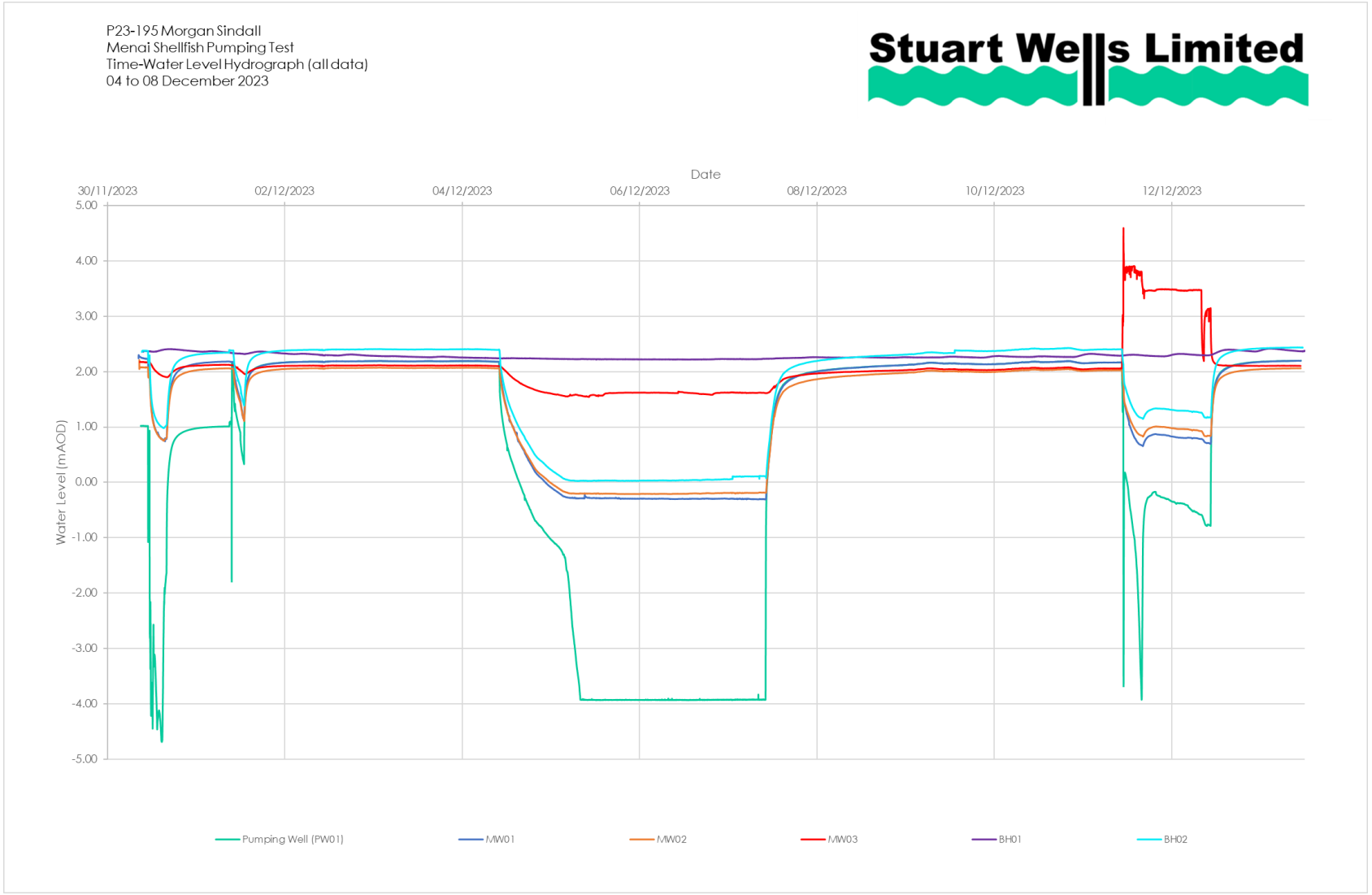

Figure 2: Pumping Test and Recharge Trial – Time-Water Level Hydrograph (all data)

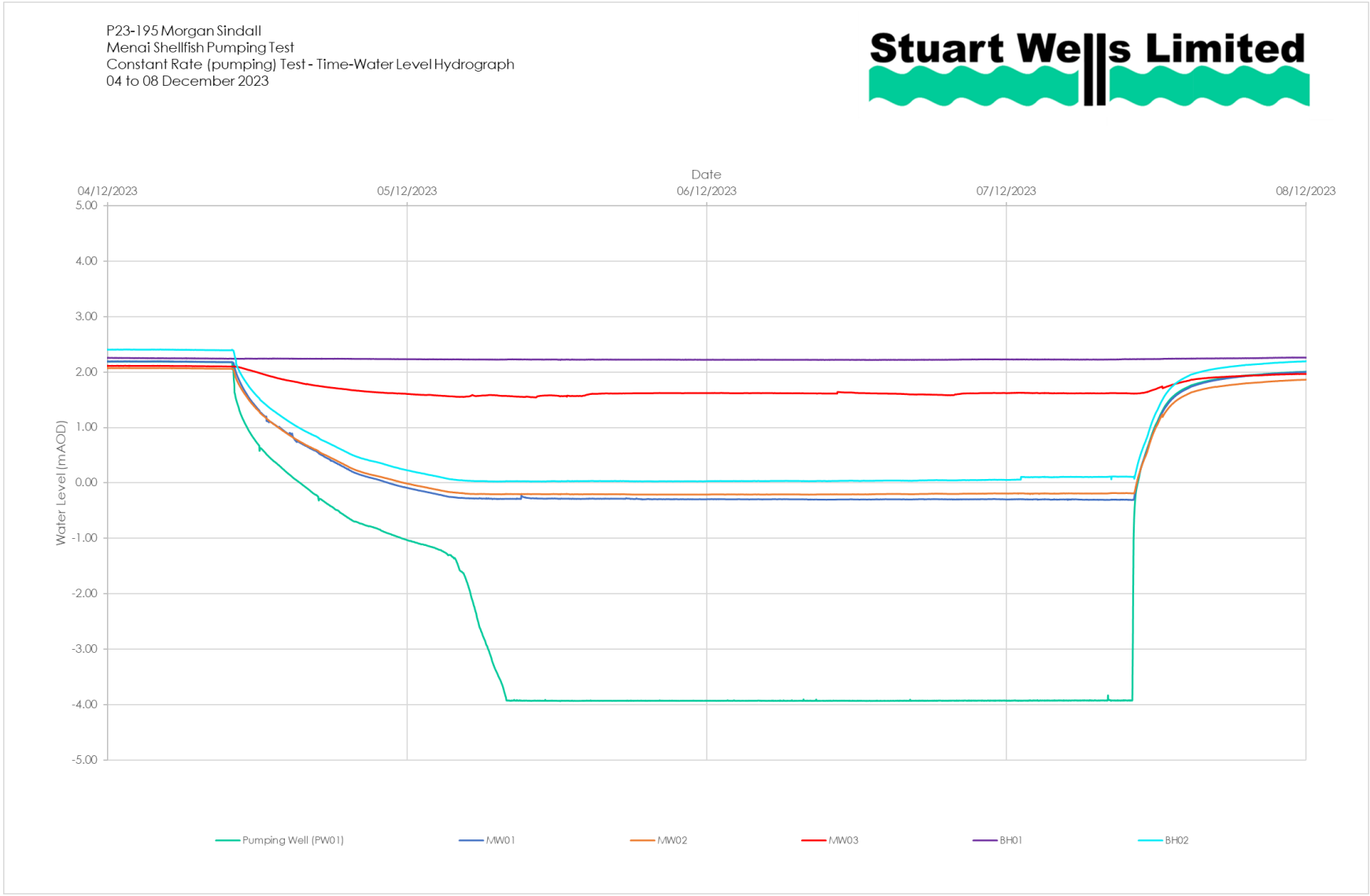

Figure 3: Constant Rate (pumping) Test – Time-Water Level Hydrograph

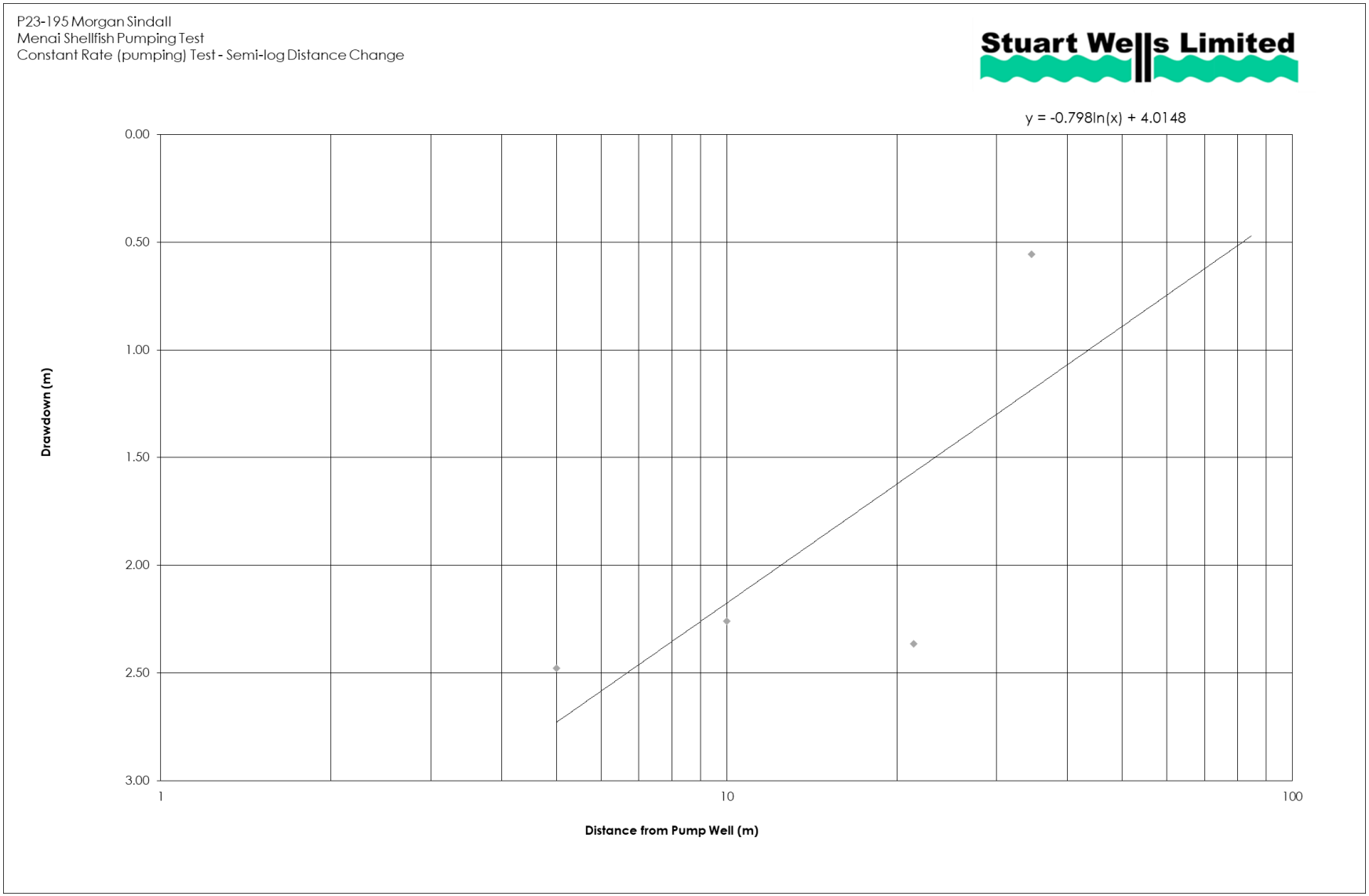

Figure 4: Constant Rate (pumping) Test Semi-Log Plot of The Distance Drawdown

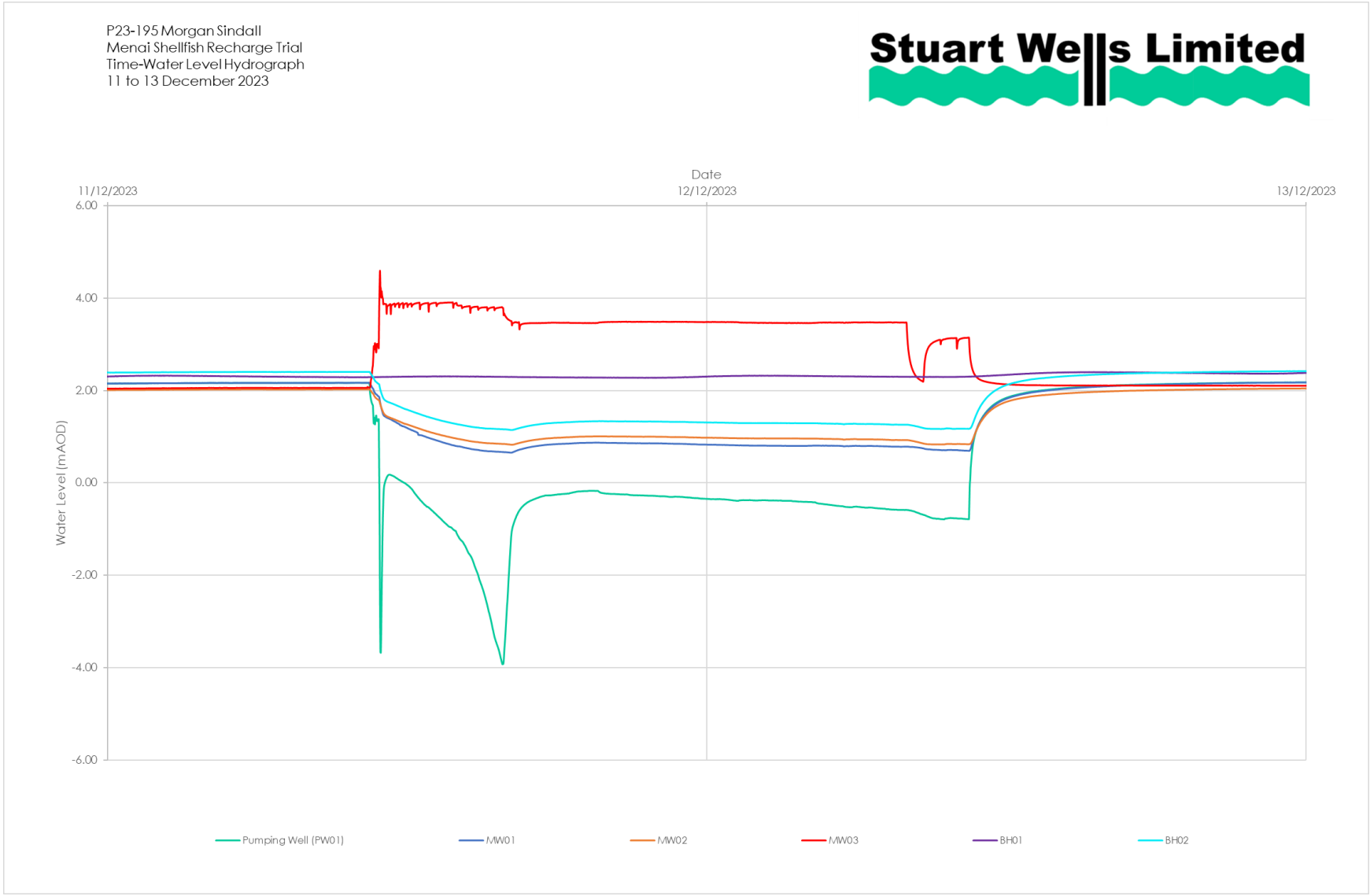

Figure 5: Recharge Trial – Time-Water Level Hydrograph

6 Groundwater Quality

6.1 Field Parameters

Groundwater quality monitoring was undertaken to minimise the risk of migration of any abstracted contaminated water during the pumping test and recharge trial. A SmartTROLL multiparameter handheld probe was used to digitally record the following parameters:

- pH
- Electrical Conductivity
- Redox potential
- Temperature
- Dissolved Oxygen

Water quality was monitored at the discharge location at approximately hourly intervals during the working day.

