INTEGRATED WASTE MANAGEMENT FACILITY AT HOLLYWOOD CIRCULAR ECONOMY CAMPUS

Environmental Impact Assessment Report Volume IV: Hydrogeological Assessment

MDR1492Rp0006d
F01
21st October 2022

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INTEGRATED WASTE MANAGEMENT FACILITY AT HOLLYWOOD CIRCULAR ECONOMY CAMPUS

Hydrogeological Assessment – Part 1 Hydrogeological Assessment Report

MDR1492ARp0013
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1 INTRODUCTION

1.1 Preamble

Integrated Materials Solutions Limited Partnership (IMS) is seeking planning permission and an EPA licence review to provide additional sustainable waste solutions in line with circular economy principals and the waste hierarchy and to continue the operation of the existing waste facility Hollywood Great, Nag's Head, Naul, Co. Dublin (hereinafter referred to as the IMS facility). The location of the IMS facility and associated application boundary for the proposed development is shown in **Figure 1**.

The IMS facility is a former limestone and shale quarry that has been operating as an engineered landfill site for inert waste since 2003. Under the terms of the current planning permissions and the existing Waste Licence (Ref. W0129-02) issued by the Environmental Protection Agency (EPA), only waste which meets the criteria for inert landfill as set out in the Landfill Directive (Directive 1999/31/EC) may be accepted at the site. The current cap on the waste volumes accepted at the site is restricted to 500,000 tonnes per annum both by the planning consents and the Waste Licence.

IMS is seeking consent to diversify the waste materials accepted at the Hollywood site to include a broader mix of wastes at a series of specially engineered cells to meet the demands of the construction sector and to allow for State self-sufficiency in particular waste streams. The proposal consists of permission for a 25-year lifetime of operation to develop engineered landfill cells on the site to landfill a mixture of non-hazardous and inert wastes at a rate of 500,000 tonnes per annum as per the existing operation.

This report has been prepared to support the Environmental Impact Assessment Report (EIAR) for the planning and licensing applications and to specifically address the hydrogeological concerns raised by the EPA in a 2016 Decision Notice for a similar application at the site. The report presents the detailed hydrogeological investigations that have been undertaken at the site to address the EPA concerns raised in 2016 and to present an updated conceptual site model for the proposed development based on the new information available. The report presents a clear evidence base that the proposed development at the Hollywood site will not have an adverse impact on potential receptors in the area.

This report should be read in conjunction with the supporting LandSim Report included in this application (RPS Report Reference MDR1492Rp00015). This supporting report presents the findings of the application of the LandSim model which is an interactive programme used to model new and existing landfills. LandSim is used to track leachate production, chemistry, migration and leakage through structures assessing the potential of leachate migration to the underlying aquifer. The LandSim model uses the site-specific input parameters at the Hollywood facility to assess the impact of the proposed development on hydrogeology.

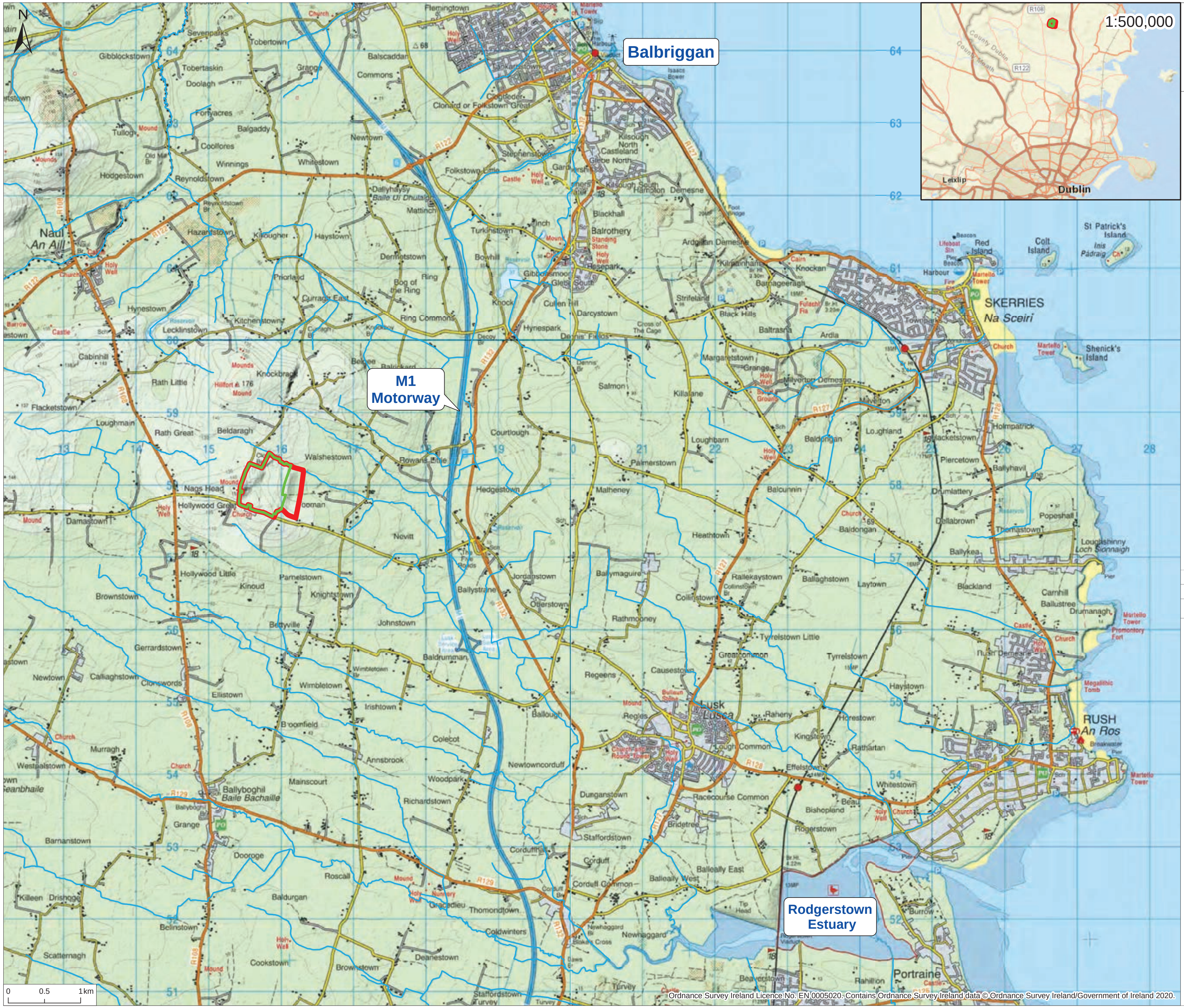
1.2 Site Planning and Licensing Background

The site was first granted a 15-year permission by Fingal County Council (FCC) in June 1988 to infill, restore and reinstate the portion of the quarry that was excavated to that date (Reg. Ref. 88a/32). For this application FCC granted a 15-year permission (expiring 2003).

As a secondary consent, a Waste Licence was first issued in 2002 to operate the Hollywood site as an inert landfill accepting soil and stone in addition to other inert construction and demolition material (Licence Reference No. W0129-01). Condition 3.21 of the licence included a requirement for the landfill liner to consist of a mineral layer of a minimum thickness of 1m with a hydraulic conductivity less than or equal to $1\text{x}10^{-7}$ m/sec or similar with equivalent protection to avoid groundwater contamination. The EPA granted a maximum waste acceptance of 340,000 tonnes per annum (in line with the planning permission Reg. Ref. 88a/32) for the disposal and recovery of inert construction and demolition waste and inert dredging spoils.

In 2004, planning permission from FCC (Reg. Ref. F04A/0363) was granted to extend the existing operation to infill the quarry void with inert waste materials within engineered cells at a rate of 340,000 tonnes per annum as part of the restoration and reinstatement of the quarry. For this application FCC granted a 15-year permission and this operation continued under the Waste Licence Reference W0129-01.

Subsequently in 2007 a further planning permission was granted by FCC (Reg. Ref. F07A/0262) to amend the 2004 permission (F04A/0363) to permit an extended area to be infilled and to permit the continued infill of the quarry at a rate of 500,000 tonnes per annum of inert construction and demolition waste.



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Legend

🟥 IMS Facility
🟩 Waste Licence Boundary
— Rivers

Rev	Description	By	CB	Date

MAKING COMPLEX EASY

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Client Integrated Material Solutions (IMS)

Project Hollywood Great

Title Site Location Plan

Status	Drawn By	PM/Checked By
DRAFT	RW	AG
Project Number	**Scale @ A3**	**Date Created**
JER1631	1:50,000	MAR 2020

Drawing Number
Figure 1

Rev
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For this increased tonnage a revised Waste Licence was required and Murphy Environmental submitted a Waste Licence Review Application. The revised Waste Licence (Licence Reference No. W0129-02) was granted in 2007 with the waste acceptance increasing to a maximum of 500,000 tonnes per annum of inert construction and demolition waste and inert dredging spoils with no limit on inert mineral extraction wastes arising from quarrying activities at the facility. This is the current licence that applies to site operations.

In 2010 MEHL applied to An Bord Pleanála (ABP) for SID planning permission (Case Reference PL06F.PA0018) and a revised Waste Licence (Licence Reference No. W0129-03) to redevelop and operate the site as an integrated waste management facility to accept 500,000 tonnes per annum of a mix of non-biodegradable hazardous wastes (45% of waste input), non-hazardous wastes (35% of waste input) and inert wastes (20% of waste input). This application also included the provision of a re-engineered Dense Asphaltic Concrete (DAC) liner for the proposed hazardous waste cells. An Environmental Impact Statement (EIS) was prepared to support the application.

Whilst the application was granted planning permission following an oral hearing by ABP in 2011, in January 2016 the EPA refused to grant a revised licence following the inspector's recommendation to refuse despite the applicant providing further technical submissions. The grounds of refusal presented in the EPA’s Decision Notice of 2016 were as follows:

> ‘*It is considered that the proposed activity that is subject of the licence review application presents unacceptable risk of input of hazardous substances into groundwater which is prohibited under the Directive 2006/118/EC on the protection of groundwater against pollution as implemented by SI No. 9 of 201, EC Environmental Objectives (Groundwater) Regulations, 2010*
>
> *The Groundwater Protection Responses for Landfills (DoEC&LG, EPA & GSI 1999) indicated that the installation of the proposed activity in the geological setting, as proposed, is not generally acceptable. The conditions in which the proposed activity would be acceptable have not been demonstrated;*
>
> *The groundwater beneath the landfill site, as proposed, is vulnerable to contamination from the proposed activity;*
>
> *The abstraction of groundwater at the Bog of the Ring (PWS) may influence groundwater levels beneath the landfill site, as proposed. Consequently, if the water abstraction at the Bog of the ring were to reduce significantly or cease altogether, this may result in the rebound if groundwater levels beneath the land fill site as proposed. This scenario would present an unacceptable risk to groundwater because the rising groundwater levels would have the potential to undermine the integrity of the landfill,*
>
> *It is considered that the situation and design of the proposed activity do not meet the necessary conditions for preventing pollution of the soil and groundwater. It is further considered that the landfill liner system, including the artificially completed geological barrier and the potential for its integrity to be undermined by rising groundwater levels, to prevent a potential risk to soil and groundwater, which are requirements of the Landfill Directive.*
>
> *It is therefore considered that it is not open to the Agency to grant a licence.*’

The site was acquired by IMS in 2017. Following acquisition of the site, IMS commissioned a review of the grounds for refusal presented in the EPA 2016 decision notice. IMS then commissioned an extensive programme of targeted investigation, monitoring and third-party data acquisition to provide the necessary dataset to directly address those areas of hydrogeological concern outlined in the EPA decision notice.

In 2020, Fingal County Council granted permission (Ref. F19A/0077) for the continued infilling of the former quarry with construction and demolition waste material at a rate of 500,000 tonnes per annum permitted under Reg. Refs. F07A/0262 and F04A/0363 for a further 15 no. year period. In addition, the permission consented the development of new site infrastructure including a new facility entrance to the south, an administration building and associated infrastructure and a waste processing yard at the centre of the site. This extended permission did not trigger the need for a review of the Waste Licence.

For the development of the application addressed in this report, a pre-application meeting for the Licence Review was arranged with the EPA for 11th April 2019. RPS provided the EPA with responses to nine questions to inform discussion at that meeting (see **Appendix A**). Those responses reflect the decision to remove the hazardous waste stream previously proposed and its replacement with the development and operation of a series of ‘*specifically designed composite clay and geo-membrane liner installed on the base and side walls of the proposed cells for non-hazardous waste*’ in conjunction with the ongoing inert waste landfilling licensed under W0129-02.

These responses made clear that '*IMS is committed to now eliminating the acceptance and landfilling of hazardous waste from the site thereby eliminating the 'source' characteristics for hazardous leachable substances*'.