The results are presented in Figures 6 through to 10, and the full data is available upon request.

6.2 Water Sampling

During the Constant Rate (pumping) Test, groundwater samples were collected from the pumping well (PW01) in general accordance with the GIC. Samples were collected on the 04 and 07 December 2023.

The groundwater samples were taken to a UKAS accredited laboratory and analysed for the suite included in Table 6. The full laboratory test results are included in Appendix B.

TABLE 6: Groundwater Analysis Suite

Groundwater Sampling Suite				
Antimony	Arsenic	Boron	Barium	Cadmium
Total Chromium	Copper	Iron	Lead	Molybdenum
Magnesium	Nickel	Selenium	Zinc	Manganese
Sodium	TPH	Speciated PAH	Chloride	Sulphur
Nitrate	Nitrite	Ammoniacal Nitrogen	Total Suspended Solids	Total Dissolved Solids
Chemical Oxygen Demand	Biological Oxygen Demand	Dissolved Oxygen	Orthophosphate	pH
Total Alkalinity	Total Hardness as CaCO3			

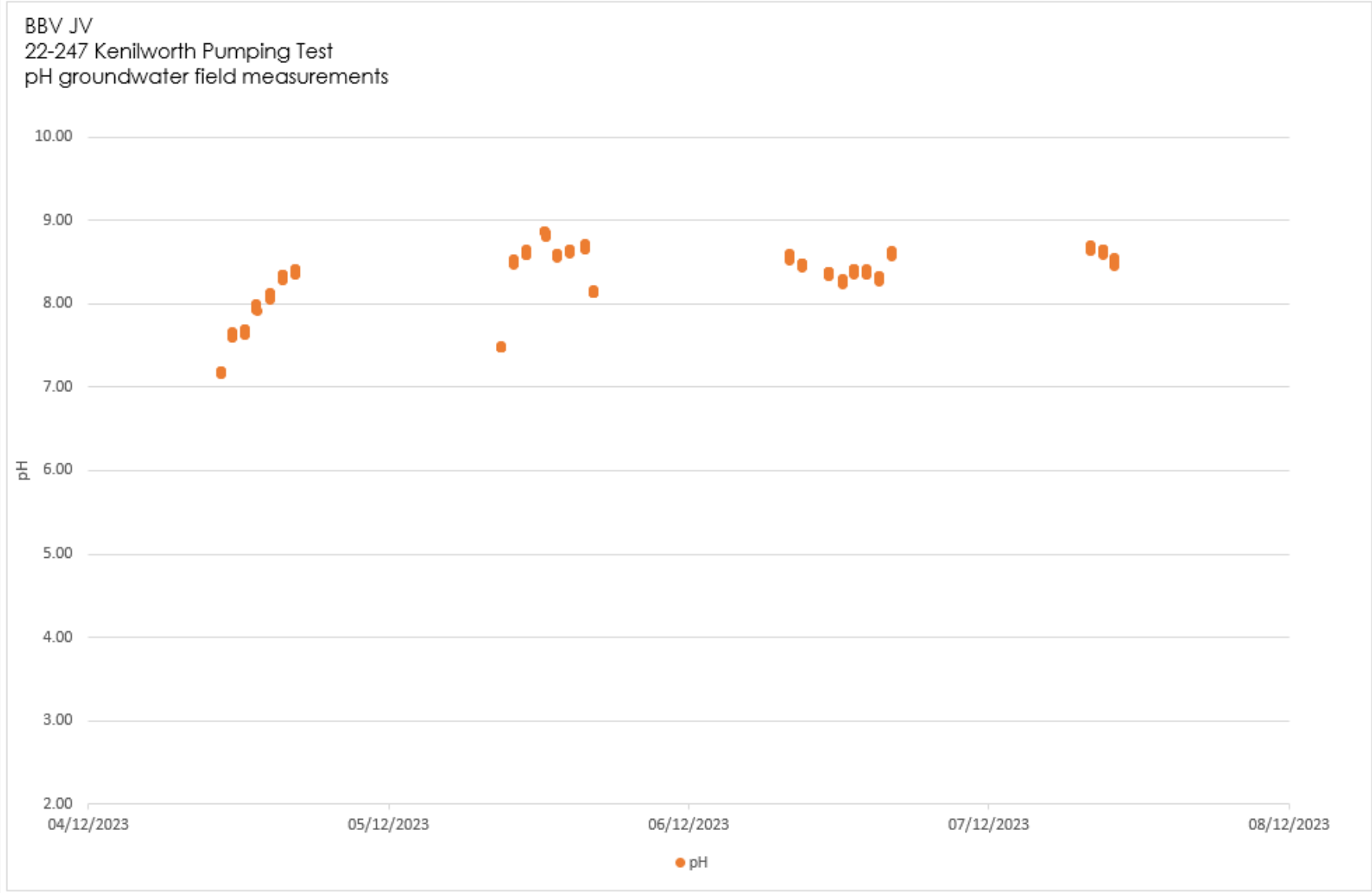

Figure 6: pH Groundwater Field Measurements

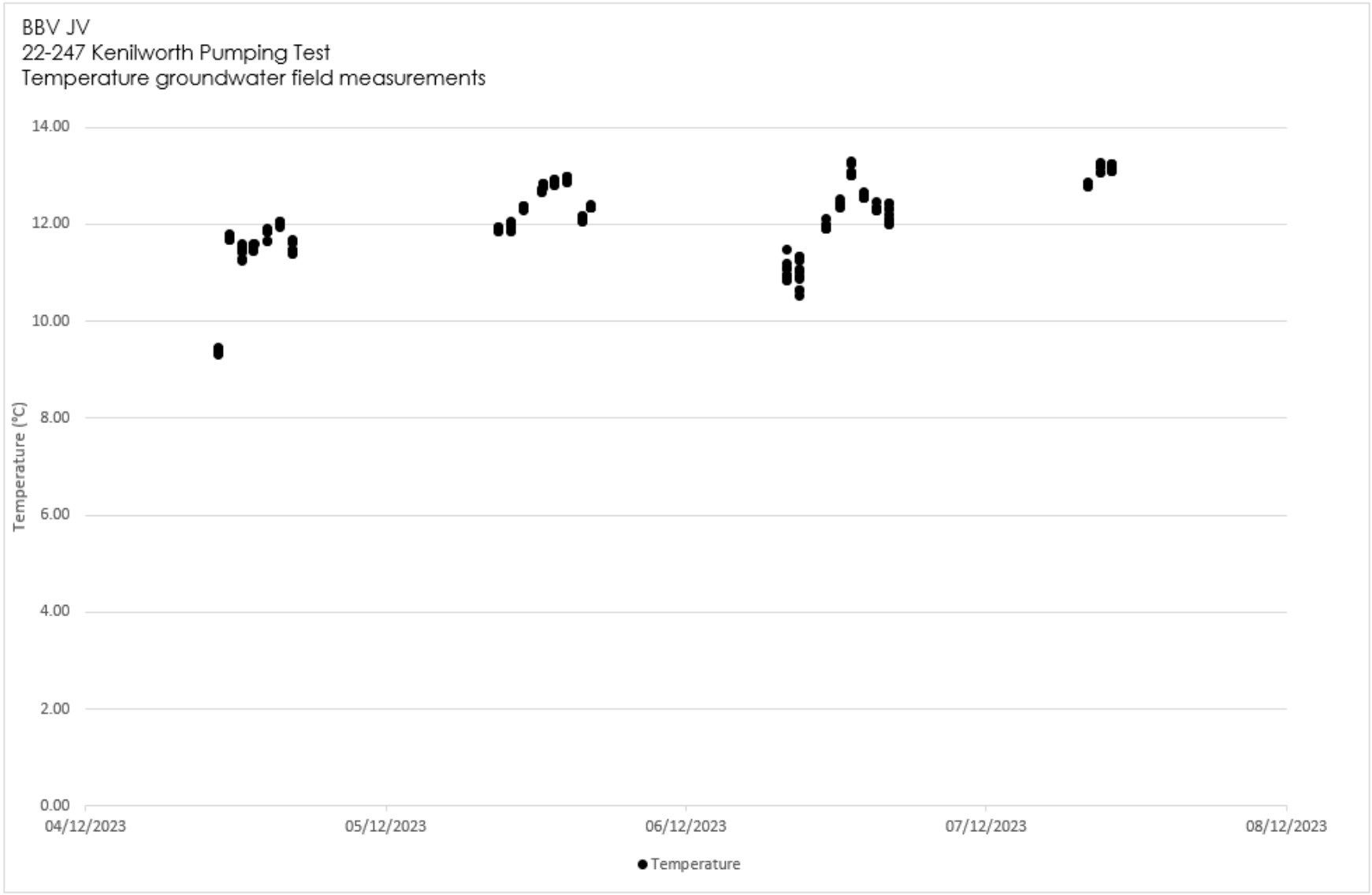

Figure 7: Temperature Groundwater Field Measurements

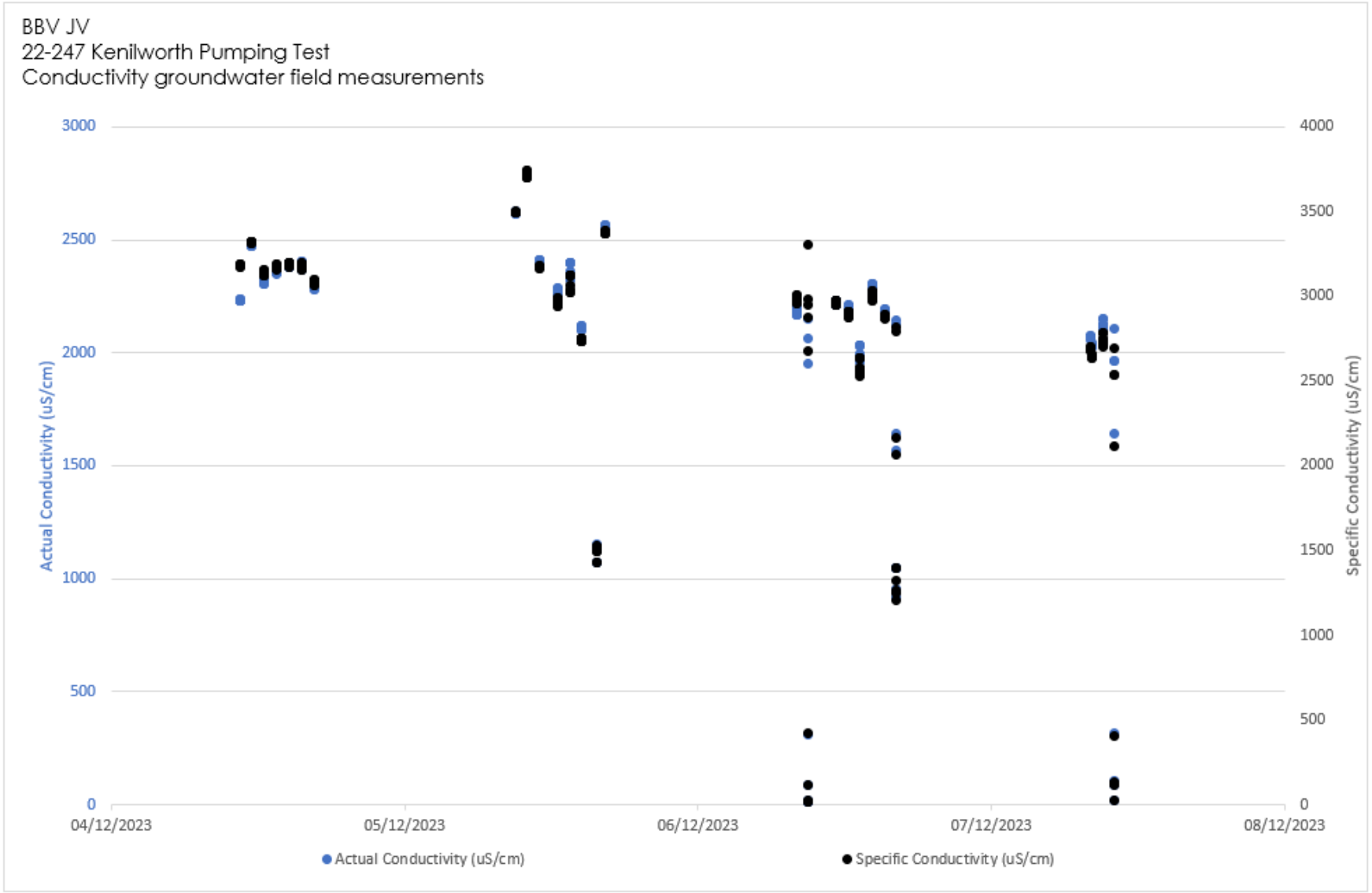

Figure 8: Conductivity Groundwater Field Measurements

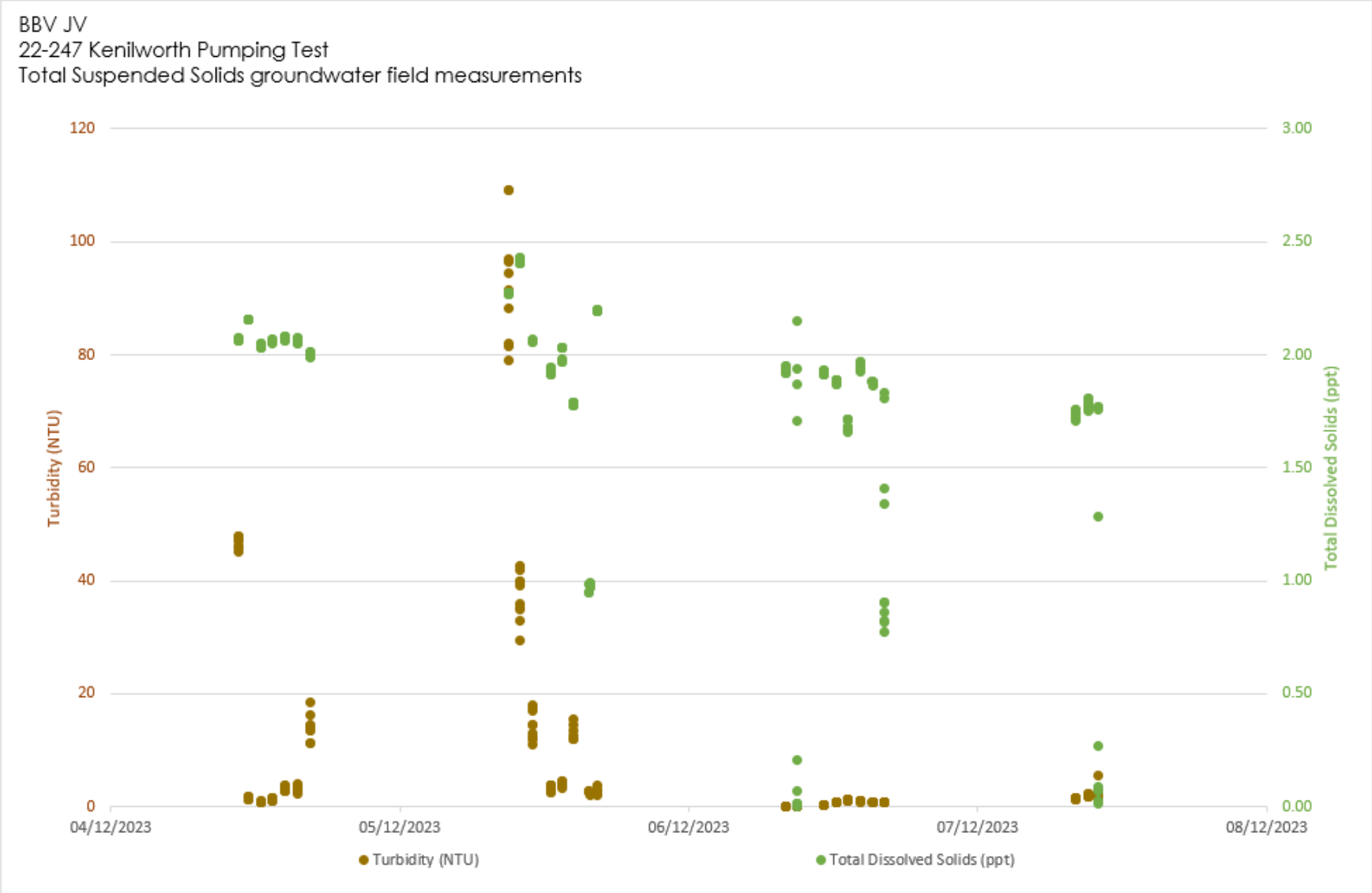

Figure 9: Total Suspended Solids Groundwater Field Measurements

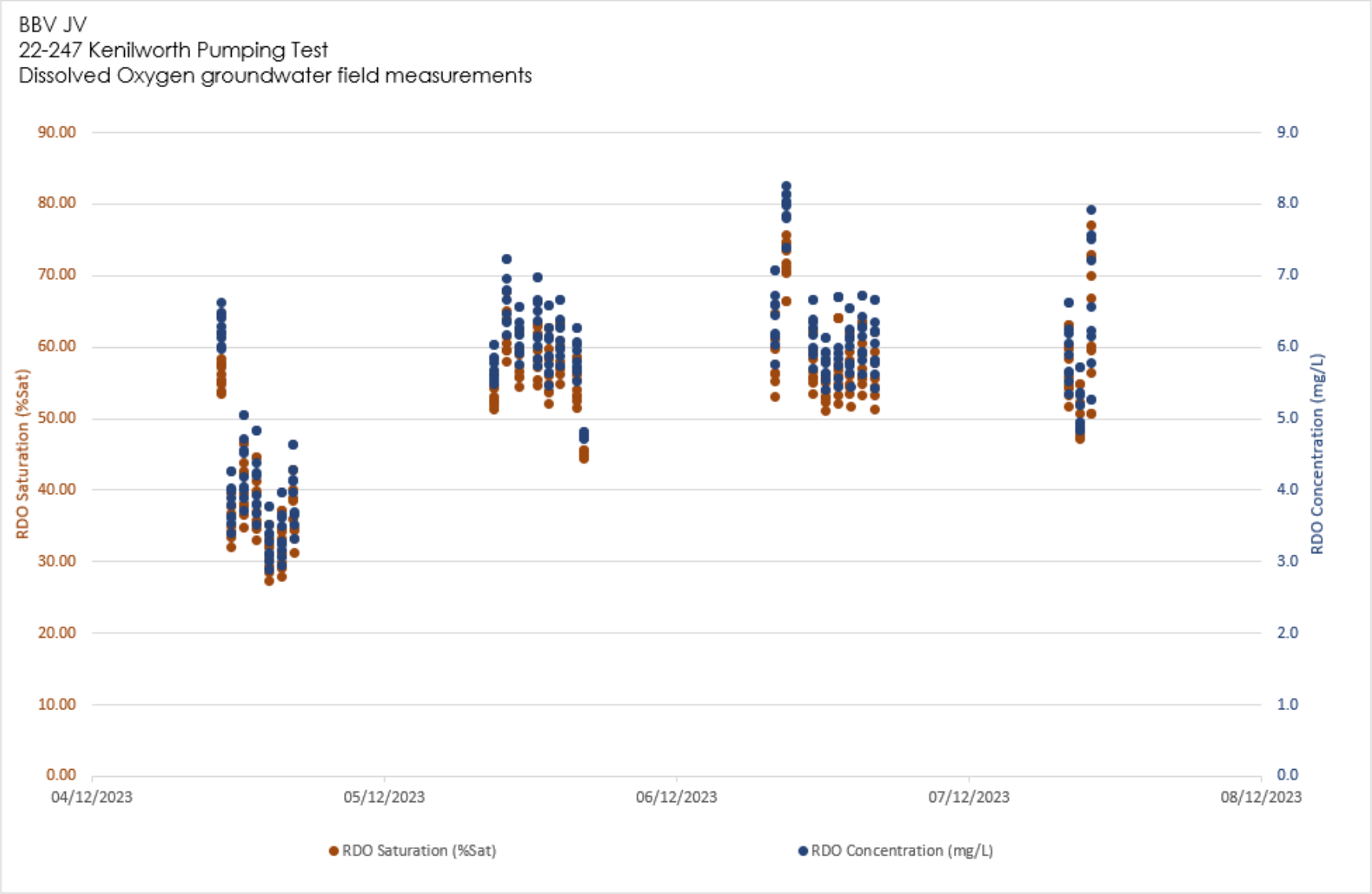

Figure 10: Dissolved Oxygen Groundwater Field Measurement

7. Discussion

Please find below a summary of known non-conformities with the issued GIC and additional commentary.

1. Groundwater levels monitored during this pumping test were not influenced by tidal movements.
2. The existing standpipe installed at BH01 has a response zone that extends over the Made Ground only, extending to a depth of 4.9 m. During the Constant Rate (pumping) Test and Recharge Trial, the groundwater level within BH01 remained unchanged. As a result, it is not included in the distance-drawdown plots.
   Furthermore, BH01 was the only monitoring location that showed a minor amount of tidal influence, with groundwater levels ranging between 2.22 to 2.41 mAOD.
3. During the recharge trial, the flow rate was reduced from 0.15 to 0.12 l/s at 15:50 on the 11 December 2023. The reported changes in groundwater level presented in Table 5 are for the period 17:00 11 December 2023 and 10:30 12 December 2023 when the flow rate was maintained at 0.12 l/s.

For all pumping test data, including all water level data, groundwater quality, borehole logs and laboratory testing result data, please refer to appendices and associated spreadsheets.

8. References

Geotechnics Ltd (2023). Menai SPS – *Factual Report, Report* no. PN234513 dated July 2023.

Stuart Wells Limited

APPENDIX A:

BOREHOLE LOGS

Stuart Wells Limited
Stuart House, Hargham Road
Shropham, Norfolk NR17 1DT
Telephone: 01953 454 540
mark.pickett@stuartwells.co.uk

Stuart Wells Limited

BOREHOLE LOG

Project				BOREHOLE No
Menai Strait				MW01
Job No	Date	Ground Level (m)	Co-Ordinates ()	
P23-195	22-11-23 22-11-23	6.00	E 258,639.0 N 372,857.0	
Contractor				Sheet
Danbar				1 of 1

SAMPLES & TESTS			Water	Reduced Level	Legend	Depth (Thick-ness)	STRATA DESCRIPTION	Geology	Instrument/ Backfill
Depth	Type No	Test Result							
				5.80		0.20	Soil		
						(5.00)	Rubble fill		
			1 1	0.80		5.20			
						(2.60)	Silt		
			2 2	-1.80		7.80			
						(1.20)	Silty sandy GRAVEL		
				-3.00		9.00			

Boring Progress and Water Observations						Chiselling			Water Added		GENERAL REMARKS
Depth	Date	Time	Casing Depth	Casing Dia. mm	Water Depth	From	To	Hours	From	To	1) Chiselling; None. 2) Water Added; Drilling Flush. 3) Casing; 200 mm to 9.0 mbgl. 4) Installation; 140 mm Plane; GL to 3m. Slotted; 3m to 9m.

All dimensions in metres Scale 1:62.5	Client Morgan Sindall	Method/ Plant Used Beretta T51	Logged By Driller

Stuart Wells Limited
Stuart House, Hargham Road
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Stuart Wells Limited

BOREHOLE LOG

Project				BOREHOLE No
Menai Strait				MW02
Job No	Date	Ground Level (m)	Co-Ordinates ()	
P23-195	22-11-23 22-11-23	6.00	E 258,635.0 N 372,850.0	
Contractor				Sheet
Danbar				1 of 1

SAMPLES & TESTS			Water	Reduced Level	Legend	Depth (Thick-ness)	STRATA DESCRIPTION	Geology	Instrument/ Backfill
Depth	Type No	Test Result							
				5.80		0.20	Soil		
						(5.00)	Rubble fill		
			1 2	0.80		5.20			
						(2.60)	Silt		
			2	-1.80		7.80			
						(1.20)	Silty sandy GRAVEL		
				-3.00		9.00			

Boring Progress and Water Observations					
Depth	Date	Time	Casing Depth	Casing Dia. mm	Water Depth

Chiselling			Water Added	
From	To	Hours	From	To

GENERAL REMARKS

1) Chiselling; None. 2) Water Added; Drilling Flush. 3) Casing; 200 mm to 9.0 mbgl. 4) Installation; 140 mm Plane; GL to 3m. Slotted; 3m to 9m.

All dimensions in metres Scale 1:62.5	Client Morgan Sindall	Method/ Plant Used Beretta T51	Logged By Driller

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Stuart House, Hargham Road
Shropham, Norfolk NR17 1DT
Telephone: 01953 454 540
mark.pickett@stuartwells.co.uk

Stuart Wells Limited

BOREHOLE LOG

Project				BOREHOLE No
Menai Strait				MW03
Job No	Date	Ground Level (m)	Co-Ordinates ()	
P23-195	23-11-23 23-11-23	6.00	E 258,610.0 N 372,836.0	
Contractor				Sheet
Danbar				1 of 1

SAMPLES & TESTS			Water	Reduced Level	Legend	Depth (Thick-ness)	STRATA DESCRIPTION	Geology	Instrument/ Backfill
Depth	Type No	Test Result							
				5.80		0.20	Soil		
						(5.00)	Rubble fill		
				0.80		5.20			
						(2.60)	Silt		
				-1.80		7.80			
						(1.20)	Silty sandy GRAVEL		
				-3.00		9.00			

Boring Progress and Water Observations					
Depth	Date	Time	Casing Depth	Casing Dia. mm	Water Depth

Chiselling			Water Added	
From	To	Hours	From	To

GENERAL REMARKS

1) Chiselling; None. 2) Water Added; Drilling Flush. 3) Casing; 200 mm to 9.0 mbgl. 4) Installation; 140 mm Plane; GL to 3m. Slotted; 3m to 9m.

All dimensions in metres Scale 1:62.5	Client Morgan Sindall	Method/ Plant Used Beretta T51	Logged By Driller

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Stuart Wells Limited

BOREHOLE LOG

Project				BOREHOLE No
Menai Strait				PW01
Job No	Date	Ground Level (m)	Co-Ordinates ()	
P23-195	21-11-23 21-11-23	6.00	E 258,635.0 N 372,860.0	
Contractor				Sheet
Danbar				1 of 2

SAMPLES & TESTS			Water	Reduced Level	Legend	Depth (Thick-ness)	STRATA DESCRIPTION	Geology	Instrument/ Backfill
Depth	Type No	Test Result							
				5.80		0.20	Soil		
							MADE GROUND (Rubble ash fill)		
						(5.00)			
			1 1	0.80		5.20			
							Silt		
						(2.60)			
				-1.80		7.80			
							Silty sandy GRAVEL		
			2 2			(4.20)			

Boring Progress and Water Observations						Chiselling			Water Added		GENERAL REMARKS
Depth	Date	Time	Casing Depth	Casing Dia. mm	Water Depth	From	To	Hours	From	To	
											1) Chiselling; None. 2) Water Added; Drilling Flush. 3) Casing; 300 mm to 12.0 mbgl. 4) Installation; 140 mm Plane; GL to 3m. Slotted; 3m to 12m.

All dimensions in metres Scale 1:62.5	Client Morgan Sindall	Method/ Plant Used Beretta T51	Logged By Driller

Stuart Wells Limited
Stuart House, Hargham Road
Shropham, Norfolk NR17 1DT
Telephone: 01953 454 540
mark.pickett@stuartwells.co.uk

Stuart Wells Limited

BOREHOLE LOG

Project				BOREHOLE No
Menai Strait				PW01
Job No	Date	Ground Level (m)	Co-Ordinates ()	
P23-195	21-11-23 21-11-23	6.00	E 258,635.0 N 372,860.0	
Contractor				Sheet
Danbar				2 of 2

SAMPLES & TESTS			Water				STRATA		
Depth	Type No	Test Result		Reduced Level	Legend	Depth (Thick-ness)	DESCRIPTION	Geology	Instrument/ Backfill
							Silty sandy GRAVEL *(continued)*		
				-6.00		12.00			

Boring Progress and Water Observations						Chiselling			Water Added	
Depth	Date	Time	Casing Depth	Casing Dia. mm	Water Depth	From	To	Hours	From	To
12.00	01-03-23	00.00	4.50	300						

GENERAL REMARKS

1) Chiselling; None. 2) Water Added; Drilling Flush. 3) Casing; 300 mm to 12.0 mbgl. 4) Installation; 140 mm Plane; GL to 3m. Slotted; 3m to 12m.