1.3 Revised Site Plan

The revised site plan is presented in **Figure 2** (showing minor changes to the existing consented infrastructure including to new entrance, administration building and associated infrastructure granted by F19A/0077) and **Figure 3** (showing the proposed cell layouts). The key elements of the revised site plan include:

- Development and re-profiling of the landfill void to accommodate specially engineered landfill cells for non-hazardous wastes in addition to the existing engineered inert cells;
- Enhancement of the existing aggregate recovery processing on site (undertaken on the processing yard) including upgrading the existing aggregate recovery operations which produce low carbon, recovered sands and aggregates from various granular wastes by removing residues and other trace contaminants and separating the resulting aggregates into various size fractions;
- Manufacture of secondary materials including enhanced soils and low-energy bound materials (e.g. concrete);
- Additional waste recovery activities including soil/concrete batching and blending;
- Repurposing of an existing structure on site as a testing laboratory unit for the research, development and testing of recovered materials;
- A leachate management system including a leachate collection system and a storage tank prior to tankering off site for treatment at a suitably licensed WWTP with provision for a future on-site leachate treatment facility;
- A mobile enclosure for the maturation of Incinerator Bottom Ash (IBA);
- An internal un-paved road network serving the deposition areas from the reception area which will be modified throughout the development phasing; and
- Ancillary site works and landscaping.

The proposed development, while including many of the waste stream elements of the application permitted by ABP in 2011 but refused by the EPA in January 2016, effectively addresses the refusal of the waste licence principally by significantly reducing and altering the nature and quantity of the waste stream to be landfilled.

1.4 Report Objectives

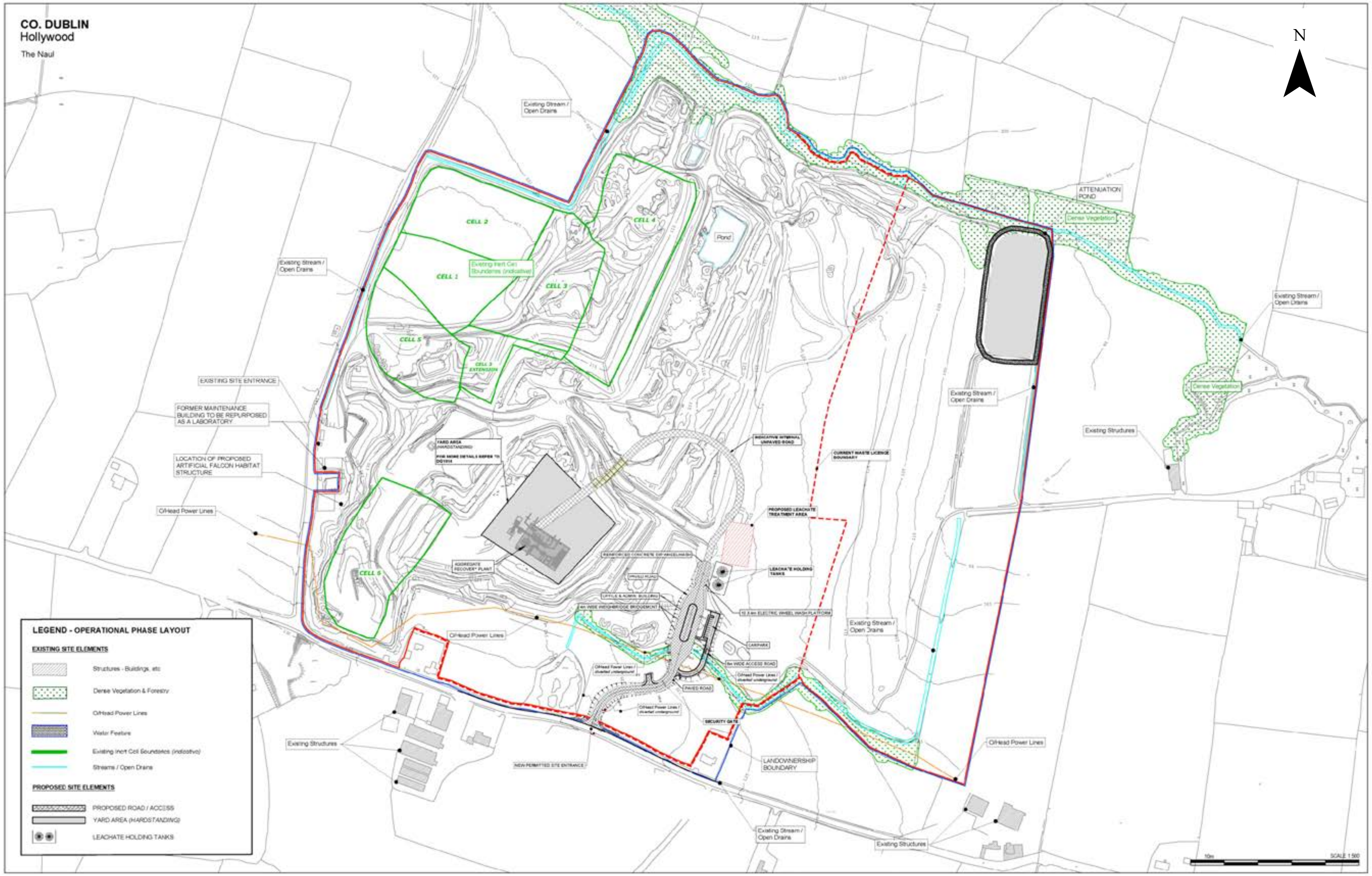
The principal objectives of this report are to undertake the following:

- Update the site's Conceptual Hydrogeological Model following interpretation of new hydrogeological data collected for the site; and
- Address the key areas of hydrogeological concern and uncertainty identified in the EPA's 2016 decision notice to refuse permission for the licence application.

This includes for a significantly modified source term from that refused in 2016 whereby hazardous waste is no longer included in this application (45% of waste in the previous permission was hazardous waste) which will have significantly reduced the source term at the site.

In addition, the greater understanding of the site's hydrogeological characteristics (hence, pathway assessment) are demonstrated through the presentation of an updated conceptual hydrogeological model of the facility as delivered by the programme of additional works commissioned by IMS since acquisition of the site.

This evaluation has been presented within the context of the modified proposals for the site and supports both the planning application and the review of the existing Waste Licence (to an Industrial Emissions Licence, IEL) for the proposed waste cells at the facility.



Client

Integrated Materials Solutions (IMS) Limited Partnership

IMS Hollywood 2022 Update

Title

Figure 2: Operational Site Layout

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Co Dublin, Ireland.

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Issue Details

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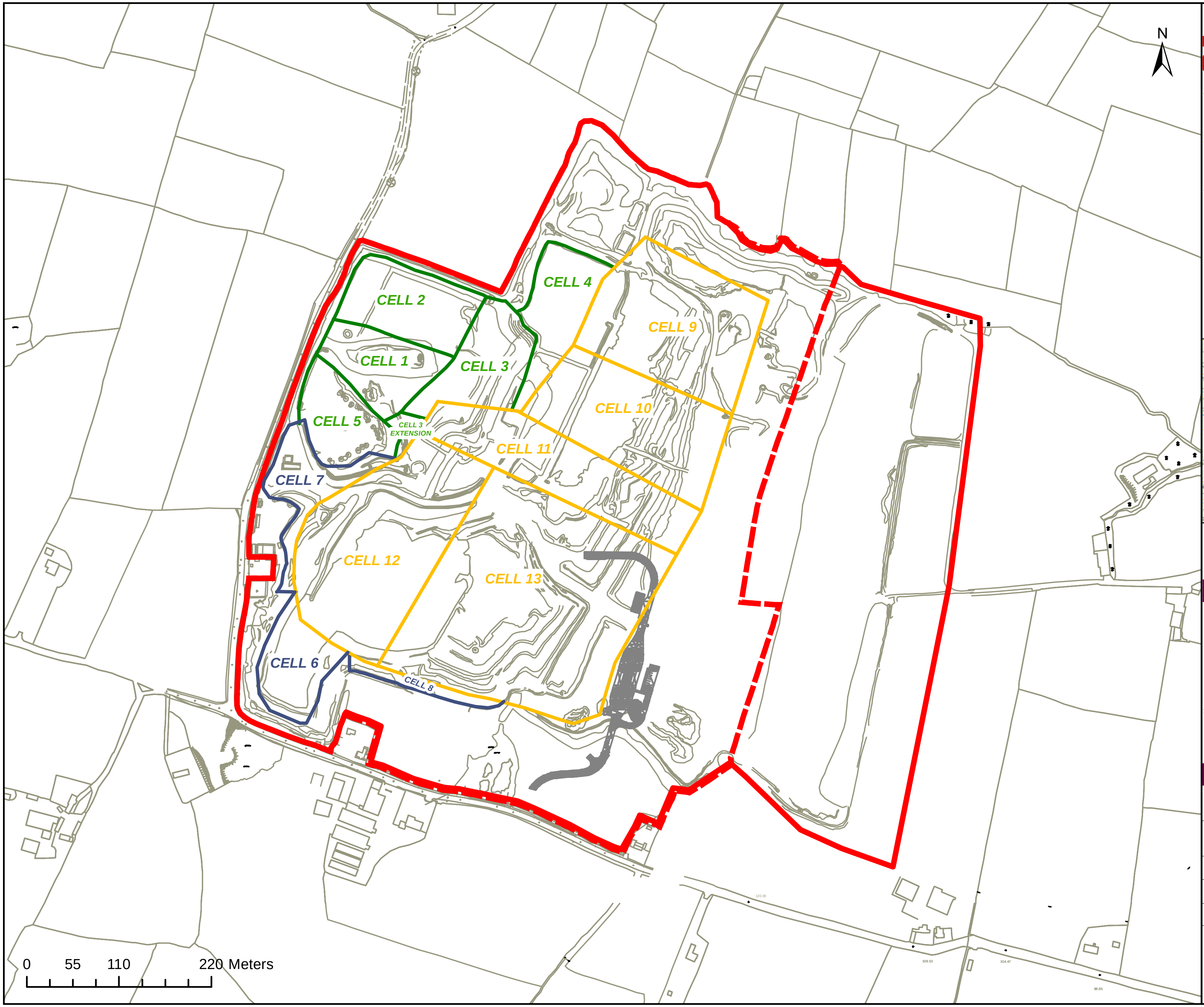
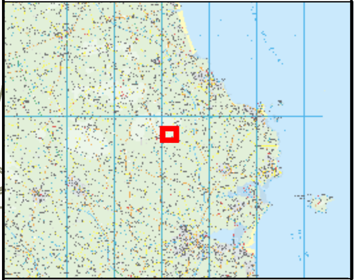


Legend

- 🟥 Waste Licence Boundary
- 🟥 Proposed Planning Boundary
- Existing Cell Boundaries (Indicative)
- Proposed Non-Hazardous Waste Cell Boundaries (Indicative)
- Proposed Inert Cells Boundaries (Indicative)



Client

Integrated Materials Solutions (IMS) Limited Partnership

IMS Hollywood 2022 Update

Title

Figure 3:
Cell layout
for the Proposed Development

rps

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Issue Details

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1.5 Approach and Methodology

The approach required to enable the key areas of hydrogeological concern and uncertainty to be addressed included the following stages of work:

- Delivery of a robust programme of targeted intrusive investigation and monitoring to provide an updated and improved dataset that directly relates to those areas of uncertainty identified in the EPA decision notice;
- Collection and review of additional third-party information relevant to the above;
- Interpretation of the new hydrogeological dataset and development of an updated or refined conceptual hydrogeological model for the facility; and
- Review of the legislative and regulatory framework relevant to the proposed development at the facility.

1.6 Data and Information Sources

1.6.1 Overview

The data and information sources used for this report were obtained from both private and public entities that are identified below.

- EPA online resources that include Hydronet (EPA Hydronet) and Hydrotool (EPA HydroTool);
- Geological Survey Ireland geological and hydrogeological datasets (GSI Public Data Viewer Series);
- Groundwater monitoring of the Bog of the Ring. Final Hydrogeological Assessment Report (Fingal County Council, 2006);
- Bog of the Ring: Source Protection Zones (Geological Survey Ireland, 2005);
- GSI Bedrock 3D Model of Dublin (accessible from GSI’s website);
- Geological Survey of Ireland (1999). 1:100,000 scale Bedrock Series geology Map Sheet 13;
- Geological Survey of Ireland (19th Century). 1:10,560 scale Bedrock Series geology Map Sheet Dublin 14/2;
- Geological Survey of Ireland (1901). 1:63,360 scale Bedrock Series geology Map Sheet 102 (1901); and
- An Foras Taluntais. Ireland, General Soils Map, Second Edition, Published by the National Soil Survey.

1.6.2 Historical Investigations and Reporting

It is not the intention of this report to reproduce in full the background to the current regulatory position with regard to the original EPA refusal to grant the site a revision of the licence. Key documents have, however, been reviewed and are listed as follows in reverse chronological order:

- Report of the Technical Committee on Objections to Licence Conditions re. ‘Objection to Proposed Determination for MEHL, Industrial Emissions Licence Register No: W0129-03’, EPA, 30th June 2015;
- Inspector’s Report on a Licence Application – Recommendation to refuse an application for an Industrial Emissions licence in relation to an integrated waste management facility including landfill, at Hollywood Great, Nag’s Head, Naul, Co. Dublin, EPA, 12th June 2014;
- Review Report on a Licence Application by MEHL with focus on geological and hydrogeological aspects, Geosyntec, 9th June 2014;
- Assessment of Hydrogeological Isolation (Bog of the Ring and MEHL Site), Arup, 14th February 2013; and
- Letter to the EPA re. ‘Apparent main data gaps and related concerns in the information provided by MEHL in their waste licence application W0129-03’, Ford Consulting Group, 16th March 2012.

The following investigations and associated technical reports have also informed the hydrogeological assessment presented herein:

- Arup (2013): MEHL Integrated Waste Facility - Assessment of Hydrogeological Isolation (Bog of the Ring and the MEHL Site);
- Arup (2010): MEHL Integrated Waste Facility - Hydrogeological Quantitative Risk Assessment;
- Jones, G.L. (2010). Conodate Micropalaeontology report on sample MEHL – 18, 15.2-15.8 m, The Naul, Co. Fingal;
- APEX (2010). Report on the Geophysical Survey at the MEHL Integrated Waste Facility Site in Naul, Co. Dublin;
- Site investigation report: IGSL (2010) Ground Investigation Factual report on MEHL Integrated Waste Management Facility;
- Patel Tonra (2010). Historic groundwater level and quality monitoring data;
- Minerex (2010) Well survey report;
- Jones, G.Ll. (2009). Conodate Report on the geology of the landfill site Hollywood, Naul, Co. Fingal;
- Supplementary drilling and monitoring data supplied by CDM for the subject site; and
- Borehole logs and well records for monitoring wells drilled as part of the current EPA waste licence.

1.6.3 Environmental Monitoring for Waste Licence

Condition 6 and Schedule C of Waste Licence Reg. W0129-02 define the current scope of environmental monitoring undertaken at the site. The following monitoring schedules are of relevance to the hydrogeological assessment and have formed part of this assessment:

- Groundwater (quality and level) undertaken since 2006;
- Leachate (quality and level) within infilled cells undertaken since 2010; and
- Surface water including discharges (quality) undertaken since 2014.

1.6.4 Consultation

The Geological Survey of Ireland (GSI) was consulted during 2018 to 2022 regarding the proposed development of the facility. The responses raised the following comments pertinent to hydrogeology:

- Identified Nag’s Head Quarry County Geological Site / Geoheritage site in the immediate vicinity of the site (Lower Carboniferous limestone, shale and sandstone displaying structural deformation). No impact on the integrity of the County Geological Site is envisaged, however the GSI should be contacted if proposed development plan changes;
- The site is located within an area with Extreme Groundwater Vulnerability. This should be taken into account when engaging in planning;
- Geohazards and the need to reference same in the GSI Map Viewer for the area; and
- The need to identify the suitability of the area for geothermal energy.

1.6.5 IMS Additional Works

To directly address the areas of hydrogeological concern and uncertainty outlined in the decision notice for Waste Licence Application W0129-03 (EPA, 2016), IMS commissioned an extensive programme of targeted investigation works and associated monitoring. IMS also made the decision to modify the application by removing the hazardous waste stream.

The additional works delivered on behalf of IMS include:

- Drilling and test pumping of a new onsite trial well (BH32) completed within the limestones of the Loughshinny Formation (only), as detailed in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith, 2019), provided in **Appendix C**;
- Drilling and installation of a new deep offsite observation well (BH31) in the area of high ground that separates the IMS facility and the Bog of the Ring Public Water Supply, as detailed in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith, 2019), provided in **Appendix C**;
- The collection of onsite and offsite groundwater level data and streamflow measurements during the period 2017 – 2022 by CDM Smith, as detailed in CDM Smith 2018b, 2018c and 2019, and provided in **Appendices C & F**; and
- A long duration (13-day) constant rate pumping test of onsite well BH32 with associated groundwater and surface water monitoring, as detailed in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith, 2019), provided in **Appendix C**.

The objective of each element of the additional works described above is summarised in **Table 1-1**.

Table 1-1 Summary of Additional Works delivered on behalf of IMS

EPA Position **[Excerpts from Decision Notice (EPA, 2016)]**		**Additional Works Undertaken**
1	The Groundwater Protection Responses for Landfills (DoEC&LG, EPA & GSI 1999) indicated that the installation of the proposed activity in the geological setting, as proposed, is not generally acceptable. The conditions in which the proposed activity would be acceptable have not been demonstrated	Removing the hazardous waste stream from the application. Adjusting the plan and moving the SHRNW to a naturally lower risk area of the site (away from the outcrops of the Loughshinny Fm (which forms a Locally Important Aquifer unit (Lm) as defined by the GSI). Updating and improving the conceptual hydrogeological model of the site based on new site investigative work which examines the hydraulic properties of the bedrock formations onsite, groundwater levels and flow gradients, hydraulic connections between formations, and permeability distribution and variability (i.e. high permeability zones).
2	The groundwater beneath the landfill site, as proposed, is vulnerable to contamination from the proposed activity	Removing the hazardous waste stream from the application. Adjusting the plan and moving the non-haz cells to a naturally lower risk area of the site (away from the outcrops of the Loughshinny Fm (which forms a Locally Important Aquifer unit (Lm) as defined by the GSI). Adjusting the plan by designing a new liner system whcih takes into account the EPA review comments that formed the basis for the EPA decision. Conducting groundwater level monitoring in the different formations onsite and assessing their hydraulic relationships by test pumping. Drilling, installing and monitoring a deep offsite well to demonstrate that a natural groundwater divide exists to the northeast of the IMS facility which hydraulically separates the site from the BOTR welllfield Conducting quantitative groundwater risk modelling using Landsim (v2.) based on the updated conceptual hydrogeological model with improved certainty around model input parameters
3	The abstraction of groundwater at the Bog of the Ring (PWS) may influence groundwater levels beneath the landfill site, as proposed. Consequently, if the water abstraction at the Bog of the ring were to reduce significantly or cease altogether, this may result in the rebound if groundwater levels beneath the land fill site as proposed. This scenario would present an unacceptable risk to groundwater because the rising groundwater levels would	Accessing updated information on BOTR operations. Downloading and assessing BOTR groundtwater level data from the EPA (via HydroNet). Drilling, installing and monitoring a deep offsite well to demonstrate that a natural groundwater divide exists to the northeast of the IMS facility which hydraulically separates the site from the BOTR welllfield. Conducting long-term groundwater level monitoring onsite and offsite to ascertain flow directions and seasonal trends, plus potential influences of the BOTR pumping on said wells.

EPA Position [Excerpts from Decision Notice (EPA, 2016)]		Additional Works Undertaken
	have the potential to undermine the integrity of the landfill	Undertake extended pumping test to improve conceptual hydrogeolgical model, most notably with respect to hydraulic relationship between rock units and permeability distributions and variability (i.e. high permeability zones).
4	It is considered that the situation and design of the proposed activity do not meet the necessary conditions for preventing pollution of the soil and groundwater.	As for (2)
5	It is further considered that the landfill liner system, including the artificially completed geological barrier and the potential for its integrity to be undermined by rising groundwater levels, to prevent a potential risk to soil and groundwater, which are requirements of the Landfill Directive.	As for (2)

1.7 Report Structure

The hydrogeological monitoring datasets, historical reporting and interpretation are provided in the appendices of this report along with the quantitative groundwater risk assessment for the proposed development.

The subsequent report structure is as follows:

- Section 2: Legislative and Regulatory Framework;
- Section 3: Regional Setting;
- Section 4: Site Characteristics;
- Section 5: Updated Conceptual Hydrogeological Model; and
- Section 6: Conclusions.

2 LEGISLATIVE AND REGULATORY FRAMEWORK

2.1 Overview

As outlined in the Decision Notice (EPA, 2016) and the preceding Technical Committee Report (EPA, 2015) and Inspectors Report (EPA, 2014), it was considered that Licence Application W0129-03 was not consistent with the following legislation and guidance governing proposed landfill sites in the Republic of Ireland:

- The Landfill Directive (Directive 1999/31/EC on the landfill of waste) and the EPA Landfill Manual (EPA, 2000); and
- Groundwater Directive (2006/118/EC) and European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. No. 9 of 2010, as amended by S.I. No. 366 of 2016).

A brief summary of the relevant guidance and legislation is provided in this section.

2.2 EU and National Waste Legislation

At EU level, the Waste Framework Directive (2008/98/EC) has previously set the legal framework for waste management in the European Union. The Waste Framework Directive sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products.

The Waste Framework Directive communicates waste management principles - it requires that waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. The Waste Framework Directive was transposed into Irish law through the European Communities (Waste Directive) Regulations 2011, as amended.

In May 2018, the EU published Directive (EU) 2018/851 of the European Parliament and of the Council amending Directive 2008/98/EC on waste. The revised Waste Framework Directive provides the legislative framework for the collection, transport, recovery and disposal of waste in the EU and is transposed through the European Union (Waste Directive) Regulations 2020.

In Ireland, the primary legislative platform for waste is provided by the Waste Management Act 1996 (WMA) as amended and the Protection of the Environment Act 2003 as amended. The WMA places a general duty on everyone not to hold, transport, recover or dispose of waste in a manner that causes or is likely to cause environmental pollution.

The WMA sets out the licencing criteria and requirements for waste operations that much be satisfied before the EPA may grant a licence. The waste licences granted to the IMS facility are under the Third and Forth Schedule Waste Management Act activities. The Third Schedule refers to waste disposal activities and the Fourth Schedule refers to the recovery of waste for the purpose of reclaiming, recycling or re-use.

2.3 Landfill Directive

The Landfill Directive (Directive 1999/31/EC on the landfill of waste) sets out detailed rules on waste landfills, including non-hazardous and inert landfills. Article 6 details the waste to be accepted in the different classes of landfill and the relevant classes in relation to the proposed development are:

> *c) landfill for non-hazardous waste may be used for:*
>
> > *ii) non-hazardous waste of any other origin, which fulfil the criteria for the acceptance of waste at landfill for non-hazardous waste set out in accordance with Annex II;*
>
> *(d) inert waste landfill sites shall be used only for inert waste.*

2.4 Groundwater Directive

In granting any licence, the EPA must be satisfied that the proposed site design and management will promote compliance with European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. No. 9 of 2010; Part II: Environmental Objectives for Groundwater; Prevention and Control of Groundwater Pollution; as amended by S.I. No. 366 of 2016).

The Groundwater Regulations will be complied with by preventing and limiting inputs of pollutants into groundwater where the following shall apply:

> *(a) The input of hazardous substances into groundwater is prohibited; and*
>
> *(b) The input of non-hazardous substances shall be limited so as to ensure that such inputs do not cause deterioration in groundwater status or cause significant and sustained upward trends in the concentration of pollutants in groundwater.*

A probabilistic LandSim assessment has been undertaken for the proposed site design and management that demonstrates compliance with the Groundwater Regulations. The LandSim assessment is prepared as a complimentary report to this assessment and is also included as part of this application (RPS Report Reference MDR1492Rp00015).

2.5 Surface Water Regulations

In addition to groundwater, the EPA must also be satisfied that the proposed site design and management will promote compliance with European Communities Environmental Objectives (Surface Waters) Regulations 2009. These Regulations give statutory effect to Directive 2008/105/EC on environmental quality standards in the field of water policy. The Regulations also give further effect to Directive 2000/60/EC establishing a framework for Community action in the field of water policy and Directive 2006/11/EC on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community.

These Regulations establish environmental quality standards for priority substances and certain other pollutants as provided for in Article 16 of the Water Framework Directive that are to apply in calculating the chemical status of bodies of surface water. These standards apply to all surface water bodies including the Ballough Stream on the northern boundary and all downstream water bodies.

2.6 Industrial Emissions Directive

The Industrial Emissions Directive (2010/75/EU) of the European Parliament and the Council on industrial emissions is the main EU instrument regulating pollutant emissions from industrial installations and was adopted in November 2010.

The European Union (Industrial Emissions) Regulations SI 138 of 2013 and the EPA (Industrial Emissions) (Licensing) Regulations SI 137 of 2013 transpose the Directive and update the existing regulations in Ireland and the licensing regime managed by the EPA.

In reference to the proposed development, the First Schedule of the 1992 Act, as amended, and in conjunction with SI 138 of 2013, specifies the classes of activities that are considered Industrial Emissions Directive activities and to be licensed as such by the EPA.

An application for an Industrial Emissions (IE) Licence for the proposed development is being made to the EPA to replace the existing Waste Licence (W0129-02). Section 9(2)(d) of the (Industrial Emissions) (Licensing) Regulations 2013, S.I. 137 of 2013, also identifies the need for an EIAR to be issued to the EPA in accordance with the EPA Act of 1992.

2.7 Groundwater Response Matrix – Siting of Landfills

The Department of the Environment & Local Government (DoELG), EPA and GSI published general guidance regarding the determination of site suitability for landfilling of non-hazardous wastes (DoELG, EPA and GSI, 1999) to assist the statutory authorities to meet their responsibility to protect groundwater, as reproduced in **Appendix B**. This guidance document provides a methodology for the preparation of groundwater protection schemes to assist the statutory authorities and others to meet their responsibility to protect groundwater. It incorporates principles of land surface zoning and groundwater protection responses, including the siting or selection of landfills. In the absence of a published groundwater protection scheme for the Fingal area, the 1999 national guidance applies.