All dimensions in metres Scale 1:62.5	Client Morgan Sindall	Method/ Plant Used Beretta T51	Logged By Driller

Report ID: AGS4 UK BH || Project: P23-195 MORGAN SINDALL - MENAI STRAIT LOGS.GPJ || Library: GINT STD AGS 4_0.GLB || Date: 8 January 2024

Stuart Wells Limited

APPENDIX B:

LABORATORY TEST RESULTS

SOCOTEC

Environmental Chemistry

Certificate of Analysis

Client: Stuart Wells Limited

Project: 23120933

Quote: BEC231132440 V1.1

Project Ref: Menai Bangor

Site: Menai Bangor

Contact: Dr. Mark Pickett

Address: Stuart House
Hargham Road
Shropham
Norfolk
NR17 1DT

E-Mail: mark.pickett@stuartwells.co.uk

Phone: 07900 930 895

No. Samples Received: 1

Date Received: 08/12/2023

Analysis Date: 20/12/2023

Date Issued: 20/12/2023

Report Type: Final Version 01

This report supersedes any versions previously issued by the laboratory

Reported by Reporting Officer
Aniko Gondolne-Mantler
01283 554434

Client:	Stuart Wells Limited
Project Name:	Menai Bangor-Menai Bangor
Project No:	23120933
Date Issued:	20/12/2023

Samples Analysed

Text ID	Sample Reference	Sampling Date	Sample Type	Sample Description
23120933-001	PW 1 Bangor	04/12/2023 00:00:00	WATER	Unclassified Liquid

Client: Stuart Wells Limited
Project Name: Menai Bangor-Menai Bangor
Project No: 23120933
Date Issued: 20/12/2023

Analysis Results

Analysis	Method Code	MDL	Units	Accred.	Sample ID: 001	Customer ID: PW 1 Bangor	Sample Type: WATER	Sampling Date: 04/12/2023
Ammoniacal Nitrogen as N	KONENS	0.01	mg/l	N	2.60			
Conductivity at 25°C	PHCONDW	100	µS/cm	N	4060			
pH	PHCONDW	1	pH units	N	7.5			
Total Suspended Solids	WSLM10	5	mg/l	N	47			
TDS as mg/L	WSLM27	5	mg/l	N	2670			
Chloride as Cl	KONENS	1	mg/l	N	1050			
Nitrite as N	KONENS	0.01	mg/l	N	0.01			
Nitrate as N	KONENS	0.2	mg/l	N	0.3			
Orthophosphate as PO4	KONENS	0.03	mg/l	N	0.04			
COD (Settled)	WSLM11	5	mg/l	N	12			
Total Alkalinity	WSLM12	2	mg/l	N	526			
Dissolved Oxygen	WSLM20	0.1	mg O2/l	N	11.2			
BOD (5 day)	WSLM20	1	mg O2/l	N	<1.0 B			
Lead as Pb	ICPMSW (Dissolved)	0.001	mg/l	N	<0.001			
Antimony as Sb	ICPMSWT (Total)	0.001	mg/l	N	<0.001			
Arsenic as As	ICPMSWT (Total)	0.001	mg/l	N	0.002			
Cadmium as Cd	ICPMSWT (Total)	0.00002	mg/l	N	0.00003			
Total Chromium as Cr	ICPMSWT (Total)	0.001	mg/l	N	<0.001			
Copper as Cu	ICPMSWT (Total)	0.001	mg/l	N	0.006			

Client: Stuart Wells Limited
Project Name: Menai Bangor-Menai Bangor
Project No: 23120933
Date Issued: 20/12/2023

Analysis Results

					Sample ID	001
					Customer ID	PW 1 Bangor
					Sample Type	WATER
					Sampling Date	04/12/2023
Analysis	Method Code	MDL	Units	Accred.		
Manganese as Mn	ICPMSWT (Total)	0.002	mg/l	N	5.18
Molybdenum as Mo	ICPMSWT (Total)	0.001	mg/l	N	0.024
Nickel as Ni	ICPMSWT (Total)	0.001	mg/l	N	0.004
Selenium as Se	ICPMSWT (Total)	0.001	mg/l	N	<0.001
Zinc as Zn	ICPMSWT (Total)	0.002	mg/l	N	0.026
Iron as Fe	ICPWATVAR (Dissolved)	0.01	mg/l	N	0.01
Total Sulphur as SO4	ICPWATVAR (Dissolved)	3	mg/l	N	186
Total Hardness as CaCO3	ICPWATVAR (Dissolved)	6.6	mg/l	N	723
Barium as Ba	ICPWATVART (Total)	0.01	mg/l	N	0.05
Boron as B	ICPWATVART (Total)	0.01	mg/l	N	0.69
Magnesium as Mg	ICPWATVART (Total)	1	mg/l	N	100
Sodium as Na	ICPWATVART (Total)	1	mg/l	N	563
Acenaphthene	PAHMSW	0.01	µg/l	N	<0.01
Acenaphthylene	PAHMSW	0.01	µg/l	N	<0.01
Anthracene	PAHMSW	0.01	µg/l	N	<0.01
Benzo[a]anthracene	PAHMSW	0.01	µg/l	N	<0.01
Benzo[a]pyrene	PAHMSW	0.01	µg/l	N	<0.01
Benzo[b]fluoranthene	PAHMSW	0.01	µg/l	N	<0.01
Benzo[g,h,i]perylene	PAHMSW	0.01	µg/l	N	<0.01

Client: Stuart Wells Limited
Project Name: Menai Bangor-Menai Bangor
Project No: 23120933
Date Issued: 20/12/2023

Analysis Results

Analysis	Method Code	MDL	Units	Accred.	Sample ID: 001	Customer ID: PW 1 Bangor	Sample Type: WATER	Sampling Date: 04/12/2023
Benzo[k]fluoranthene	PAHMSW	0.01	µg/l	N	<0.01			
Chrysene	PAHMSW	0.01	µg/l	N	<0.01			
Dibenzo[a,h]anthracene	PAHMSW	0.01	µg/l	N	<0.01			
Fluoranthene	PAHMSW	0.01	µg/l	N	<0.01			
Fluorene	PAHMSW	0.01	µg/l	N	<0.01			
Indeno[1,2,3-cd]pyrene	PAHMSW	0.01	µg/l	N	<0.01			
Naphthalene	PAHMSW	0.01	µg/l	N	<0.01			
Phenanthrene	PAHMSW	0.01	µg/l	N	<0.01			
Pyrene	PAHMSW	0.01	µg/l	N	<0.01			
Total PAH 16	PAHMSW	0.16	µg/l	N	<0.16			
Total TPH >C8-C40 EH_1D_Total	TPHFID	0.01	mg/l	N	0.02			

Client: Stuart Wells Limited
Project Name: Menai Bangor-Menai Bangor
Project No: 23120933
Date Issued: 20/12/2023

Deviating Sample Report

Sample Reference	Text ID	Method Code	Incorrect Container	Incorrect Label	Headspace	Incorrect/No Preservative	No Sampling Date	Holding Time
PW 1 Bangor	23120933-001	**PHCONDW**						✓
PW 1 Bangor	23120933-001	**WSLM10**						✓
PW 1 Bangor	23120933-001	**WSLM20**						✓
PW 1 Bangor	23120933-001	**WSLM20**						✓

Analysis Method

Method Code	Method Description	Analysis Method
ICPMSW (Dissolved)	Lead (Diss.) in Water by ICPMS	Filtered
ICPMSWT (Total)	Antimony (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Arsenic (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Cadmium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Chromium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Copper (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Manganese (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Molybdenum (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Nickel (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Selenium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Zinc (Tot.) in Water by ICPMS	Unfiltered
ICPWATVAR (Dissolved)	Iron (Diss.) in Water by ICPOES	Filtered
ICPWATVAR (Dissolved)	Total Hardness as CaCO3 in Water	Filtered
ICPWATVAR (Dissolved)	Total Sulphur as SO4 (Diss.) in Water	Filtered
ICPWATVART (Total)	Barium (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Boron (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Magnesium (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Sodium (Tot.) in Water by ICPOES	Unfiltered
KONENS	Ammoniacal Nitrogen as N	Filtered
KONENS	Chloride by Colorimetry	Filtered
KONENS	Nitrate as N by Colorimetry	Filtered
KONENS	Nitrite as N by Colorimetry	Filtered
KONENS	Orthophosphate as PO4 by Colorimetry	Filtered
PAHMSW	16 PAHs by GCMS	Unfiltered
PHCONDW	Electrical Conductivity @ 25°C	Unfiltered
PHCONDW	pH	Unfiltered
TPHFID	TPH (>C8-C40): Total Petroleum Hydrocarbons	Unfiltered
WSLM10	TSS: Total Suspended Solids	Unfiltered
WSLM11	COD: Chemical Oxygen Demand (Settled)	Unfiltered
WSLM12	Total Alkalinity as CaCO3	Unfiltered
WSLM20	BOD: Biological Oxygen Demand (Total)	Unfiltered
WSLM20	Dissolved Oxygen	Unfiltered
WSLM27	TDS: Total Dissolved Solids	Filtered

Client:	Stuart Wells Limited
Project Name:	Menai Bangor-Menai Bangor
Project No:	23120933
Date Issued:	20/12/2023

Result Report Notes

Letters alongside results signify that the result has associated report notes.
The report notes are as follows:

Letter	Note
A	Due to the matrix of the sample the laboratory has had to deviate from our standard protocols to be able to process the sample and provide a result. Where applicable the accreditation has been removed and this should be taken into consideration when utilising the data.
B	The QC associated with this result has not wholly met the QMS requirements, the accreditation has therefore been removed. However, the Laboratory has confidence in the performance of the method as a whole and that the integrity of the data has not been significantly compromised.
C	Due to matrix interference, the internal standard and/or surrogate has not met the QMS requirements. This should be taken into consideration when utilising the data.
D	A non-standard volume or mass has been used for this test which has resulted in a raised detection limit.
E	Due to the parameter value being beyond our calibration range (and following the maximum size of dilution allowed, where applicable), the result cannot be quantified and as such the result will appear as a greater than symbol (>) with the accreditation removed. This data should be used for indicative purposes only.
F	Based on the sample history, appearance and smell a dilution was applied prior to testing. Unfortunately, the result is either above (>) or below (<) our calibration range. Results above our calibration range have accreditation removed. The data should be used for indicative purposes only.
G	The day 5 oxygen reading was below the capability of the instrument to detect, and therefore the calculated BOD has been reported unaccredited for guidance purposes only.

HWOL Acronym Key

Acronym	Description
HS	Headspace Analysis
EH	Extractable Hydrocarbons - i.e everything extracted by the solvent(s)
CU	Clean up - e.g. by florisil, silica gel
1D	GC - Single coil gas chromatography
Total	Aliphatics & Aromatics
AL	Aliphatics only
AR	Aromatics only
+	Operator to indicate cumulative e.g. EH_CU+HS_1D_Total

Client: Stuart Wells Limited
Project Name: Menai Bangor-Menai Bangor
Project No: 23120933
Date Issued: 20/12/2023

Additional Information

This report refers to samples as received. SOCOTEC UK Ltd takes no responsibility for accuracy or competence of sampling by others.

Results within this report relate only to the samples tested.

The accreditation codes are as follows:

U = UKAS accredited analysis
M = MCERT accredited analysis
N = Unaccredited analysis

Any units marked with ^ signify results are reported on a dry weight basis of 105° C.

All Air Dried and Ground Samples (ADG) are oven dried at less than 35° C.

This report shall not be reproduced except in full, without written approval of the laboratory.

Opinions and interpretations given are outside the scope of our UKAS accreditation.

Any samples marked with * are not covered by our scope of UKAS accreditation. If applicable, further report notes have been added.

Any solid samples where the Major Constituents are not one of the following (Sand, Silt, Clay, Made Ground) are not one of our accredited matrix types.

Any samples marked with ‡ have had MCERTS accreditation removed for this result

Any samples marked with a tick in the deviant table is deviant for the specific reason.

Any samples reported as IS, NA, ND mean the following:

IS = Insufficient Sample to complete analysis
NA = Sample is not amenable for the required analysis
ND = Results cannot be determined

Items listed with a 'SUB' method code prefix have been carried out by an external subcontracted laboratory.

Our deviating sample report does not include deviancy information for Subcontracted analysis. Please see the report from the subcontracted lab for information regarding any deviancies for this analysis.

Summaries of analysis methods are available upon request.

End of Certificate of Analysis

SOCOTEC

Environmental Chemistry

Certificate of Analysis

Client: Stuart Wells Limited

Project: 23121864

Quote: BEC231132440 V1.1

Project Ref: BANGOR MENAI

Site: BANGOR MENAI

Contact: Dr. Mark Pickett

Address: Stuart House
Hargham Road
Shropham
Norfolk
NR17 1DT

E-Mail: mark.pickett@stuartwells.co.uk

Phone: 07900 930 895

No. Samples Received: 1

Date Received: 16/12/2023

Analysis Date: 31/12/2023

Date Issued: 02/01/2024

Report Type: Final Version 01

This report supersedes any versions previously issued by the laboratory

Reported by Reporting Officer
Aniko Gondolne-Mantler
01283 554434

Client:	Stuart Wells Limited
Project Name:	BANGOR MENAI-BANGOR MENAI
Project No:	23121864
Date Issued:	02/01/2024

Samples Analysed

Text ID	Sample Reference	Sampling Date	Sample Type	Sample Description
23121864-001	PW	07/12/2023 00:00:00	WATER	Unclassified Liquid

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Analysis Results

Analysis	Method Code	MDL	Units	Accred.	Sample ID: 001	Customer ID: PW	Sample Type: WATER	Sampling Date: 07/12/2023
Ammoniacal Nitrogen as N	KONENS	0.01	mg/l	N	2.60			
Conductivity at 25°C	PHCONDW	100	µS/cm	N	4770			
pH	PHCONDW	1	pH units	N	7.3			
Total Suspended Solids	WSLM10	5	mg/l	N	23			
TDS as mg/L	WSLM27	5	mg/l	N	2920			
Chloride as Cl	KONENS	1	mg/l	N	1200			
Nitrite as N	KONENS	0.01	mg/l	N	<0.01			
Nitrate as N	KONENS	0.2	mg/l	N	0.5			
Orthophosphate as PO4	KONENS	0.03	mg/l	N	0.07			
COD (Settled)	WSLM11	5	mg/l	N	<10 D			
Total Alkalinity	WSLM12	2	mg/l	N	519			
Dissolved Oxygen	WSLM20	0.1	mg O2/l	N	11.5			
BOD (5 day)	WSLM20	1	mg O2/l	N	<1.0			
Lead as Pb	ICPMSW (Dissolved)	0.001	mg/l	N	<0.001			
Antimony as Sb	ICPMSWT (Total)	0.001	mg/l	N	<0.001			
Arsenic as As	ICPMSWT (Total)	0.001	mg/l	N	0.003			
Cadmium as Cd	ICPMSWT (Total)	0.00002	mg/l	N	<0.00002			
Total Chromium as Cr	ICPMSWT (Total)	0.001	mg/l	N	0.001			
Copper as Cu	ICPMSWT (Total)	0.001	mg/l	N	0.004			