3 REGIONAL SETTING

3.1 Topography

The IMS facility is situated in an area of high topographic elevation located approximately 23.5 km north of Dublin city. As shown in **Figure 4**, the facility is located on the northern flank of high ground that extends east from Nag’s Head (immediately west of the site entrance at an elevation of c. 150mOD) along the southern site boundary. The site gradient generally decreases in an easterly direction across the site from the site’s topographic high at the existing site entrance along the western site boundary towards the eastern boundary and to the Ballough Stream on the northern boundary. On the northern side of the stream the topography rises to 176 mOD at Knockbrack Hill.

Knockbrack Hill is located approximately 1 km north of the facility and represents the highest point on the pronounced topographic divide that separates the facility from the Matt River along which the Bog of the Ring wellfield is located. That high ground extends circa 5 km westward from Walshestown to Cabinhall then southwest to Mallahow. The gradient decreases broadly radially away from the Nags Head – Knockbrack high ground, but particularly in an easterly direction, towards the coast that is situated circa 7 km from the IMS facility at its closest point. The local topography surrounding the IMS facility is therefore dominated by an easterly decline along the valley of the northern boundary stream towards the coastline in that direction.

3.2 Climate

The regional climate has been determined from the Met Éireann online 30-year averages. The nearest meteorological station to the area is the Met Éireann Station in Dublin Airport which lies approximately 14km south of the subject site. The 30-year averages from the station at Dublin Airport are presented in **Table 3-1**.

Table 3-1 30-Year Average Meteorological Data from Dublin Airport (Average of Period 1981-2010, source: www.met.ie)

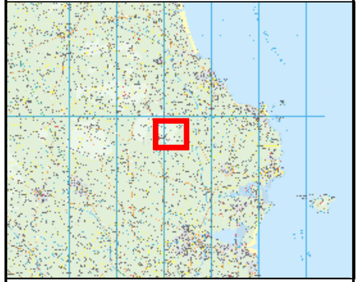
Parameter	30-Year Average
Mean Temperature (°C)	9.8
Mean Relative Humidity at 0900UTC (%)	83.0
Mean Daily Sunshine Duration (Hours)	3.9
Mean Annual Total Rainfall	758.0
Mean Wind Speed (Knots)	10.3

The 30-year record for temperature shows that the average daily temperature across a calendar year is 9.8°C with an average maximum of 13.3°C and an average minimum of 6.4°C. Across the calendar year, the average number of days with air frost is 29.4.

The prevailing wind direction is between west and southwest (10-20%). Northerly and north-easterly winds tend to be infrequent (less than 5% in the period of record) with easterly and south-easterly winds marginally more frequently (5-10%). Wind characteristics are typically moderate with relatively infrequent gales with an average of 8.2 days with gales per annum with an average maximum wind gust of 80 knots during the year (January).

The average yearly rainfall in the 30-year average is 758.0mm, this is broken down into monthly averages in **Table 3-2**. The greatest mean monthly total of rain is recorded in October (79.0mm) with moderately frequent days with ≥5.0mm per annum (42 days).

Measured snow lying in the mornings is infrequent occurring on average 3.4 days per annum. Fog occurs on average 41.5 days per annum.



Client

Integrated Materials Solutions (IMS) Limited Partnership

IMS Hollywood 2022 Update

Title

Figure 4: Topography of the Site

West Pier
Business Campus,
Dun Laoghaire,
Co Dublin, Ireland.

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Issue Details

File Identifier:
MDR1492A-RPS-00-XX-DR-Z-AG-0008

Status:	**Rev:**	**Model File Identifier:**
S0	P01	

Drawn: MV
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Checked: SA
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Table 3-2 30-Year average data for rainfall at Dublin Airport (Annual Values from 1981-2010, source: www.met.ie)

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Monthly Total	62.6	48.8	52.7	54.1	59.5	66.7	56.2	73.3	59.5	79.0	72.9	72.7	758.0
Greatest Daily Total	27.1	28.1	35.8	30.4	42.1	73.9	39.2	72.2	40.6	53.2	62.8	42.4	73.9
Mean num. Days with ≥5.0mm	4	3	3	3	3	3	3	4	4	4	4	4	42

3.3 Hydrology

3.3.1 WFD Catchments

The site is located in the Nanny-Devlin River Catchment. The regional river drainage in this catchment resembles a parallel to dendritic pattern flowing towards the east coast and the hydrology of the area is shown in **Figure 5**.

According to the EPA database, the stream that flows along the northern perimeter of the site is the Tooman Branch stream, a tributary of the Ballough Stream which originates near Knockbrack and discharges to the Rogerstown Estuary. Tooman Branch flows to the east and joins Ballough Stream by the M1 motorway approximately 2 km to the east. Along its course, the Tooman Branch is joined by the Walshestown tributary which flows from Nevitt less than 1 km from the Hollywood site.

The Ballough Stream and its tributaries are part of EPA river water body code IE_EA_08B031500 and Water Framework Directive subcatchment 'Ballough Stream _10'. Review of OSI historic maps between 1830 and 1930 show that the stream and river courses have not changed significantly in the interim.

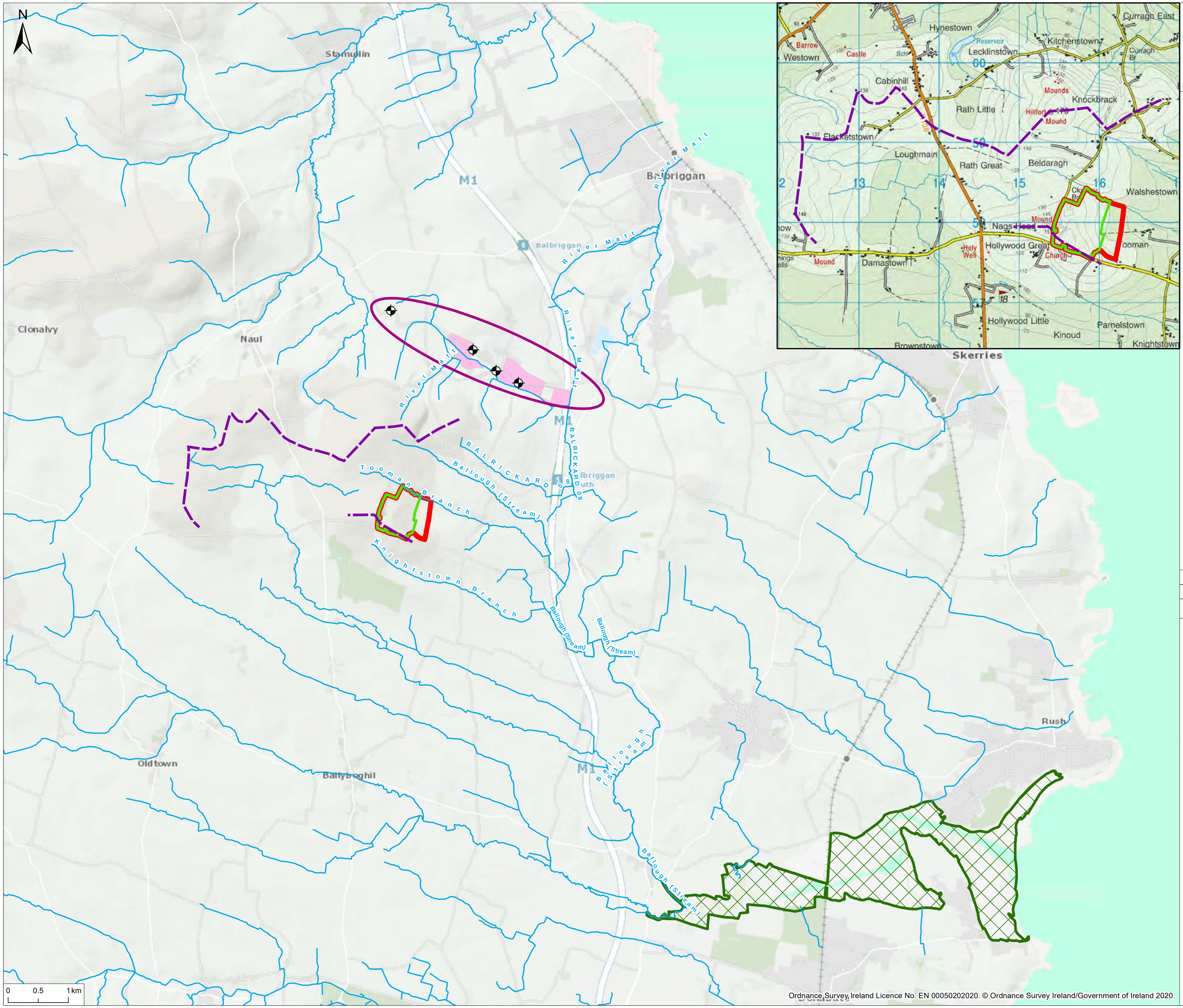
GWBs which spatially intersect the Ballough Stream subcatchment include:

- Swords GWB (IE_EA_G_011);
- Lusk-Bog of the Ring GBW (IE_EA_G_014); and
- Hynestown GWB (IE_EA_G_033).

3.3.2 Flood Risk

The site is located in the north western section of the Ballough Stream sub-catchment at a maximum topographic height of 148mAOD and is close to the catchment divide with the Delvin 20 WFD sub-catchment to the north. The OPW flood mapping website shows the site does not reside within river or coastal flood zones. Similarly, the site does not reside in any rainfall (pluvial) flood zones.

The flood mapping website also contains records of historical flooding incidents in the surrounding area. The nearest single flood event listed is approximately 4.5km south east of the site and corresponds to flooding in the Ballough, Ballystrane and Baldrumman areas of Lusk, Co. Dublin on the 9th and 10th August 2008. There are currently no OPW flow gauges present within the Ballough sub-catchment or within the Nanny-Delvin Catchment.



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Legend

- 🟥 IMS Facility
- 🟩 Waste Licence Boundary
- ▨ Rogerstown Estuary SAC
- ■ Potential Bog of the Ring Natural Heritage Area
- ▭ Bog of the Ring Wellfield
- - - Topographic Divide
- — Rivers
- ⌖ Bog of the Ring Abstraction Boreholes

Rev	Description	By	CB	Date

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JER1631	1:60,000	MAR 2020

Drawing Number	Rev
Figure 5	-

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3.4 Geology

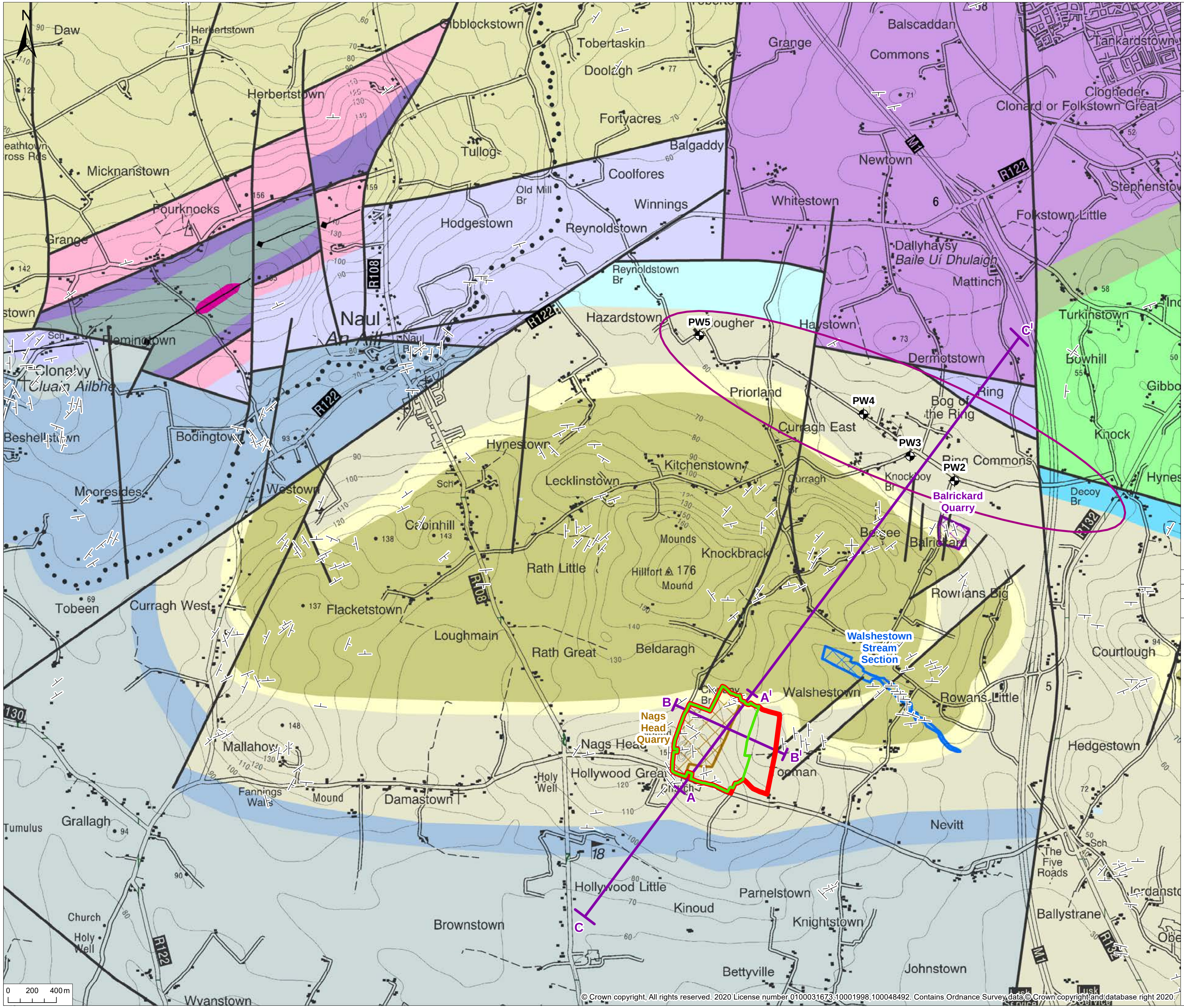
3.4.1 Stratigraphic Sequence

The regional geology has been determined from the Geological Survey Ireland online Spatial Data and Resources and are summarised in **Table 3-3** and displayed in **Figure 6**.