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Analysis Results

					Sample ID	001
					Customer ID	PW
					Sample Type	WATER
					Sampling Date	07/12/2023
Analysis	Method Code	MDL	Units	Accred.		
Manganese as Mn	ICPMSWT (Total)	0.002	mg/l	N		4.76
Molybdenum as Mo	ICPMSWT (Total)	0.001	mg/l	N		0.025
Nickel as Ni	ICPMSWT (Total)	0.001	mg/l	N		0.005
Selenium as Se	ICPMSWT (Total)	0.001	mg/l	N		0.002
Zinc as Zn	ICPMSWT (Total)	0.002	mg/l	N		0.016
Iron as Fe	ICPWATVAR (Dissolved)	0.01	mg/l	N		0.01
Total Sulphur as SO4	ICPWATVAR (Dissolved)	3	mg/l	N		170
Total Hardness as CaCO3	ICPWATVAR (Dissolved)	6.6	mg/l	N		720
Barium as Ba	ICPWATVART (Total)	0.01	mg/l	N		0.06
Boron as B	ICPWATVART (Total)	0.01	mg/l	N		0.76
Magnesium as Mg	ICPWATVART (Total)	1	mg/l	N		106
Sodium as Na	ICPWATVART (Total)	1	mg/l	N		683
Acenaphthene	PAHMSW	0.01	µg/l	N		<0.01 B
Acenaphthylene	PAHMSW	0.01	µg/l	N		<0.01 B
Anthracene	PAHMSW	0.01	µg/l	N		<0.01
Benzo[a]anthracene	PAHMSW	0.01	µg/l	N		<0.01
Benzo[a]pyrene	PAHMSW	0.01	µg/l	N		<0.01
Benzo[b]fluoranthene	PAHMSW	0.01	µg/l	N		<0.01
Benzo[g,h,i]perylene	PAHMSW	0.01	µg/l	N		<0.01

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Analysis Results

					Sample ID	001
					Customer ID	PW
					Sample Type	WATER
					Sampling Date	07/12/2023
Analysis	Method Code	MDL	Units	Accred.		
Benzo[k]fluoranthene	PAHMSW	0.01	µg/l	N		<0.01
Chrysene	PAHMSW	0.01	µg/l	N		<0.01
Dibenzo[a,h]anthracene	PAHMSW	0.01	µg/l	N		<0.01
Fluoranthene	PAHMSW	0.01	µg/l	N		<0.01
Fluorene	PAHMSW	0.01	µg/l	N		<0.01
Indeno[1,2,3-cd]pyrene	PAHMSW	0.01	µg/l	N		<0.01
Naphthalene	PAHMSW	0.01	µg/l	N		<0.01
Phenanthrene	PAHMSW	0.01	µg/l	N		<0.01
Pyrene	PAHMSW	0.01	µg/l	N		<0.01
Total PAH 16	PAHMSW	0.16	µg/l	N		<0.16
Total TPH >C8-C40 EH_1D_Total	TPHFID	0.01	mg/l	N		0.01

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Deviating Sample Report

Sample Reference	Text ID	Method Code	Incorrect Container	Incorrect Label	Headspace	Incorrect/No Preservative	No Sampling Date	Holding Time
PW	23121864-001	**PHCONDW**						✓
PW	23121864-001	**WSLM10**						✓
PW	23121864-001	**WSLM11**						✓
PW	23121864-001	**WSLM12**						✓
PW	23121864-001	**WSLM20**						✓
PW	23121864-001	**WSLM20**						✓

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Analysis Method

Method Code	Method Description	Analysis Method
ICPMSW (Dissolved)	Lead (Diss.) in Water by ICPMS	Filtered
ICPMSWT (Total)	Antimony (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Arsenic (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Cadmium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Chromium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Copper (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Manganese (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Molybdenum (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Nickel (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Selenium (Tot.) in Water by ICPMS	Unfiltered
ICPMSWT (Total)	Zinc (Tot.) in Water by ICPMS	Unfiltered
ICPWATVAR (Dissolved)	Iron (Diss.) in Water by ICPOES	Filtered
ICPWATVAR (Dissolved)	Total Hardness as CaCO3 in Water	Filtered
ICPWATVAR (Dissolved)	Total Sulphur as SO4 (Diss.) in Water	Filtered
ICPWATVART (Total)	Barium (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Boron (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Magnesium (Tot.) in Water by ICPOES	Unfiltered
ICPWATVART (Total)	Sodium (Tot.) in Water by ICPOES	Unfiltered
KONENS	Ammoniacal Nitrogen as N	Filtered
KONENS	Chloride by Colorimetry	Filtered
KONENS	Nitrate as N by Colorimetry	Filtered
KONENS	Nitrite as N by Colorimetry	Filtered
KONENS	Orthophosphate as PO4 by Colorimetry	Filtered
PAHMSW	16 PAHs by GCMS	Unfiltered
PHCONDW	Electrical Conductivity @ 25°C	Unfiltered
PHCONDW	pH	Unfiltered
TPHFID	TPH (>C8-C40): Total Petroleum Hydrocarbons	Unfiltered
WSLM10	TSS: Total Suspended Solids	Unfiltered
WSLM11	COD: Chemical Oxygen Demand (Settled)	Unfiltered
WSLM12	Total Alkalinity as CaCO3	Unfiltered
WSLM20	BOD: Biological Oxygen Demand (Total)	Unfiltered
WSLM20	Dissolved Oxygen	Unfiltered
WSLM27	TDS: Total Dissolved Solids	Filtered

Client:	Stuart Wells Limited
Project Name:	BANGOR MENAI-BANGOR MENAI
Project No:	23121864
Date Issued:	02/01/2024

Result Report Notes

Letters alongside results signify that the result has associated report notes.
The report notes are as follows:

Letter	Note
A	Due to the matrix of the sample the laboratory has had to deviate from our standard protocols to be able to process the sample and provide a result. Where applicable the accreditation has been removed and this should be taken into consideration when utilising the data.
B	The QC associated with this result has not wholly met the QMS requirements, the accreditation has therefore been removed. However, the Laboratory has confidence in the performance of the method as a whole and that the integrity of the data has not been significantly compromised.
C	Due to matrix interference, the internal standard and/or surrogate has not met the QMS requirements. This should be taken into consideration when utilising the data.
D	A non-standard volume or mass has been used for this test which has resulted in a raised detection limit.
E	Due to the parameter value being beyond our calibration range (and following the maximum size of dilution allowed, where applicable), the result cannot be quantified and as such the result will appear as a greater than symbol (>) with the accreditation removed. This data should be used for indicative purposes only.
F	Based on the sample history, appearance and smell a dilution was applied prior to testing. Unfortunately, the result is either above (>) or below (<) our calibration range. Results above our calibration range have accreditation removed. The data should be used for indicative purposes only.
G	The day 5 oxygen reading was below the capability of the instrument to detect, and therefore the calculated BOD has been reported unaccredited for guidance purposes only.

HWOL Acronym Key

Acronym	Description
HS	Headspace Analysis
EH	Extractable Hydrocarbons - i.e everything extracted by the solvent(s)
CU	Clean up - e.g. by florisil, silica gel
1D	GC - Single coil gas chromatography
Total	Aliphatics & Aromatics
AL	Aliphatics only
AR	Aromatics only
+	Operator to indicate cumulative e.g. EH_CU+HS_1D_Total

Client: Stuart Wells Limited
Project Name: BANGOR MENAI-BANGOR MENAI
Project No: 23121864
Date Issued: 02/01/2024

Additional Information

This report refers to samples as received. SOCOTEC UK Ltd takes no responsibility for accuracy or competence of sampling by others.

Results within this report relate only to the samples tested.

The accreditation codes are as follows:

U = UKAS accredited analysis
M = MCERT accredited analysis
N = Unaccredited analysis

Any units marked with ^ signify results are reported on a dry weight basis of 105° C.

All Air Dried and Ground Samples (ADG) are oven dried at less than 35° C.

This report shall not be reproduced except in full, without written approval of the laboratory.

Opinions and interpretations given are outside the scope of our UKAS accreditation.

Any samples marked with * are not covered by our scope of UKAS accreditation. If applicable, further report notes have been added.

Any solid samples where the Major Constituents are not one of the following (Sand, Silt, Clay, Made Ground) are not one of our accredited matrix types.

Any samples marked with ‡ have had MCERTS accreditation removed for this result

Any samples marked with a tick in the deviant table is deviant for the specific reason.

Any samples reported as IS, NA, ND mean the following:

IS = Insufficient Sample to complete analysis
NA = Sample is not amenable for the required analysis
ND = Results cannot be determined

Items listed with a 'SUB' method code prefix have been carried out by an external subcontracted laboratory.

Our deviating sample report does not include deviancy information for Subcontracted analysis. Please see the report from the subcontracted lab for information regarding any deviancies for this analysis.

Summaries of analysis methods are available upon request.

End of Certificate of Analysis

Appendix B

Pumping test interpretation

B.1 Background

The factual pumping test report is presented in Appendix A. Details of the drilling, testing and general arrangements is presented in that report. The interpretation of the pumping test data is principally undertaken with the aim of understanding the hydraulic properties and aquifer response to pumping in order to inform the hydrogeological impact assessment report, and abstraction licence quantities.

B.2 Pumping test arrangement

The general arrangement of the pumping and monitoring boreholes is presented in **Figure 1** of the main report, and **Figure 2** in this appendix. **Table 4** provides installation details of the wells and distances from the pumping wells.

Table 4: Well arrangement details

Borehole ID	Easting	Northing	Distance from pumping well (m)	Top response zone (mOD)	Base response zone (mOD)	Average Pre pumping groundwater level (mOD)	Maximum observed drawdown CRT (m)
PW01	258635.00	372860.00	0	3	-6	2.19	6.1
MW01	258639.00	372857.00	5	3	-3	2.19	2.5
MW02	258635.00	372850.00	10	3	-3	2.07	2.3
MW03	258610.00	372836.00	34.66	3	-3	2.11	0.5
BH01	258651.00	372854.00	17.09	3.7	0.8	2.26	0
BH02	258618.00	372847.00	21.4	3.7	-0.8	2.40	2.4

B.3 Constant rate test analysis

B.3.1 General

A 72-hour constant rate test was undertaken on PW01 between 4th December 2023 and 7th December 2023. A period of recovery monitoring was undertaken on the 7th and 8th December 2023. **Figure 3** presents the groundwater level observations between the 4th December 2023 and 8th December 2023.

Based on the flow meter totaliser readings between the start and end of the test, a total of 44,351 litres was pumped over 72 hours, equating to an average flow rate of 0.171l/s (c.14.6m^3/d). **Figure 3** presents the flow rate data shown as flow meter readings converted to a flow rate based on the period of time between the readings. The data indicates that during the first 2 hours, the flow rate was not constant and varied from between 0.02l/s and 0.4l/s. The flow rate for the remainder of the test was much steadier, ranging from around 0.16l/s to 0.19l/s.

B.3.2 Groundwater level response

Table 4 and **Figure 3** present the maximum drawdown observed at each of the observation wells during the 72-hour pumping test. **Figure 5** presents the distance maximum drawdown plot of all the observation wells and **Figure 6** presents the time-drawdown observations. Based on the observation well data, the inferred distance of influence during the test was around 150m from the pumping well (**Figure 5**).

Figure 3 General well arrangement and maximum drawdown observed (radial section - distances from pumping well)

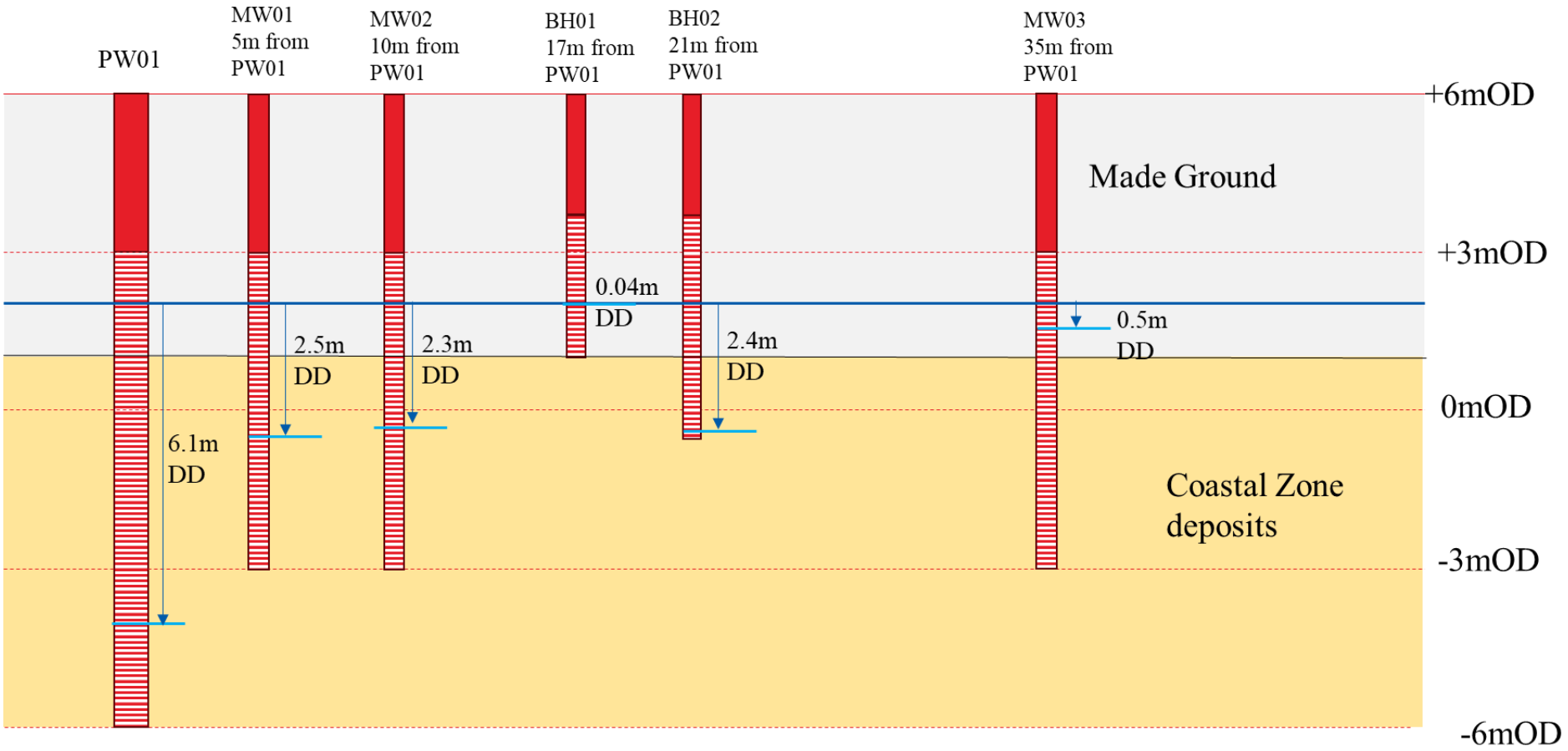


Figure 4 Constant rate pumping test – groundwater levels and flow rate information