Table 3-3 Regional Stratigraphy

Age		Name	Lithological Description*	Estimated Maximum Thickness (m)
Quaternary		Alluvium	Post-glacial deposit comprising gravel, sand, silt or clay in a variety of mixes, usually includes a high percentage of organic carbon	-
		Glacial Till (TNSSs) - derived from Namurian sandstones and shales	'Clayey' till dominating the area around the site.	-
		Glacial Till (IrSTLPSsS) - Irish Sea Till derived from Lower Palaeozoic sandstones and shales.	Dominating the area to north of the site, Clayey in texture.	-
		Glacial Till (TLs) - Till derived from limestones	-	-
Carboniferous	Upper (Namurian)	Walshestown Formation (WL)	Predominantly black shales, with subordinate siltstones, fine sandstones bands with rippled lenses, calcareous mudstone and occasional limestones.	> 200
		Balrickard Formation (BC)	Feldspathic micaceous sandstone with shale and argillaceous fossiliferous micrite interbeds. At the type section sandstones are medium-grey, well sorted, coarse to very coarse grained, feldspathic sub-litharenite.	75-100
	(Visean / Namurian)	Donore Formation (DR)	Transitional unit between the Balrickard and Loughshinny Formations.	-
	Lower (Visean)	Loughshinny Formation (LO)	Laminated to thinly-bedded, argillaceous, pyritic, locally cherty limestone interbedded with dark-grey to black shale. The limestones include argillaceous micrites and graded calcarenites	100-150
		Naul Formation (NA)	Calcarenite and, with minor chert and occasional thin shales. It is similar to the Loughshinny Formation, but the limestones are paler and less argillaceous, and there is less shale.	100
		Lucan Formation (LU)	Dark-grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey. There are rare dark coarser grained calcarenitic limestones, sometimes graded, and interbedded dark-grey calcarenites.	210

** Lithological descriptions taken from GSI Bedrock Geology 100K (Link); GSI, 1999; and McConnell et al., 2001.*



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Legend
- 🟥 IMS Facility
- 🟩 Waste Licence Boundary
- ▭ Bog of the Ring Wellfield
- — Cross Section Lines
- ⊕ Bog of the Ring Abstraction

Geo-heritage Sites
- ▨ Balrickard Quarry (IGH 9 - Upper Carboniferous)
- ▨ Nags Head Quarry (IGH 8 - Lower Carboniferous)
- ▨ Walshestown Stream Section (IGH 9 - Upper Carboniferous and Permian)

Bedrock Stratigraphy
- ■ Balbriggan Formation
- ■ Belcamp Formation
- ■ Herbertstown Formation
- ■ Holmpatrick Formation
- ■ Loughshinny Formation
- ■ Lucan Formation
- ■ Mullaghfin Formation
- ■ Naul Formation
- ■ Clashford House Formation
- ■ Balrickard Formation
- ■ Walshestown Formation
- ■ Denhamstown Formation
- ■ Fourknocks Formation
- ■ Diorite
- ■ Mudbank Limestone
- ■ Snowtown Formation
- ■ Skerries Formation

Structural Features
- ◆ Anticlinal Axis
- — Fault

Structural Symbols
- ┼ Horizontal Bedding
- ┤ Strike and dip of bedding, way up unknown

Data Source: Geological Survey Ireland (GSI)

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JER1631	1:30,000	APR 2020

Drawing Number
Figure 6

Rev
-

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GSI regional geological data indicates that the facility is partially situated on limestone bedrock of the Loughshinny Formation which consists of limestones and shales. The Loughshinny Formation is underlain by the Naul Formation which is predominantly a calcarenite with minor chert and occasional thin shales. The lithology is similar to the Loughshinny Formation, but the limestones are paler and less argillaceous (with less shale). The Loughshinny Formation is estimated to be 100-150m thick and the Naul Formation is estimated to be 100m thick.

The Loughshinny Formation is overlain by rocks of Namurian age. The Namurian sequence incorporates the Walshestown Formation (as the youngest formation), which predominantly consists of black shales with subordinate siltstones, fine sandstones bands with rippled lenses, calcareous mudstone and occasional limestones (biosparite). The Walshestown Formation is underlain by the Balrickard Formation, which consists of metre-thick feldspathic micaceous sandstone with shale and argillaceous fossiliferous micrite interbeds. Sandstones are medium-grey, well sorted, coarse to very coarse grained, feldspathic sub-litharenites (Mc Connell *et al*, 2001). This in turn is underlain by Donore Formation which is generally considered a transitional unit between the Namurian sequence and Loughshinny Formation.

The bedrock geology is variously overlain by unconsolidated superficial deposits that principally include Glacial Till and alluvium.

3.4.2 Geological Structure

Regional geological structure is dominated by a large syncline with its axis running approximately west-northwest to east-southeast, beneath the Knockbrack Hill ridge, approximately 1 km to the northeast of the IMS facility. The facility is situated on the southern limb of the syncline, with younger Namurian bedrock present at the surface immediately to the north and beneath the Knockbrack Hill ridge. Bedrock near the site dips northwards, at c. 5° to 40°, exposing the outlier of younger Namurian bedrock in the core of syncline in that direction. The Lower Carboniferous limestone outcrops once again on the northern limb of the syncline, on the opposite side of the Knockbrack Hill, in the vicinity of Bog of the Ring, Hazardstown and Naul.

The bedrock within the syncline in the study area is faulted, typically with a north-south or northeast-southwest orientation. As shown in **Figure 6**, the GSI has interpreted the presence of normal and strike slip faults extending from close to the site to the north or northeast.

3.4.3 Geological Protected Sites

Three Geological Heritage Sites (GHSs) are present in the study area and are shown in **Figure 6**. GHSs are defined by the GSI through an audit of County Geological Sites as sites considered to be of national importance. These sites provide type sections of the key Lower Carboniferous and Upper Carboniferous bedrock unit and include:

- *Nags Head Quarry (DF016) [IGH 8 - Lower* Carboniferous] *which forms part of the development site.* Exposure of Lower Carboniferous rocks of the Loughshinny Formation, comprising a mixture of thin to medium bedded limestone and shale. The structural deformation seen here, for example as chevron folds, reflects the geology also visible 12km away on the coast at Loughshinny;
- *Balrickard Quarry (DF017) [IGH 9 – Upper Carboniferous] located circa 2km NE of the site*. Displays good exposures of thickly bedded coarse grained sandstone interbedded with dark grey shale, all dipping shallowly to the west; and
- *Walshestown Stream Section (DF018) [IGH 9 - Upper Carboniferous and Permian] located circa 0.4km NE of site.* Consisting of Upper Carboniferous (Namurian) shale, sandstone and limestone of the Walshestown and Balrickard Formations. A small deeply incised stream with exposed long sections of dark shale, which is occasionally interbedded with limestone and sandstone. This stream section displays bedding, jointing and the occurrence of a fault.

The Balrickard Quarry and Walshestown Stream Section GHSs are both located in the inlier of Namurian bedrock situated beneath the Knockbrack Hill high ground to the north of the facility. These three sites therefore provide exposure of all the key geological units of relevance to this hydrogeological assessment.

3.4.4 Regional Geological Model

The geology within the study area has been determined from GSI mapping and GSI's 3D model of the Dublin Basin, as well as the borehole logs summarised in **Table 3-4** and shown in the cross-sections provided in

Figure 7 (west to east), **Figure 8** (south-southwest to north-northeast) and **Figure 9** (extended south-southwest to north-north east). The trajectories of the cross-sections are indicated on **Figure 6**.

Borehole BH31 (the new offsite Monitoring Well) was drilled c. 0.7 km north-northeast of the IMS facility in the direction of the Bog of the Ring (BOTR) wellfield on Knockbrack Hill (ground elevation c. 128.4 mOD). A full description of borehole BH31 is provided in **Appendix C** (CDM Smith, 2019). The borehole was drilled to a total depth of 126 m and encountered Namurian bedrock throughout, with an elevation for the base of the borehole that approaches sea level (i.e. 0.0mOD). The upper 21 m of Namurian bedrock comprised extensively weathered mudstone, interpreted as the Walshestown Formation (i.e. to a depth of c. 107 mOD). At 96 mbgl the frequency of sandstones and siltstones units increase and was considered to represent the transition to the Balrickard Formation.

The boreholes drilled near or by the BOTR wellfield penetrated alluvium, overburden (boulder clay / glacial till) and/or river sand and gravel deposits before intercepting bedrock of the underlying Loughshinny Formation. As shown on the cross-section in **Figure 9**, the BOTR wellfield is situated at c. 30 to 40 mOD which is approximately 90 m lower in elevation than Knockbrack Hill.

Figure 9 also shows that borehole TW10, situated at an elevation of c. 52.5 mOD penetrates the Loughshinny Formation. The continuous exposure of Namurian bedrock to the north-east of the facility is clearly shown in **Figure 8**. The contact between the Loughshinny Formation and overlying Namurian bedrock to the northeast of the facility becoming deeper as it dips northwards. The Loughshinny Formation then rises back to the ground surface to the north of the Knockbrack Hill high ground in the vicinity of the BOTR wellfield, where it is locally overlain by superficial deposits.

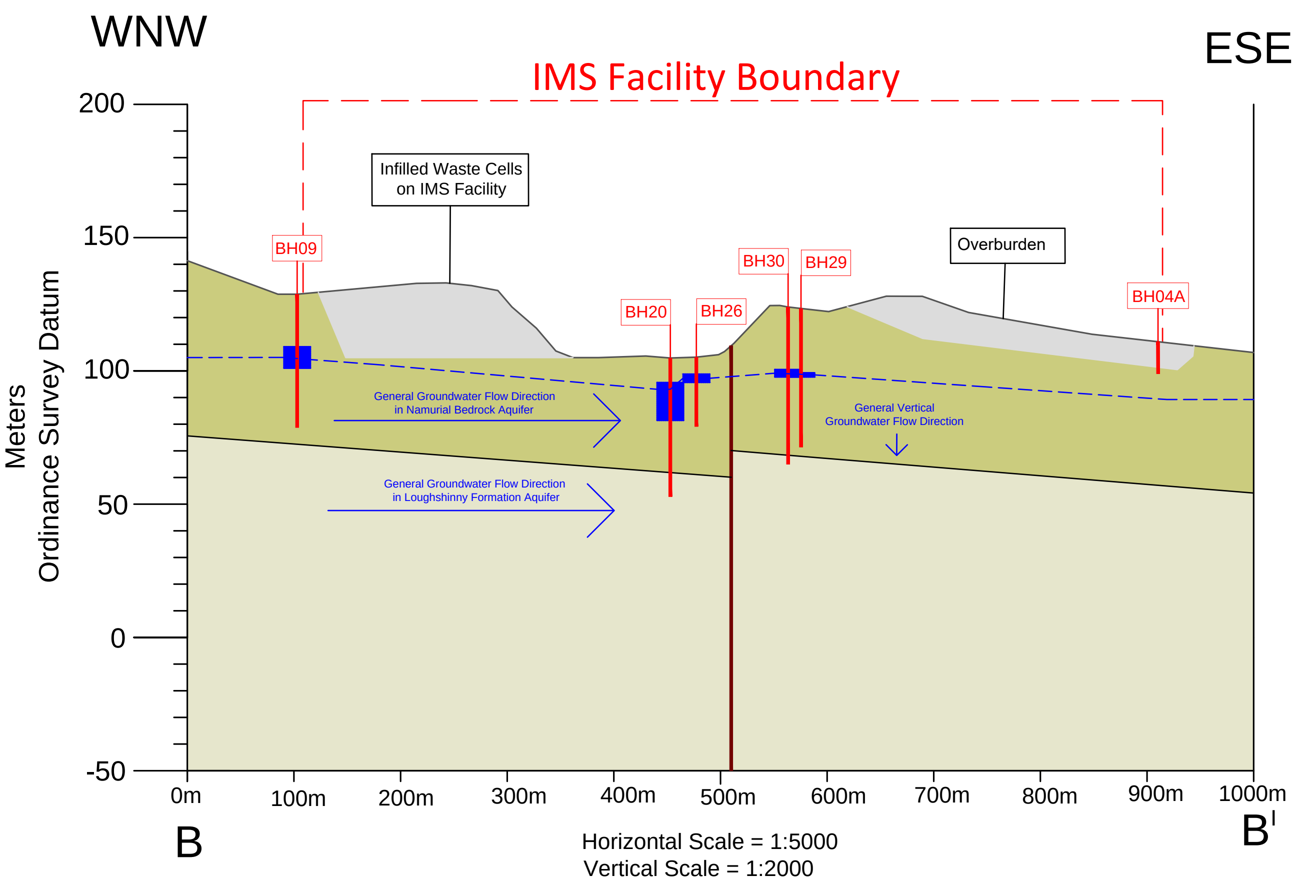
The cross section provided in **Figure 9** emphasises how the regional geological structure is dominated by the synclinal structure shown in **Figure 6**. The syncline results in the Loughshinny Formation being overlain by in excess of 175m of Namurian bedrock beneath Knockbrack Hill. Ground elevation along the Knockbrack Hill ridge exceeds 135 mOD, which is c. 100 m higher in elevation compared to the Bog of the Ring wellfield.

Table 3-4 Summary of Borehole Information

Borehole Reference	Response Zone / Unit	Date Constructed	Borehole Depth (m)	Approx. Ground Elevation (mOD)	Geology at Ground Level	Depth to Loughshinny Formation (m)	Elevation Top of Loughshinny Formation (mOD)
BH02	Loughshinny (LO)	Sep-1998	14	103.3	LO#	None	-
BH04		Sep-1998	10	96.9	Till	3 m	-
BH10A		Mar-2007	68	(136.99)*	Overburden	21 m	116.14
BH12		May-2007	65	(146.99)**	Overburden	46 m	100.99
BH15A		Apr-2010	30	106.13*	Namurian	26 m	81.89
BH18		Apr-2010	21.2	110.40*	Namurian	15.2 m	95.30
BH25		May-2010	26	105.18*	LO	None	-
BH30		Jun-2013	59	123.98*	Namurian (presumed)	55.7 m	c. 55.7
BH32 (Trial Well)		Nov-2018	66	106.03*	Namurian	45 m	60.03
TW10 (Offsite BOTR)		1993	76.5	52.478	Loughshinny	-	-
BH14	LO & Namurian	Mar-2007	38	125.06*	Namurian	30 m	95.06
BH17		Apr-2010	54	105.30**	Namurian	33 m	72.41
BH01	Namurian	Sep-1998	56	145.9	Namurian (presumed)	>56 m	Not Proven (NP)
BH05		Sep-1998	35	118.2**	Till	>35 m (6m till)	NP
BH06		Sep-1998	19.5	117	Till	>19.5 m (4m till)	NP
BH08A		Aug-2001	27	136.69**	Till	> 27m (4m Till / Boulder Clay)	NP
BH09		Aug-2001	50	128.76**	Nam	>50 m	NP
BH11A		May-2007	30	99.96**	Namurian	>30 m	NP
BH13		Apr-2010	48	146.92*	Overburden?	46 m	100.92
BH19		Apr-2010	18	105.52**	Namurian	>18 m	NP
BH20		Apr-2010	52	104.72**	Namurian	43m	61.84 *(Installed just above contact with possible LO)*
BH24		Jun-2013	48	106.04**	Namurian	>48m	NP
BH26		Apr-2013	26	105.15**	Namurian	>23.1	NP
BH27		Apr-2013	14	106.32**	Namurian	>14	NP
BH28		Apr-2013	38	125.88	Namurian	>38	NP

Borehole Reference	Response Zone / Unit	Date Constructed	Borehole Depth (m)	Approx. Ground Elevation (mOD)	Geology at Ground Level	Depth to Loughshinny Formation (m)	Elevation Top of Loughshinny Formation (mOD)
BH29		Apr-2013	52	123.42**	Namurian	>52	-
BH31 (New offsite MW)		Nov-2018	126	128.43**	Namurian	126	-
TW07 (Offsite BOTR)		1993	72.-74	69.32	Namurian	-	NP
BH16		Apr-2010	60	104.79	Namurian	>60 m	NP
BH08	Overburden & Namurian	Aug-2001	27	136.748	Overburden	> 27m (4m Till / Boulder Clay)	NP
BH07	No Installation	Sep-1998	41	132	Till	>26 m (2m till)	NP
BH15	No Installation	Apr-2010	31.99	105.89	Overburden?	26.1 m	76.79

** Datum not at ground level (e.g. top of casing); **Taken from Table 1 in CDM Smith, 2019;*



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Legend

- 🟨 Namurian Formation
- ⬜ Loughshinny Formation
- — Fault
- — Borehole
- 🟦 Minimum and Maximum Groundwater Level
- - - - Approximate Groundwater Level

Rev	Description	By	CB	Date

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Figure 7	-

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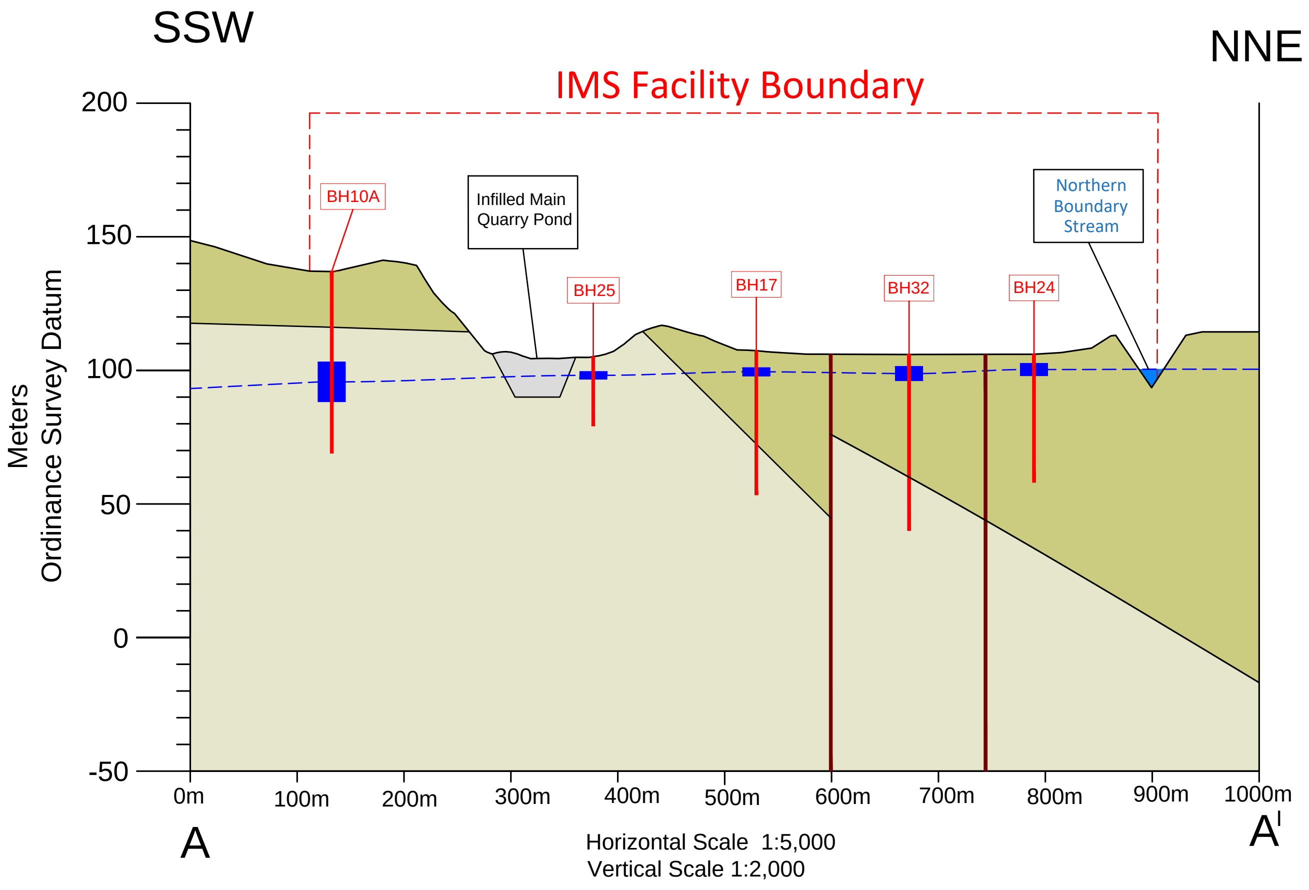

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Legend

🟨	Namurian Formation
⬜	Loughshinny Formation
—	Fault
—	Borehole
🟦	Minimum and Maximum Groundwater Level
- - -	Approximate Groundwater Level

Rev	Description	By	CB	Date

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Figure 8	-

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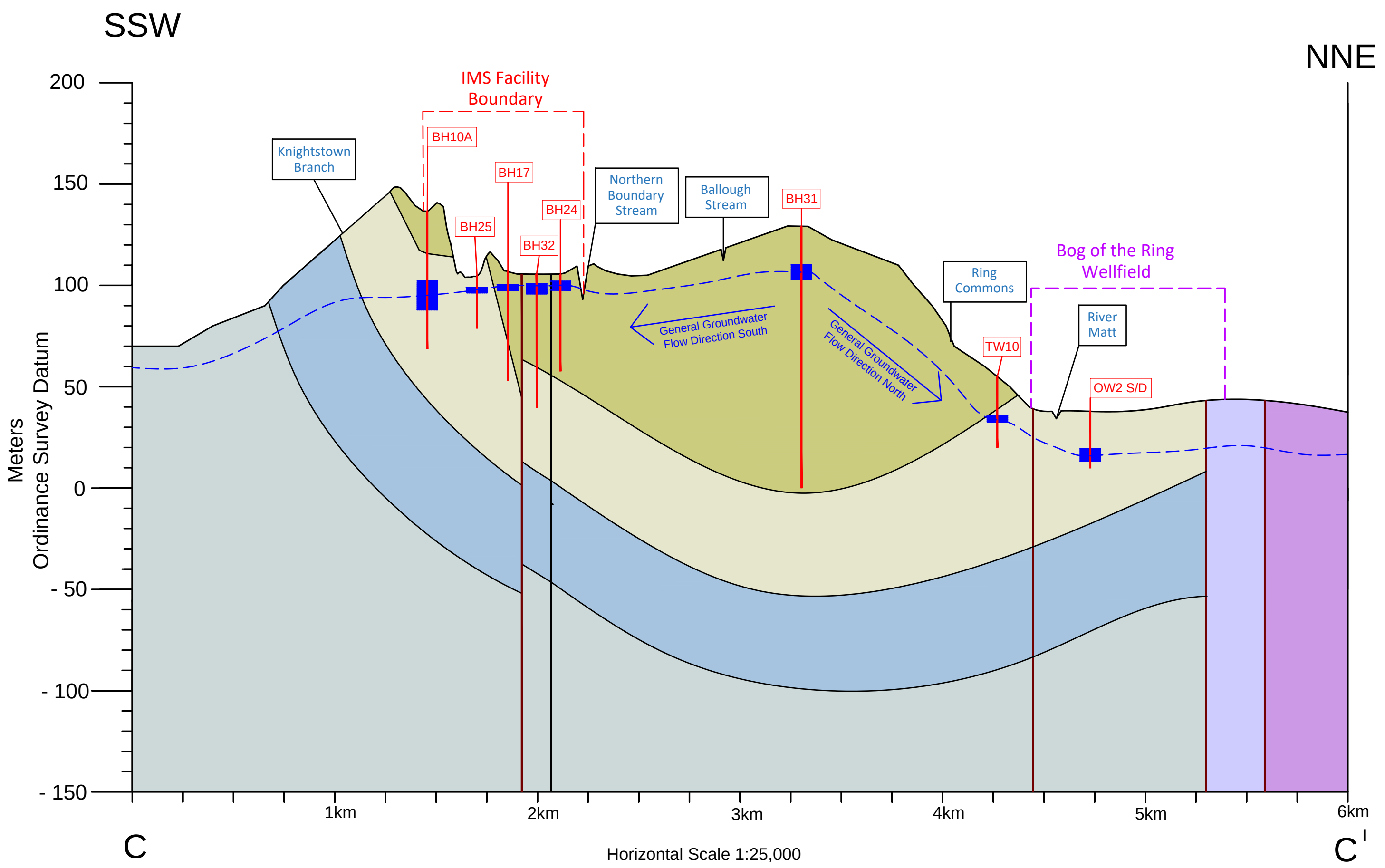

Horizontal Scale 1:25,000
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Legend

- ▨ Namurian Formation
- ▨ Loughshinny Formation
- ▨ Naul Formation
- ▨ Lucan Formation
- ▨ Mudbank Limestone
- ▨ Belcamp Formation
- ─ Fault
- ─ Borehole
- - - Uncertain Boundary
- ■ Minimum and Maximum Groundwater Level
- - - Approximate Groundwater Level

Rev	Description	By	CB	Date

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Project Hollywood Great

Title Geological Cross Section C

Status	Drawn By	PM/Checked by
DRAFT	RW	AG

Job Ref	Scale @ A3	Date Created
JER1631	Refer to Frame	MAR 2020

RPS Drawing / Figure Number	Rev
Figure 9	-

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3.5 Hydrogeology

3.5.1 Hydrogeological Study Area

The hydrogeological assessment considers the entire area potentially affected by the proposed development and/or the area that could potentially affect the development in the long-term. The study area is defined by the IMS facility and its geological setting in context of the Bog of the Ring (BOTR) wellfield and the associated downgradient areas with connectivity to the site.