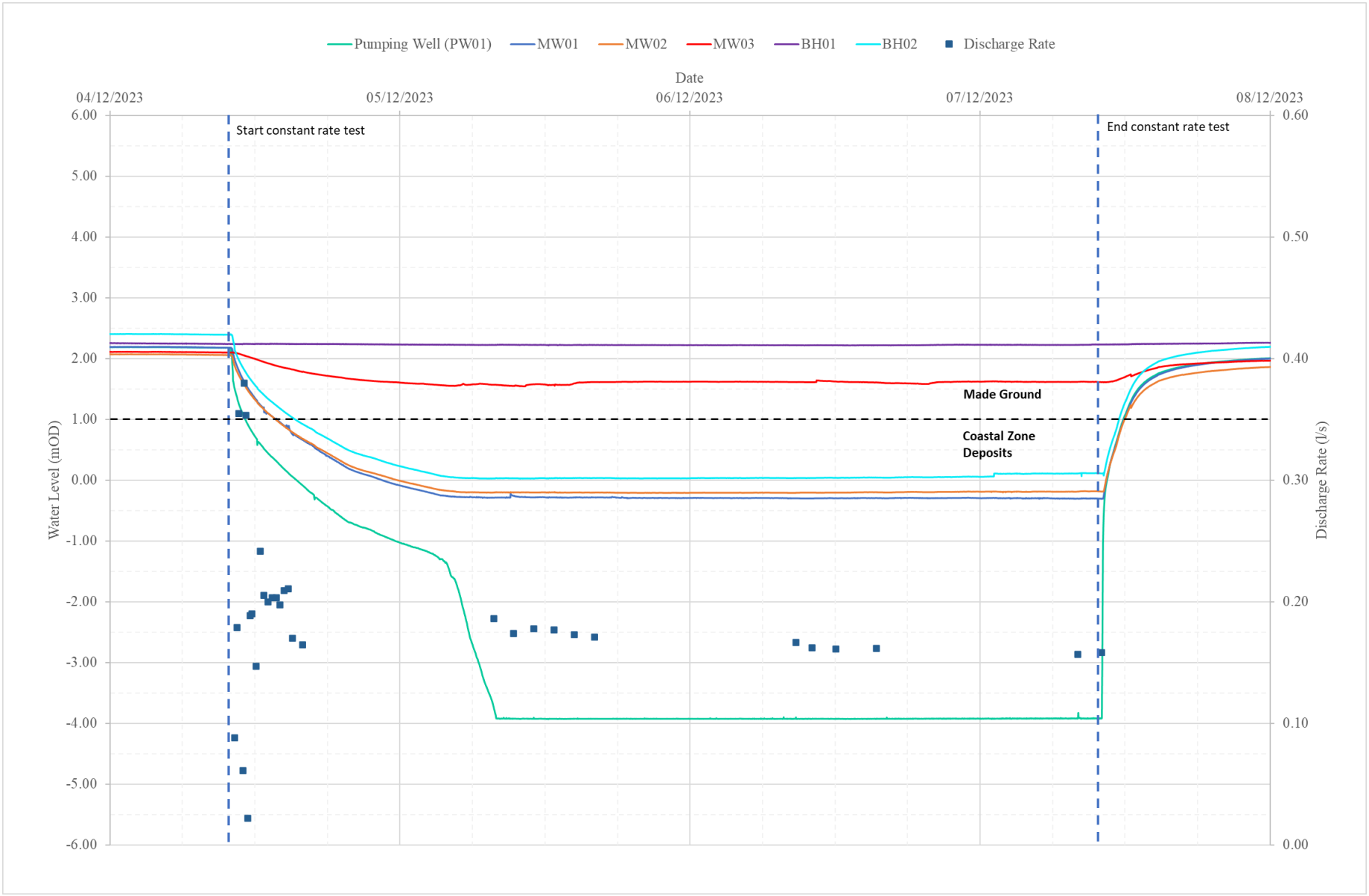
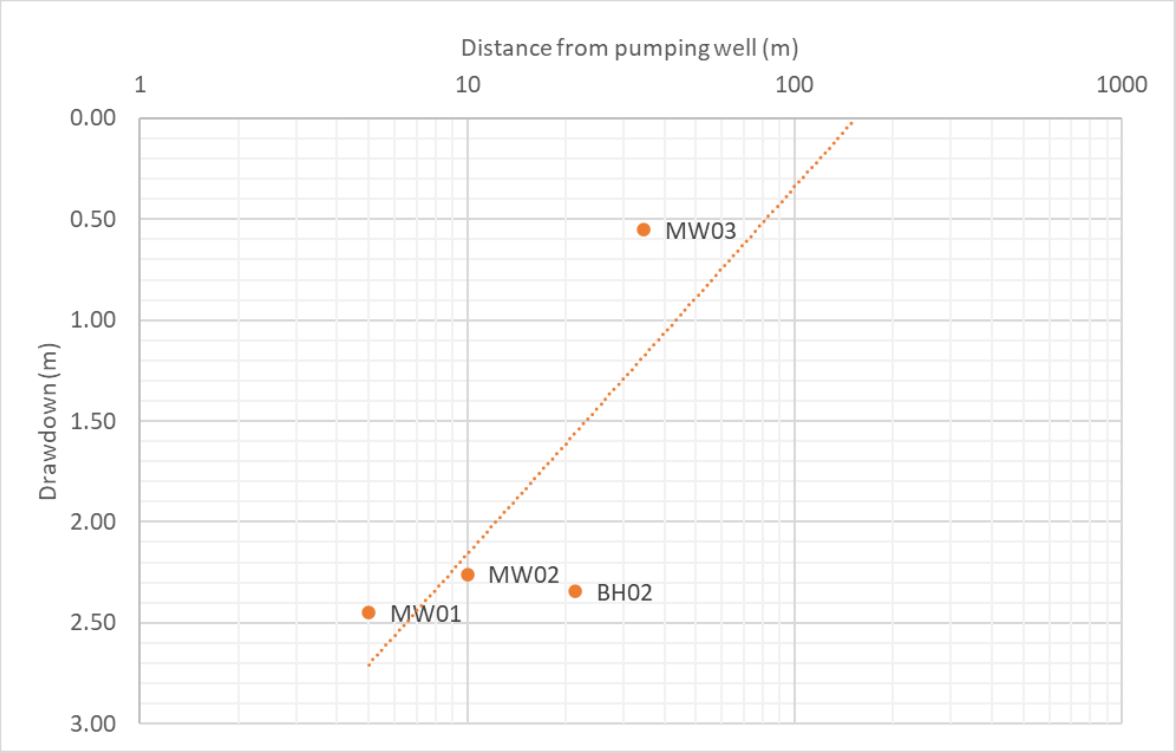


Figure 5 Distance maximum drawdown plot for 72-hour constant rate test

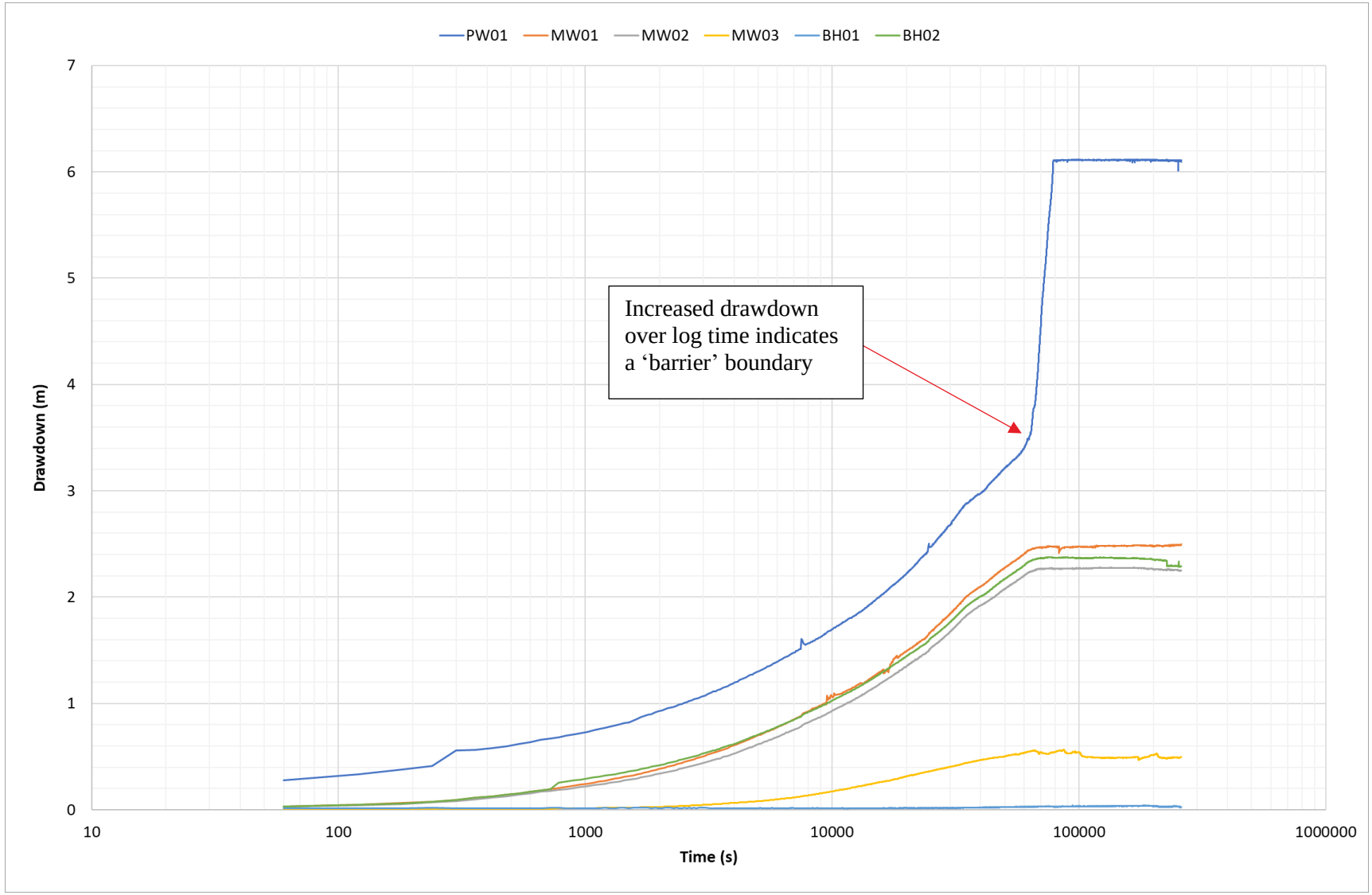


Review of the test data shows the following key observations with respect to groundwater levels during the pumping test:

- A decline in groundwater levels was observed at all monitoring well locations except at BH01, which is the only borehole to be screened in the Made Ground only, and which showed no apparent response to pumping. Minor tidal fluctuations were still observed at BH01 during the pumping test; the other boreholes showed very slight tidal variation.
- Groundwater drawdown at the pumping well (PW01) was relatively steady until around 18 hours into the test. At this point there was an apparent deflection in the rate of drawdown which increased significantly until 22 hours into the test. Following this, groundwater drawdown ceased and remained more or less static for the remainder of the test at a groundwater elevation in the pumping well of -3.9mOD (**Figure 4**).
- At around the same time of the deflection in drawdown at PW01 (18 hours into the test), groundwater drawdown at each of the monitoring wells flatlined and remained relatively static for the remainder of the pumping test.
- Discharge rate monitoring was not undertaken across this period so any changes in flow rate during these deviations cannot be evaluated.
- The observation well drawdown is inconsistent. More drawdown was observed at BH02 than at MW02 despite it being closer to the pumping well. It is possible that this may be due to differences in response zone elevations within the boreholes and heterogeneity within the Coastal Zone deposits.

The differences in response between the pumping well drawdown and the observation well drawdown are not easily explained. The increased rate of drawdown observed at the pumping well may be indicative of a barrier boundary i.e. caused by a reduction in groundwater flow towards the pumping well. However, this is the opposite response to the observation wells which appear more reflective of a leaky aquifer or a recharge boundary response. That the drawdown in all of the observation wells flatlines at the same time may point towards a reduction in the pumping rate however there is not sufficient granularity in that dataset to confirm whether this was the cause. The sudden flatlining of the pumping well drawdown 22 hours into the test, without obvious change in pumping rate is unusual. The manual dip data and transducer both indicate that there was groundwater within the well during this period (i.e. the water level was still above the transducer and dip tube).

Figure 6 Constant rate pumping test – time-drawdown plot



B.3.3 Constant rate test analysis

Aquifer parameters were estimated using distance drawdown analysis and time variable drawdown analysis for each of the observation well responses (except BH01 which showed no response). The pumping well and observation wells were screened across both the Made Ground and the underlying Coastal Zone Deposits. As a result, the evaluated hydraulic properties from the pumping test are only reflective of a bulk average permeability. It is not possible to define different hydraulic properties for the Made Ground and Coastal Zone deposits based on the results of the pumping test.

Steady state distance drawdown (Theim analysis)

An initial estimate of the aquifer hydraulic conductivity was made used a steady state Theim analysis. Although this analysis assumes confined aquifer conditions, it is typically used as an initial estimate in aquifer test analyses. The analysis uses the drawdown at each observation well plotted versus radial distance from the pumping well (**Figure 4**) where the slope of the line can be used to estimate the hydraulic conductivity of the aquifer using:

$$KD = \frac{2.3Q}{2\pi\Delta s}$$

The results are provided in **Table 5**.

Table 5: Theim steady state analysis results

Parameter	Description	Value	Source
D	Aquifer thickness (m)	8m	Assumed to be from base of pumping well to static water level
Q	Pumping rate (m3/s)	$1.71x10^{-4}$	Average discharge rate during test
ΔS	Estimated drawdown over 1 log cycle (m)	1.8	Estimated from Figure 4
K	Hydraulic conductivity (m/s)	**$4.4x10^{-6}$**	Calculated

Time-drawdown analysis

Aqtesolv curve matching software was used to analyse the pumping test drawdown at observation wells MW01, MW02, MW03 and BH02. The software uses automatic curve matching analysis to estimate the aquifer parameters from the time dependant drawdown response based on different analytical solutions for different aquifer types and geometries.

For the purposes of the analysis, two different solutions were used, the Hantush Jacob leaky confined solution and the Neuman unconfined solution. Based on the response observed at the observation wells, which showed a flatlining of the drawdown beyond 18 hours, the leaky confined aquifer solution generally showed better fit to the data compared to the unconfined solution. However, the estimated hydraulic conductivity from both solutions was generally similar, except for MW03 where the unconfined solution showed poor fit to the data.

Table 6 presents the results of the time dependant analysis. **Figure 7** provides an example of the curve matching for MW01. Curve matching for each of the other monitoring wells has not been reproduced.