The study area includes the groundwater catchment area(s) relevant to the consideration of the IMS facility and potential receptors (as described in **Section 5**) to include:

- The expected groundwater catchment area in which the facility is situated and the adjacent groundwater catchments, including that of the BOTR water supply c. 3 km northeast of the facility; and
- Environmental receptors considered likely to receive a groundwater contribution, most notably local streams.

In defining the study area, consideration has been given to the BOTR Groundwater Source Protection Zone report (GSI, 2005).

3.5.2 Updated Hydrogeological Assessment

The updated hydrogeological assessment presented in this report is based on a review of all data sources summarised in **Section 1.6** with key documents provided in **Appendix C** to **Appendix E** inclusive. Key datasets are provided in **Appendix E** (borehole information) and **Appendix F** (monitoring datasets). The hydrogeological assessment the updated Hydrogeological Conceptual Model developed for the facility and wider study area presented in **Section 5**.

3.6 Aquifer Types

3.6.1 Aquifer Designation

The GSI aquifer classification for the key geological units identified within the study area are summarised in **Table 3-5**.

Table 3-5 GSI Aquifer Classification for Key Geological Units within the Study Area

Geological Unit	Age	Lithology	GSI Aquifer Classification
Walshestown Formation (WL)	Namurian Bedrock (Upper Carboniferous)	Shales, thin sandstones / siltstones, occasional thin limestones	Pl (Poor Aquifer – Bedrock which is generally unproductive except for local zones)
Balrickard Formation (BC)		Coarse micaceous sandstone with shale interbeds.	
Donore Formation (DR)		Transitional between Balrickard and Loughshinny Formations	
Loughshinny Formation (LO)	Visean (Lower Carboniferous)	Layered dark grey micrite and calcarenite (fine-coarse grained limestone) and shale	Lm (Locally Important Aquifer – Bedrock which is generally moderately productive)

3.6.2 Water Framework Directive Groundwater Bodies

The two GWBs relevant to the study area are (note that the Swords GWB is not considered further in this analysis given the distance to the site):

- Lusk-Bog of the Ring (IE_EA_G_014) - FI (Productive fissured bedrock); and
- Hynestown (IE_EA_G_033) - PP (Poorly productive bedrock).

The Hynestown GWB represents the outlier of Namurian bedrock that underlies Knockbrack Hill to the northeast of the facility and forms the core of the regional syncline structure shown in **Figure 6**. The Hynestown GWB comprises Namurian bedrock. The GSI describes this as typically being of low permeability except in localised areas of enhanced permeability, e.g. associated with structural faulting. However, faulting of shales and mudstones can also result in fault gouges, which can serve to impede and divert groundwater flow locally.

The Lusk-Bog of the Ring GWB comprises Lower Carboniferous bedrock that underlies the Namurian sequence and therefore entirely surrounds the Hynestown GWB inlier situated immediately north of the facility (**Figure 6**). The Lusk-Bog of the Ring GWB therefore includes the site (and area to south thereof) and the BOTR wellfield, situated on opposite sides of the regional syncline. The Lusk-Bog of the Ring GWB is described as being composed of moderately permeable limestone units, which in some places are karstified (i.e. the fracture porosity is enhanced by solution). The Lusk-Bog of the Ring GWB is principally associated with the Loughshinny Formation and is characterised by groundwater flow along fractures and in places solution enhanced karstic conduits. The aquifers are typically considered to be unconfined but may be locally confined where overlain by Namurian strata. Recharge to the GWB is typically diffuse through subsoils and via outcrop.

The designation of GWBs present within the study area clearly differentiate between the predominantly limestone units of the lower Carboniferous and the overlying Namurian bedrock. However, the GSI summaries do indicate that the hydrogeological differentiation can be expected to be less clear in areas of locally enhanced permeability, with the hydrogeology potentially being affected the structure and structural deformation principally of the of the Namurian bedrock. Such permeability enhancement is likely to be associated with faulting and fault.

3.6.3 Groundwater Vulnerability

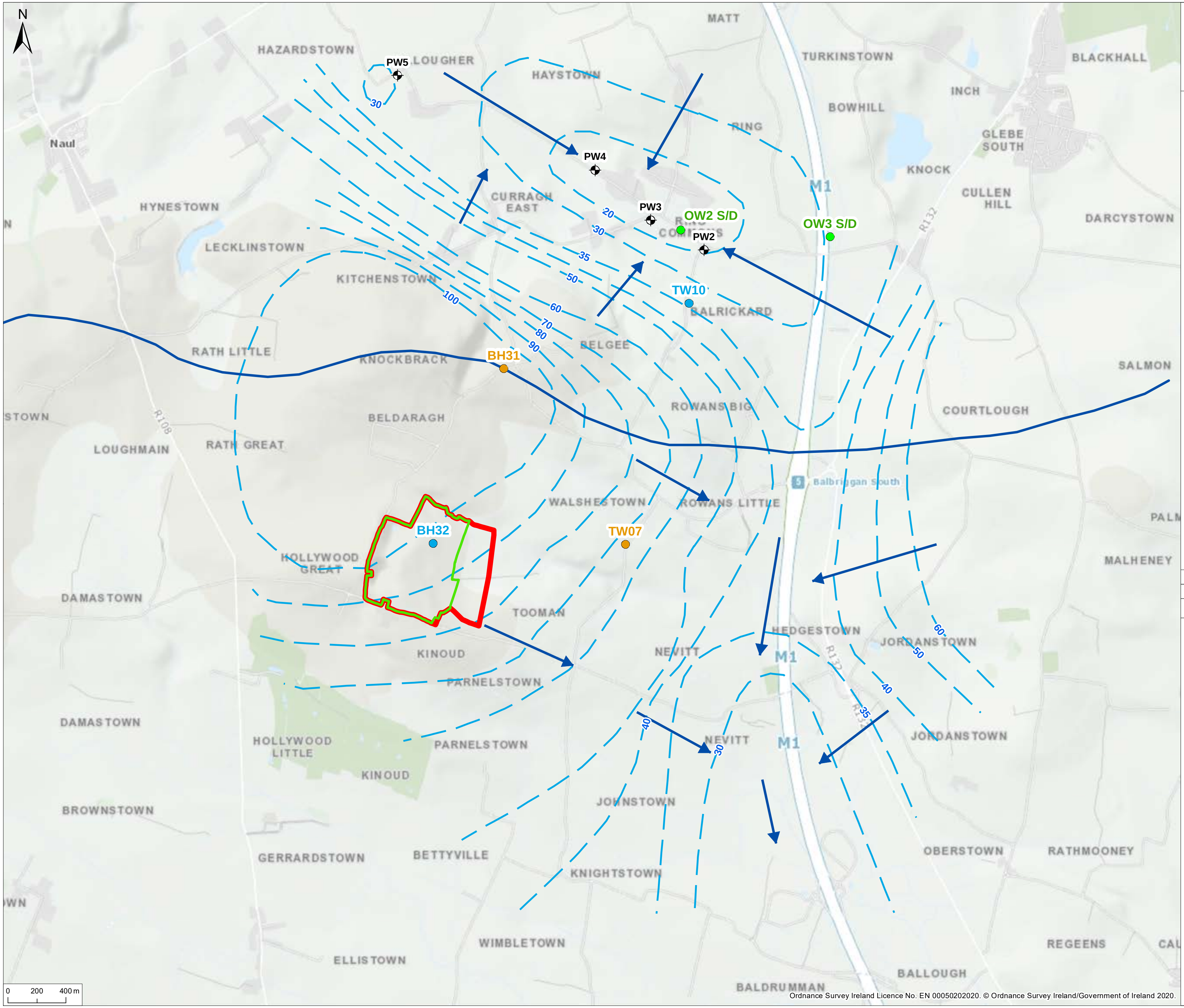
Groundwater vulnerability defines the natural ground characteristics that determine the ease with which groundwater may be contaminated by human activities. Groundwater vulnerability is regionally mapped by the GSI and is typically extreme (E) or Extreme (X) in the vicinity of the facility and local areas of high ground, where the bedrock is outcrops or is closer to ground surface. Groundwater vulnerability within the boundary of the site has been affected by the historical quarrying and infilling activities undertaken thereon, the removal of subsoils allied with alterations to the characteristics of the unsaturated zone.

3.6.4 Regional Groundwater Flow System

A schematic regional groundwater contour plot has been produced for the study area, shown in **Figure 10**, by synthesizing the recent groundwater monitoring data collected by CDM Smith with historical data collected for the Fingal Landfill Project (see report in **Appendix D**).

Figure 10 demonstrates a south-easterly groundwater flow direction from the site (see also **Section 4.4.2**) within the Loughshinny Formation. The site and its associated groundwater catchment is separate from the groundwater catchment of the BOTR wellfield. It is inferred from available groundwater level data that a groundwater divide is defined by the Knockbrack Hill high ground, notably by wells BH31 (new offsite monitoring), TW07 and TW10.

The groundwater divide identified to the northeast of the site is clearly identifiable in the regional groundwater and hydrogeological cross section presented in **Figure 7**, **Figure 8** and **Figure 9** and the timeseries water level data presented in **Graph 1**. **Graph 1** also illustrates that the groundwater levels on the site and at BH31 are over 80 metres higher than the groundwater levels in well OW2D which monitors the Loughshinny Formation at the BOTR wellfield.



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Legend

- 🟩 Waste Licence Boundary
- 🟥 IMS Facility
- – – Groundwater Contours
- — Groundwater Divide
- → Groundwater Flow Direction

Geology of Monitoring Borehole Response Zone

- ● Overburden and Loughshinny Formation
- ● Namurian Bedrock
- ● Loughshinny / Namurian
- ● Loughshinny Formation
- ● No installation / Response Zone

Rev	Description	By	CB	Date

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Title Interpreted Regional Groundwater Flow Directions

Status	Drawn By	PM/Checked By
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Project Number	Scale @ A3	Date Created
JER1631	1:25,000	JUL 2020

Drawing Number	Rev
Figure 10	-

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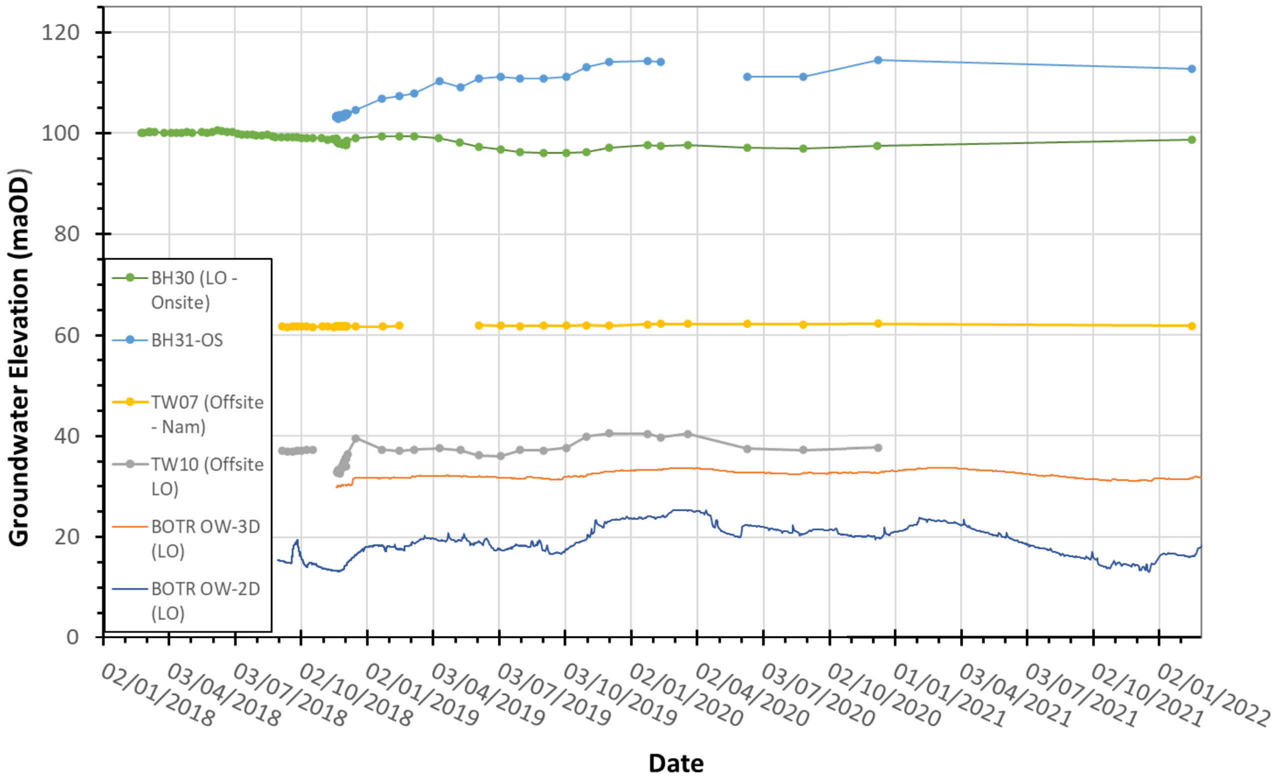


Graph 1 Timeseries Groundwater Level Data for Onsite and Offsite Monitoring Network (Namurian and Loughshinny Formation)

Graph 1 demonstrates that the highest groundwater levels identified within the study area (in mOD) are always recorded at BH31, the offsite monitoring well situated c. 700m northeast of the IMS facility. The groundwater levels observed at borehole BH31 are typically 5-10 m greater than groundwater levels observed on the IMS facility itself (data for borehole BH30) and more than 100m greater than the groundwater level observed at the Bog of the Ring wellfield situated c. 2.2km to the northeast.