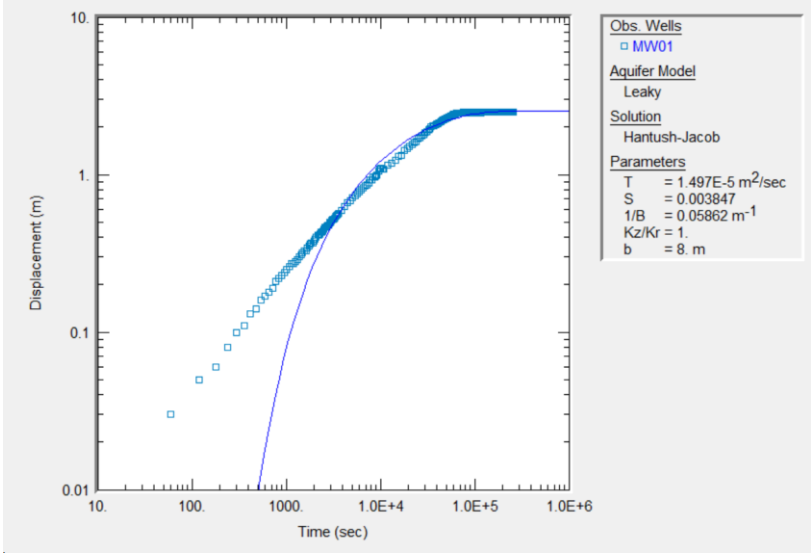
Table 6: Theim steady state analysis results

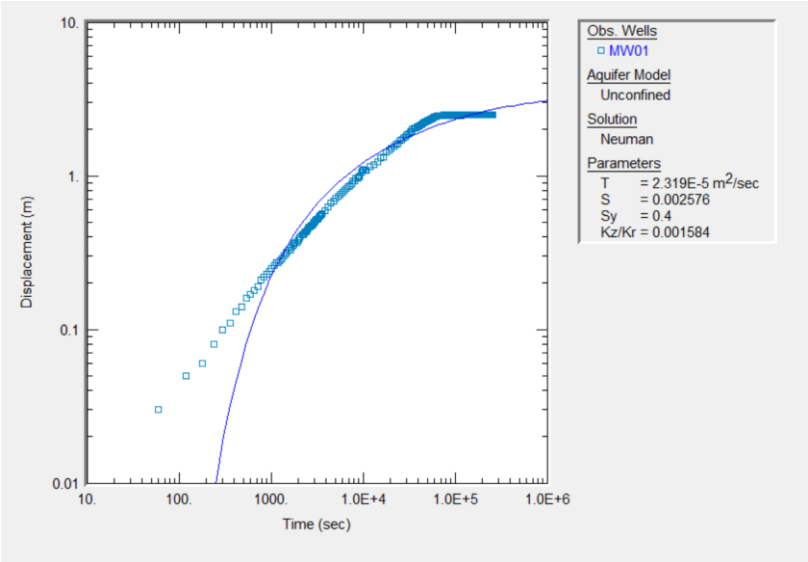
Monitoring well	Hantush Jacob leaky confined		Neuman unconfined solution	
	Hydraulic conductivity (m/s)	Storativity (-)	Hydraulic conductivity (m/s)	Storativity (-)
MW01	$1.9x10^{-6}$	$3.8x10^{-3}$	$2.9x10^{-6}$	$2.6x10^{-3}$
MW02	$2.0x10^{-6}$	$1.1x10^{-3}$	$2.6x10^{-6}$	$8.4x10^{-4}$

Monitoring well	Hantush Jacob leaky confined		Neuman unconfined solution	
	Hydraulic conductivity (m/s)	Storativity (-)	Hydraulic conductivity (m/s)	Storativity (-)
BH02	$2.1x10^{-6}$	$2.0x10^{-4}$	$2.8x10^{-6}$	$1.5x10^{-4}$
MW03	$2.5x10^{-6}$	$5.7x10^{-3}$	$1.3x10^{-5}$*	$4.4x10^{-3}$
Average	$2.1x10^{-6}$	$2.7x10^{-3}$	$2.8x10^{-6}$	$1.2x10^{-3}$
*Poor data fit – result not included in average value				

Based on the results of the results of the constant rate test analysis the bulk average hydraulic conductivity of the strata below the Site appears to range from around $2x10^{-6}$ m/s to $4x10^{-6}$ m/s. Given the heterogeneity of the materials, it is unlikely that the material will act as a homogenous unit, and more permeable zones may be responsible for the bulk of the groundwater flow during dewatering. Variable head tests undertaken during the initial ground investigation corroborates this as the results from these tests indicated a wider range of hydraulic conductivity values than the pumping tests. The lateral and vertical heterogeneity will need to be carefully considered in the design of the dewatering system.

Figure 7 Time drawdown analysis plots – MW01





Appendix C

Water Features Survey Report

ARUP

Dŵr Cymru Welsh Water

Menai Strait - Shellfish Waters Project

Water Feature Survey

Reference: B16888-102503-XX-XX-RP-NA-HY6703

1 | 15 August 2023

Job number 275282

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ARUP

Document Verification

Project title	Menai Strait - Shellfish Waters Project
Document title	Water Feature Survey
Job number	275282-00
Document ref	B16888-102503-XX-XX-RP-NA-HY6703
File reference	

Revision	**Date**	**Filename**			
1	15 August 2023	**Description**	Initial Water Feature Survey		
			Prepared by	**Checked by**	**Approved by**
		Name	Tom Goodfellow	Natasha Wilkinson	Jason Fairbairn
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Tables

Figures

1. Introduction

The Welsh Water Menai Shellfish Project aims to improve the storm overflow performance from the Bangor Beach Road Sewage Pumping Station. This pumping station is one of four assets that fall under the Asset Management Plan (AMP) 7 National Environmental Programme (NEP) to meet the Shellfish Water Directive of 10 No. spills per annum for the Menai Strait.

The identified solution requires new infrastructure to be installed below ground level at a site located between the A5 Beach Road and the promenade along the Menai Strait. The current proposals include a 24m x 60m storm storage tank, new rising main and new gravity pipe. The invert level of the storage tank is 1.565m OD, circa 5m below ground level, and the gravity pipe falls even deeper to 1.273m OD where it connects to an existing Manhole.

Tidally influenced groundwater levels have been monitored on site in the order of 1.5m OD to 2.25m OD. As such, groundwater control measures are likely to be required to enable excavation in the dry.

Since January 2018, abstraction for building or engineering works has not been exempt from abstraction licensing unless it meets the criteria in Regulation 5 of the Water Abstraction and Impounding (Exemptions) Regulations 2017. With the site, located within 500m of a designated site (the Menai Strait) compliance with the exemption abstraction limit of $50m^3/d$ (0.58 lit/sec) is unlikely during higher groundwater level conditions.

A pumping test is proposed at the site to inform dewatering and abstraction licensing requirements, which will require a Groundwater Investigation Consent (GIC). To inform the GIC and a potential future abstraction license, a water features survey has been undertaken to identify receptors within the study area (see section 2.1) that may be impacted by any future dewatering operations.

This report documents the identified water features and factual survey information. No analysis or interpretation of the data has been undertaken.

The site surveys were undertaken by Morgan Sindall engineers on the 20th and 21st July 2023.

2. Approach and Methods

2.1 Study Area

The proximity of the site to the dominant head boundary of the Menai Strait, together with the temporary nature of the works and limited drawdown required (less than 2.0m) means that any dewatering is likely to have a relatively limited zone of influence. However, for the purpose of this Water Feature Survey, a conservative study area of 1km from the site has been selected.

2.2 Planned Surveys

2.2.1 Feature Identification

A review of available Ordnance Survey, Natural Resource Wales and British Geological Survey mapping was undertaken prior to the surveys to identify potential water features within 1km of the proposed site.

This review looked to identify features including:

- Boreholes and wells;
- Licensed abstractions;
- Springs;
- Watercourses;
- Ponds and lakes;
- Wetland areas;
- Seepage lagoons and catch-pits; and
- Adits.

2.2.2 Survey Methodology

The water features survey was designed to align with the information recorded in Natural Resources Wales (NRW) Form WR36 (Water Resources Act 1991 Section 32) so that the information can be submitted to NRW in support of a GIC application.

At each identified survey location, the engineers have collated data and photos including the indicative items listed below:

- Survey feature ID;
- Location (Easting and Northing);
- Time and date of survey;
- Weather conditions;
- Photos (at distance from feature, close to feature, upstream and downstream);
- Feature type (e.g. BH/Spring/water course);
- Use (if any/known – e.g. used for water supply);
- Feature dimensions (e.g. channel width/depth/well/bh depth) (estimated where access/health and safety constraints);
- Water depth (water course) or depth to water (BH/well);
- Water flow (estimated/qualitative);

- Water quality (visual – clear/muddy etc.);
- Bed/base material/lining (e.g. concrete channel, mud/sands/gravels/cobbles);
- Channel bank vegetation;
- General setting (e.g. domestic/pier/by road/field); and
- Any other pertinent notes.

The Engineers utilised a Leica GS16 GPS to calculate locations and elevations, together with a tape measure utilised for general measurements. Water quality and flows were visually assessed only.

2.2.3 Proposed Water Feature Survey Locations

Following review of available baseline mapping and data sources, proposed survey locations were identified as outlined in **Table 1** and **Figure 1**Table 1.

Note that no licensed abstractions are mapped within the study area. Cyngor Gwynedd council were also contacted for details of any private (unlicensed) water supplies within 1km of the site. They confirmed on 29th June 2023 that, searching by wards, the following results were returned:

- Canol Bangor Ward – 0 supplies within 1km;
- Dwyrain Bangor Ward – 0 supplies within 1km;
- Dewi Ward – 0 supplies within 1km; and
- Arllechwedd Ward – 0 supplies within 1km.

Table 1: Proposed Survey Locations

Survey ID	Easting	Northing	Type of feature	Notes
01	258726	372806	The Menai Strait/Bangor Flats	
02	258660	372931	Watercourse outfall to sea	
03	258565	372958	Watercourse/Drainage outfall to sea	
04	258228	373613	Menai Strait. Potential Outfall/Discharge	At end of Bangor Pier
05	257711	372751	Watercourse entry to sea	
06	257764	372707	Watercourse midpoint. Potential spring	
07	257754	372561	Watercourse headwaters. Potential spring	
08	259080	371859	Afon Cegin at 1km distance	
09	259270	372404	Afon Cegin/Wetlands/Potential discharge	
10	259192	372586	Watercourse entry to sea	
11	259108	373002	Menai Strait	
12	258166	373082	Potential Wells	Two wells marked on OS map
13	258320	371993	Potential Spring	
14	259231	372803	Potential Outfall/Discharge to sea	
15	258334	372618	Potential Watercourse	May be culverted. Review upstream/downstream if water course visible in this area.
16	258085	372136	Potential Watercourse	May be culverted

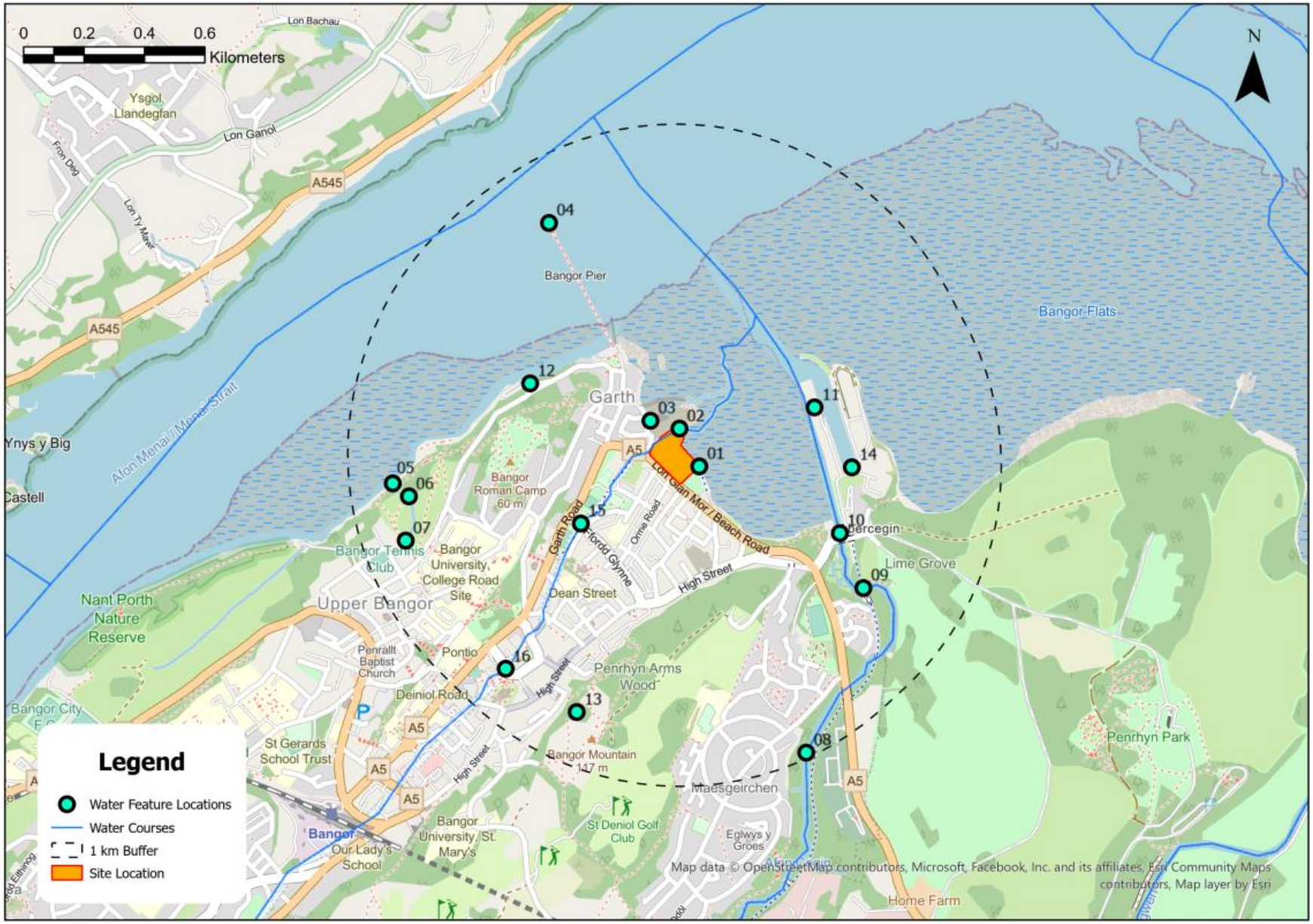


Figure 1: Proposed Water Feature Locations

3. Water Feature Survey

Sections **3.1** to **3.16** summarise the findings of the water feature surveys at each of the locations identified in **Figure 1**.

3.1 Feature 01 – Menai Strait/Bangor Flats

Table 2: Feature 01 Survey Results

	Results
Location	E: 258724.84 N: 372802.25 5.432m OD at top of wall, 3.115m OD at base of wall
Date and Time	20th July 2023 at 09:00
Weather	Warm and cloudy. Heavy persistent rain over past two weeks.
Feature Type	Bangor Flats – Beach.
Use	N/A
Feature Dimensions	N/A
Water depth	N/A – Survey undertaken at low tide
Water flow observations	N/A
Water quality observations	N/A – No obvious signs of pollution.
Bed/base material/lining	Pebbly beach
Vegetation	Seaweed in places
General setting	Bangor flats adjacent to proposed location of SPS.
Other notes	No discharges visible in area.

Feature Photo(s) 1

3.2 Feature 02 – Bangor Flats & watercourse outfall to sea

Table 3: Feature 02 Survey Results

	Results
Location	E: 258660 N: 372931
Date and Time	20th July 2023 at 09:30
Weather	Warm and cloudy. Heavy persistent rain over past two weeks.
Feature Type	Discharge from culverted watercourse onto Bangor Flats.
Use	N/A
Feature Dimensions	Culvert circa 5m wide. Channel circa 300mm deep after exiting culvert (at time of survey but tidal mud flats, so varies)
Water depth	Level 1.114m OD
Water flow observations	Gentle
Water quality observations	Clear, no discolouration present
Bed/base material/lining	Sand/Mud after exiting concrete culvert.
Vegetation	Seaweed in places
General setting	Bangor flats adjacent to proposed location of SPS. Culverted water course discharge.
Other notes	

Feature Photo(s) 2

3.3 Feature 03 – Bangor Flats & watercourse/drainage outfall

Table 4: Feature 03 Survey Results

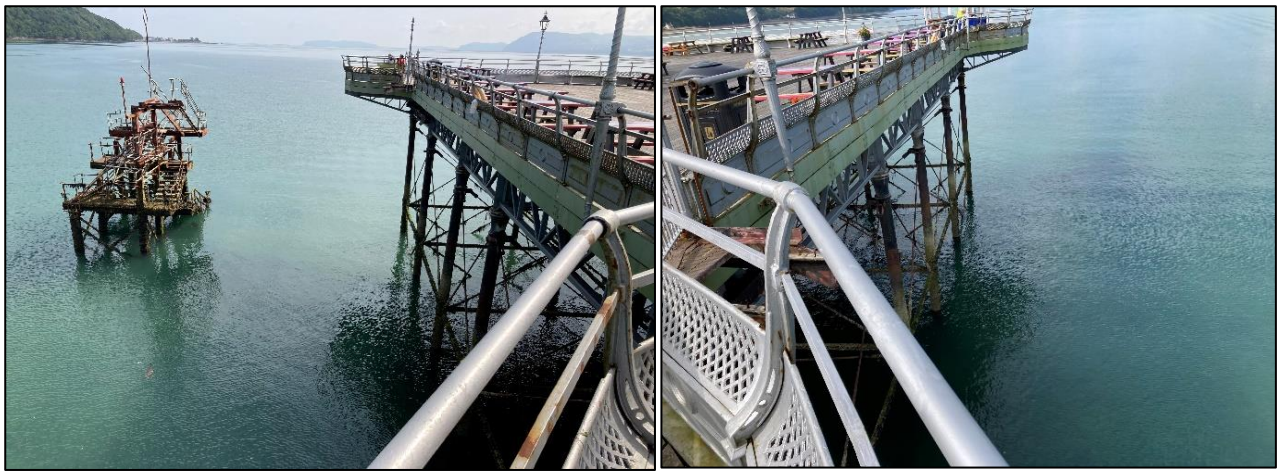
	Results
Location	E: 258563.52 N: 372956.55 Top of wall: 4.836m OD
Date and Time	20th July 2023 at 10:00
Weather	Warm and cloudy. Heavy persistent rain over past two weeks.
Feature Type	Outlet into sea from harbour wall in disused dock.
Use	Disused dock. Outfall source unknown (potentially surface water runoff)
Feature Dimensions	N/A
Water depth	Low tide – limited water in dry dock. No water from outfall
Water flow observations	None from outlet
Water quality observations	N/A
Bed/base material/lining	Muddy, Cobbles, Wood
Vegetation	Overgrown vegetation surrounding dry dock.
General setting	Disused dock. Overgrown vegetation and Heras fencing surrounding dock. Residential area beyond
Other notes	

Feature Photo(s) 3

3.4 Feature 04 – Menai Strait & Potential discharge/outfall

Table 5: Feature 04 Survey Results

	Results
Location	E: 258223.62 N: 373611.56 Pier deck: 8.045m OD
Date and Time	20th July 2023 at 10:30
Weather	Warm and cloudy. Heavy persistent rain over past two weeks
Feature Type	Menai Strait viewed from end of Bangor Pier.
Use	N/A
Feature Dimensions	N/A
Water depth	N/A – Unable to quantify
Water flow observations	N/A – Unable to quantify
Water quality observations	N/A – No obvious pollution/contamination
Bed/base material/lining	N/A – Unable to see
Vegetation	N/A
General setting	End of Bangor Pier
Other notes	No outfalls/discharges observed



Feature Photo(s) 4

3.5 Feature 05 – Watercourse entry to Menai Strait

Table 6: Feature 05 Survey Results

	Results
Location	E: 257700.56 N: 372760.66 Elevation: 1.021m OD E: 257707.45 N: 372750.39 Elevation: 2.579m OD
Date and Time	21st July 2023 at 09:00
Weather	Sunny.
Feature Type	Outfall into sea
Use	N/A
Feature Dimensions	Circa 50cm diameter
Water depth	N/A
Water flow observations	N/A – None visible
Water quality observations	N/A – No clear signs of pollution
Bed/base material/lining	Towards land – cobbles/pebbles/gravels. Towards sea – sand and mud
Vegetation	Seaweed surrounding culvert. Wooded area at landside end of culvert.
General setting	Beach
Other notes	Pipe damaged

Feature Photo(s) 5

3.6 Feature 06 – Watercourse midpoint / potential spring

Table 7: Feature 06 Survey Results

	Results
Location	E: 257764.32 N: 372706.76
Date and Time	21st July 2023 at 09:30
Weather	Cloudy
Feature Type	N/A
Use	N/A
Feature Dimensions	600/700mm wide
Water depth	Water depth c400mm. Level 16.686m OD
Water flow observations	Steady – slow.
Water quality observations	Clear – no sign of pollution
Bed/base material/lining	Unknown - vegetated
Vegetation	Dense vegetation along embankment. Trees.
General setting	Bridge over water course within public area
Other notes	

Feature Photo(s) 6

3.7 Feature 07 – Watercourse headwaters / potential spring

Table 8: Feature 07 Survey Results

	Results
Location	E: 257759.81 N: 372565.95 Elevation: 30.851m OD
Date and Time	21st July 2023 at 10:00
Weather	Cloudy
Feature Type	Signs of spring. Wet, boggy ground.
Use	N/A – natural feature
Feature Dimensions	N/A
Water depth	<1cm where water visible – mainly boggy/wet ground
Water flow observations	Slow, diffuse spring flow.
Water quality observations	Clear, where visible
Bed/base material/lining	Mud/vegetation – geology not visible
Vegetation	Dense vegetation
General setting	Vegetated public open space
Other notes	

Feature Photo(s) 7

3.8 Feature 08 – Afon Cegin at 1km distance

Table 9: Feature 08 Survey Results

	Results
Location	E: 259080 N: 371859
Date and Time	20th July 2023 at 11:00
Weather	Sunny
Feature Type	Watercourse (Afon Cegin)
Use	N/A
Feature Dimensions	Couple of metres
Water depth	300-400mm
Water flow observations	Steady (non-turbulent flow)
Water quality observations	Muddy – poor visibility. No contamination visible
Bed/base material/lining	Mud and cobbles.
Vegetation	Vegetation on either bank and trees
General setting	Woodland
Other notes	

Feature Photo(s) 8

3.9 Feature 09 – Afon Cegin / Wetlands / Potential discharge

Table 10: Feature 09 Survey Results

	Results
Location	E: 259276.99 N: 372391.14 Elevation 8.241m OD (Lower Bridge)
Date and Time	20th July 2023 at 11:30
Weather	Sunny
Feature Type	Watercourse - Two bridges (pedestrian and old cattle bridge) over Afon Cegin, upstream of Cegin Pool
Use	N/A
Feature Dimensions	Bridge >20m long.
Water depth	Fairly shallow (bottom visible)
Water flow observations	Steady water flow (non-turbulent)
Water quality observations	Clear generally – murky in areas. No clear pollution.
Bed/base material/lining	Mud, gravels and cobbles.
Vegetation	Dense vegetation + trees on verges. Grassland on verges downstream. Algae in water in areas.
General setting	Woodlands.
Other notes	

Feature Photo(s) 9

3.10 Feature 10 – Afon Cegin entry to sea

Table 11: Feature 10 Survey Results

	Results
Location	E: 259192 N: 372586
Date and Time	20th July 2023 at 12:30
Weather	Sunny
Feature Type	Watercourse flowing underneath bridges into harbour area
Use	N/A
Feature Dimensions	Watercourse circa 5m wide under bridge
Water depth	Tidal (low tide during survey) Upstream of bridge shallow. Downstream depth not visible
Water flow observations	Steady water flow from upstream
Water quality observations	Very murky downstream of bridge. Clear upstream of bridge
Bed/base material/lining	Muddy sandy bed. Gravels in places
Vegetation	Cut grass, occasional trees/shrubs
General setting	Harbour, adjacent to Porth Penrhyn. Upstream of bridge meandering river through field.
Other notes	

Feature Photo(s) 10

3.11 Feature 11 – Menai Strait at Porth Penrhyn

Table 12: Feature 11 Survey Results

	Results
Location	E: 259108.00 N: 373002.00
Date and Time	20th July 2023 at 13:30
Weather	Sunny
Feature Type	Menai Strait at Porth Penrhyn (Harbour)
Use	N/A
Feature Dimensions	N/A
Water depth	Unknown (deep)
Water flow observations	N/A
Water quality observations	Clear water conditions. No clear contamination
Bed/base material/lining	Not visible – assume sands to gravels
Vegetation	N/A
General setting	On Wharf at Porth Penrhyn
Other notes	No signs of discharge or outlets (potentially submerged)

Feature Photo(s) 11

3.12 Feature 12 – Potential Wells

Table 13: Feature 12 Survey Results

	Results
Location	E: 258164.11 N: 373082.91 Elevation: 3.02m OD E: 258189.79 N: 373091.59 Elevation: 2.80m OD
Date and Time	21st July 2023 at 12:30
Weather	Cloudy
Feature Type	Two wells – first inaccessible, second in brick chamber. Local resident has pumps setup and is using as water source.
Use	Private supply
Feature Dimensions	Well 1 - Unable to access Well 2 - Brick chamber circa 1.0m long x 0.5m wide containing pump
Water depth	Well 1 – Unable to access Well 2 – Water circa 1.0m below ground level
Water flow observations	Unknown
Water quality observations	Well 1 - Unable to access Well 2 - Crystal clear
Bed/base material/lining	N/A
Vegetation	Dense vegetated area
General setting	Close to Menai Strait, in wooded area near to Old Baths.
Other notes	





Feature Photo(s) 12

3.13 Feature 13 – Potential Spring

Table 14: Feature 13 Survey Results

	Results
Location	E: 258298.48 N: 372041.51 GL: 37.808m OD
Date and Time	21st July 2023 at 13:30
Weather	Cloudy
Feature Type	Potential spring – unable to locate any signs.
Use	N/A
Feature Dimensions	N/A
Water depth	N/A
Water flow observations	N/A
Water quality observations	N/A
Bed/base material/lining	Muddy underfoot
Vegetation	Dense overgrown vegetation
General setting	Back of housing estate on Bangor Mountain
Other notes	

Feature Photo(s) 13

3.14 Feature 14 – Potential Outfall / Discharge to Sea

Table 15: Feature 14 Survey Results

	Results
Location	E: 259227.54 N: 372802.14
Date and Time	21st July 2023 at 08:30
Weather	Cloudy
Feature Type	Outfall/discharge onto Bangor Flats from harbour wall (marked as issues on map)
Use	N/A
Feature Dimensions	Unable to measure
Water depth	Tidally dependent Outfall Invert: -0.793m OD
Water flow observations	No discharge visible, but a lot of debris at outlet location.
Water quality observations	Unknown
Bed/base material/lining	Lots of debris. Muddy/sandy seabed
Vegetation	None
General setting	Penrhyn Wharf
Other notes	

Feature Photo(s) 14

3.15 Feature 15 – Potential watercourse (culverted)

Table 16: Feature 15 Survey Results

	Results
Location	E: 258331.66 N: 372626.69 Elevation: 6.635m OD (Manhole)
Date and Time	21st July 2023 at 14:00
Weather	Cloudy
Feature Type	Culverted watercourse.
Use	N/A
Feature Dimensions	N/A
Water depth	N/A
Water flow observations	Could hear flows under manhole cover.
Water quality observations	N/A
Bed/base material/lining	N/A
Vegetation	N/A
General setting	In field by Bangor swimming baths
Other notes	Could not find any visible culvert/ watercourse upstream or downstream of location

Feature Photo(s) 15

3.16 Feature 16 – Potential watercourse (culverted)

Table 17: Feature 16 Survey Results

	Results
Location	E: 258087.78 N: 372133.28 Elevation: 11.795m OD (Manhole)
Date and Time	21st July 2023 at 14:00
Weather	Cloudy
Feature Type	Culverted water course
Use	N/A
Feature Dimensions	N/A
Water depth	N/A
Water flow observations	Could hear flows through manhole cover
Water quality observations	N/A
Bed/base material/lining	N/A
Vegetation	N/A
General setting	Built up area, manhole in road (not opened) opposite Bangor police station
Other notes	

Feature Photo(s) 16

Appendix D

Preliminary dewatering calculations

D.1 Equivalent well dewatering assessment

An assessment of steady state dewatering rates for the excavation has been undertaken using the Dupuit-Forcheimer equation for steady state flow in an unconfined aquifer, as follows[1]:

$$Q = \frac{\pi k(H^2 - h_w^2)}{\ln\left[{}^{R_0}/_{r_e}\right]}$$

Where k = soil hydraulic conductivity

H = initial piezometric level

h_w = piezometric level in the equivalent well (target level)

R_0 = radius of influence

r_e = radius of equivalent well = (L+W)/π

The following assumptions apply to the Dupuit-Forcheimer equation:

- The aquifer has infinite areal extent.
- The aquifer is homogenous, isotropic and of uniform thickness.
- The initial water table is flat.
- The aquifer is pumped at a constant discharge rate.
- The pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer.
- The flow to the well is in a steady state.

The estimated dewatering flow rate has been evaluated for two scenarios using the hydraulic conductivity estimated from the pumping test (Appendix B), and a weighted average hydraulic conductivity based on the pumping test and the variable head tests, which indicated higher hydraulic conductivity values. The weighted average is based on a 2m saturated Made Ground with a hydraulic conductivity of $6x10^{-5}$m/s, and 7m saturated thickness of Coastal Zone Deposits, with a hydraulic conductivity of $2x10^{-6}$m/s.

For the purposes of the flow analysis, the Sichardt equation has been used for the estimation of radius of influence (note that this has only been used to conservatively assess flows and not to assess drawdown impacts which consider a larger zone of influence). This is expected to be conservative since the estimated radius of influence values are smaller than those estimated during the pumping test, which leads to an increased estimated flow rate. For the purposes of the calculation, the radius of influence also includes the radius of the equivalent well.

$$R_o = r_e + 3000(H - h)\sqrt{K}$$

The input parameters and results of the analysis are provided in Table 7

[1] Preene, M, Roberts, T O L and Powrie, W (2016). Groundwater Control – Design and Practice, 2nd edition. Construction Industry Research and Information Association, CIRIA Report C750, London.

Table 7: Estimated dewatering flow rates

Parameter	Scenario 1	Scenario 2
Initial water table above base of aquifer (m)	8.5	8.5
Target water level above base of aquifer (m) [1]	6.5	6.5
Hydraulic conductivity (m/s)	$2x10^{-6}$	$1.5x10^{-5}$
Radius of influence (m) [2]	8.5	23.2
Radius of equivalent well (m) [3]	27.1	27.1
Calculated Flow Rate (m^3/d)	60	200
Calculated Flow Rate (l/s)	0.7	2.3

[1] base of aquifer taken at same elevation as base of pumping well -6mOD

[2] The actual radius of influence will be influenced by the local boundary conditions (such as the river) and rainfall. A lower radius of influence results in higher calculated flow rates. As such, a relatively small radius of influence has been selected for this assessment.

[3] Radius of equivalent well based on the proposed excavation dimensions (13.5m by 32m) of the storage tank, using the equation $(a+b)/\pi$ from CIRIA C750.