This general interpretation of the regional groundwater flow system is broadly consistent with that presented by the GSI as part of the BOTR Groundwater Source Protection Zone project (GSI, 2005). In that report a groundwater contour map for 'winter 'pre-pumping water levels was provided with the following key observations:

> *'Groundwater contours show that groundwater flows northwards, NW and eastwards from Knockbrack Hill. Gradients are steep, reflecting both the steep topography and the low aquifer transmissivity, and range from 0.05 to 0.07. Some groundwater discharges to springs and to the streams that incise the hillside. The amount of groundwater discharging to the streams depends on the thickness and permeability of the subsoil. The thickness of the subsoil increases towards the base of the hill, reducing the contribution of groundwater to the stream flow in these areas. The remaining groundwater flows into the high transmissivity shaly limestone aquifer at the base of the hill. '*

The contour map provided in the BOTR Groundwater Source Protection Zone report is consistent with easterly flow identified through the most recent monitoring data gathered for the site additional works.

3.7 Public and Private Water Supplies

3.7.1 Public Water Supply

Fingal County Council developed the BOTR wellfield which is now operated by Irish Water and supplies approximately 3,000 m^3/day mainly from the Loughshinny Formation.

The GSI has defined a Source Protection Area for the BOTR public water supply composed of an Inner Protection Area and Outer Protection Area. The IMS facility is located outside the defined Outer Source Protection Zone.

The BOTR wellfield comprises four active production wells, PW2, PW3, PW4 and PW5. These range in depth from 53 to 91 m. Each well is completed in, and pumps groundwater from, the Loughshinny Formation although wells PW2 and PW3 are also screened across shallow gravels which contributes groundwater to respective wells.

3.7.2 Private Water Supply

A well survey was undertaken by Minerex Environmental Limited (MEL) in August 2010 for MEHL. The well survey involved MEL staff visiting all residential properties situated within a 1km downgradient and 0.5km up-gradient radius and commercial / business within 2km down-gradient and 1 km up-gradient. Three properties were identified with groundwater abstraction wells, of which only one is located hydraulically downgradient from the site (i.e. to the east thereof) at a distance of c. 0.7km.

3.8 Designated Sites and European Sites

Designated sites refer to National Heritage Areas (NHAs) and proposed National Heritage Areas (pNHA) that are deemed to be of national ecological importance and are afforded protection under the Wildlife (Amendment) Act 2000. European designated sites include Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

Nationally designated NHAs and pNHA within 25km of the proposed development include:

- Skerries Islands NHA;
- Loughshinny Coast pNHA;
- Feltrim Hill pNHA;
- Bog of the Ring pNHA;
- Knock Lake pNHA;
- Portraine Shore pNHA;
- Cromwell’s Bush Fen pNHA;
- Rogerstown Estuary Pnha;
- Malahide Estuary pNHA; and
- Laytown Dunes/Nanny Estuary pNHA.

The European designated sites within the vicinity of the proposed development include:

- Malahide Estuary SAC;
- Rogerstown Estuary SAC;
- Rockabill to Dalkey Island SAC;
- Rogerstown Estuary SPA;
- Broadmeadow/Swords Estuary SPA;
- River Nanny Estuary and Shore SPA;
- Skerries Islands SPA; and
- Rockabill SPA.

3.9 Water Framework Directive Status

The WFD required ‘Good Water Status’ for all European waters by 2015 or at the latest by 2027. The Directive requires that management plans be prepared on a river basin basis and specifies a structured method for developing these plans.

3.9.1 Groundwater

The Water Framework Directive (WFD) status 2013 to 2018 of the Lusk-Bog of the Ring Groundwater Body (GWB) (IE_EA_G_014) is currently under review and classified as ‘Not at Risk’ of meeting WFD environmental objectives. The WFD status 2013 to 2018 of the Hynestown (IE_EA_G_033) is ‘Good’ and the risk is currently under review.

3.9.2 Surface Water

The WFD status 2013 to 2018 for the Ballough Stream_10 is assigned a Poor WFD status and is at ‘at Risk’ of not achieving ‘Good’ status. Agriculture is listed as the significant pressure on this surface water body. The Ballough Stream_10 flows into the Ballough Stream_20 which is assigned a Moderate WFD status and also ‘at Risk’.

The WFD status 2013 to 2018 for Rogerstown Estuary transitional waterbody is assigned as ‘Bad’ due to poor ecological status and overall is ‘at Risk’ of not achieving Good status by 2021.

The biological quality of the Ballough Stream is assessed by the EPA at the bridge west of the Five Roads monitoring station (RS08B031400) located approximately 2.5km east of the site and at Corduff Bridge monitoring station (RS08B031600) located 6.7 km south east of the site.

Q-Values are used by the EPA to express biological water quality, based on changes in the macro invertebrate communities of riffle areas brought about by organic pollution. The EPA Q values for the Ballough Stream indicate predominantly moderate pollution within this surface waterbody. The EPA note that the Ballough Stream maintained moderate ecological condition in July 2020 with evidence of heavy siltation and excess flamentous algae.

3.10 Land Use

The local area surrounding the site features a mix of commercial, agricultural and undeveloped lands and detached one-off residential properties.

Using An Post GeoDirectory, approximately 346 residential and 72 commercial properties were identified within a 3km radius of the site. In total, there are 16 residential properties and three commercial operations (excluding agriculture) located along the LP-1080 between the site and the M1 motorway to the east of the site.

3.10.1 Commercial and Industrial Development

There are a small number of commercial enterprises located within the surrounding area but outside the site boundary, including TEAM Accessories Ltd, an aviation maintenance and repair business, located to the southwest at the corner of the site landownership boundary. A farm and commercial premises (Ecopipe, a plumbing and heating supplier) is situated along the LP-1080 immediately opposite the southern boundary of the site.

Other commercial premises of note in the locality include dog kennels (west), a joinery business (east), a kennels and cattery (north), and a farm shop (north). A number of recreational businesses are also located close to the site including a golf club approximately 1km south of the site and a shooting range located immediately to the west of site on the LP-1090.

3.10.2 Settlements and Housing

There is a low population density in the area surrounding the site. The local area is rural and consists mainly of one-off detached residential properties located along the local roads including the LP-1090 (west), LP-1080 (south), Bhailsigh Road (north), and Rowan and Nevitt Roads (east).

The nearest residential property to the site is a bungalow located at the southern site boundary along the LP-1080 to the east of the junction with the LP-1090 (in the ownership of IMS). A vacant bungalow which is also owned by IMS is located at the south east corner of the site boundary.

Some of the nearest clustered settlements in the area include Naul Village located approximately 4km north west of the site and Ballyboughal Village located 4km to the south of the site. Both villages are located on the regional road R108.

3.10.3 Agriculture

Much of the land surrounding the site is utilised for various agricultural practices including, but limited to, tillage and dry stock. There are also a numerous farm buildings dispersed throughout the area. The fields contiguous to the site have a mixture of tillage and pasture uses, with evidence of livestock on the lands located immediately to the south of the site.

4 SITE CHARACTERISTICS

4.1 Site Description

The IMS facility is situated on a former quarry that operated from the 1940s up to 2007. Permission for the infilling and restoration of the former quarry using inert waste was first granted in 1988 and has continued to the present date. The total area in the ownership of IMS is 54.4 hectares. The principal physical characteristics of the operational landfill site are presented in **Figure 2** and includes:

- Site entrance, buildings and other infrastructure situated outside the quarry void on the western boundary of the IMS facility;
- Fully restored inert waste cells (Cells 1, 2, 3, 4 and 5) and partially infilled Cells 6 & 7 in the west of the site;
- The area to the south and east of the facility outside of the quarry void that represents natural ground capped by former quarry spoil and is characterised by a declining topographic elevation to the east;
- The principal quarry void that includes:
    - Haul roads and ramps to allow vehicle access across the site;
    - Infilled inert waste cells currently under restoration (Cells 1, 2, 3, 4 and 5);
    - Operational engineered inert waste cells that are being actively infilled at present (Cell 6);
    - Currently empty void to be engineered as new waste cells; and
    - 3 No. small ponds typically used for settlement of surface water pumped from the quarry void during active operation of the IMS facility.

Note that there are a number of new infrastructural elements which are consented by planning and currently undergoing design/construction that are also shown in **Figure 2**. This includes the following infrastructure:

- A facility entrance on the LP-1080 local road which bounds the south of the site. This is to replace the existing facility entrance at the western boundary of the site which is maintained as a secondary and emergency access;
- An eight-metre-wide internal access road from the entrance to the main site reception area including wheel wastes, weighbridges and car parking;
- An administration building adjacent to the access road;
- An internal un-paved road network serving the site from the reception area; and
- A designated hardstanding yard (for waste processing) with associated drainage infrastructure and ancillary structures located on the former quarry floor to the south of the site.

4.2 Site Topography

The detailed topographic survey data for the IMS facility undertaken in 2022 is shown in **Figure 4** and demonstrates the following:

- Maximum elevation at the site entrance in the southwest IMS facility of c. 145 mOD;
- A decline in elevation along the road forming the southern boundary from c. 125 mOD in the southwest corner to c. 110 mOD approximately 1 km further to the east-southeast;
- A decline in elevation along the stream that forms the northern site boundary. Decline from 112.1 mOD in the north-western (upstream) corner to of the site to 88.3 mOD and the north-eastern (downstream) corner of the facility; and
- General easterly or north-easterly decline in ground levels toward the northern boundary stream and other water courses further to the to the east.

4.3 Site Geology

The detailed site-specific geological model presented below for the IMS facility is based on geological records from the boreholes that were identified in **Section 3.4** and augmented by:

- Geophysical Survey (Apex, 2010): which identifies faults at the site and provides information regarding the deep bedrock (**Appendix D**); and
- Geology of the Landfill Site, Hollywood Naul, Co. Fingal (Conodate, 2009): Geological field study undertaken in November 2009 to understand rock types present on the former quarry and their structural relationship. This included an analysis of micropalaeontology and palynology of rock samples (**Appendix D**).

Geological logs for the new boreholes commissioned by IMS as part of the additional works are provided in **Appendix C**. The geological logs for all other boreholes used in this assessment are provided in **Appendix E** and summarised in **Table 4-3**. The hydrogeological assessment presented herein has placed reliance on the boreholes installed between 2010 and 2018 inclusive.

The new offsite monitoring well (Borehole BH31) was installed c. 1 km northeast of the IMS facility to the east of Knockbrack Hill, at elevation of 128.4 mOD. Borehole BH31 is a fundamental addition to the monitoring network that was installed for the following reasons:

- Verification of the basal level / elevation of the Namurian bedrock (Walshestown Formation) towards the core of the regional synclinal structure;
- Examination if, or the extent to which, Namurian rocks exhibit fracture permeability at an offsite location; and
- Provision of a deep installation to monitor groundwater levels in the vicinity of the groundwater divide expected in this direction.

The geological units dip to the north in-line with the regional structure. The rocks that overlie the Loughshinny Formation, as exposed in the western quarry sidewall, are the transitional Donore Formation and the overlying Balrickard Formation. The predominantly black shales of the Walshestown Formation are observed towards the northern end of the quarry and on the higher ground at the eastern side of the quarry. Photographs of the geological formations exposed within the former quarry taken in 2009 and presented support of Chapter 14 of Environmental Impact Statement for MEHL Waste Management Facility at Hollywood Great, Nag’s Head, Naul, Co. Dublin (Arup, 2010) are provided in **Appendix D**. A representative photograph of the Loughshinny Formation exposure within the site is presented as **Figure 11**.

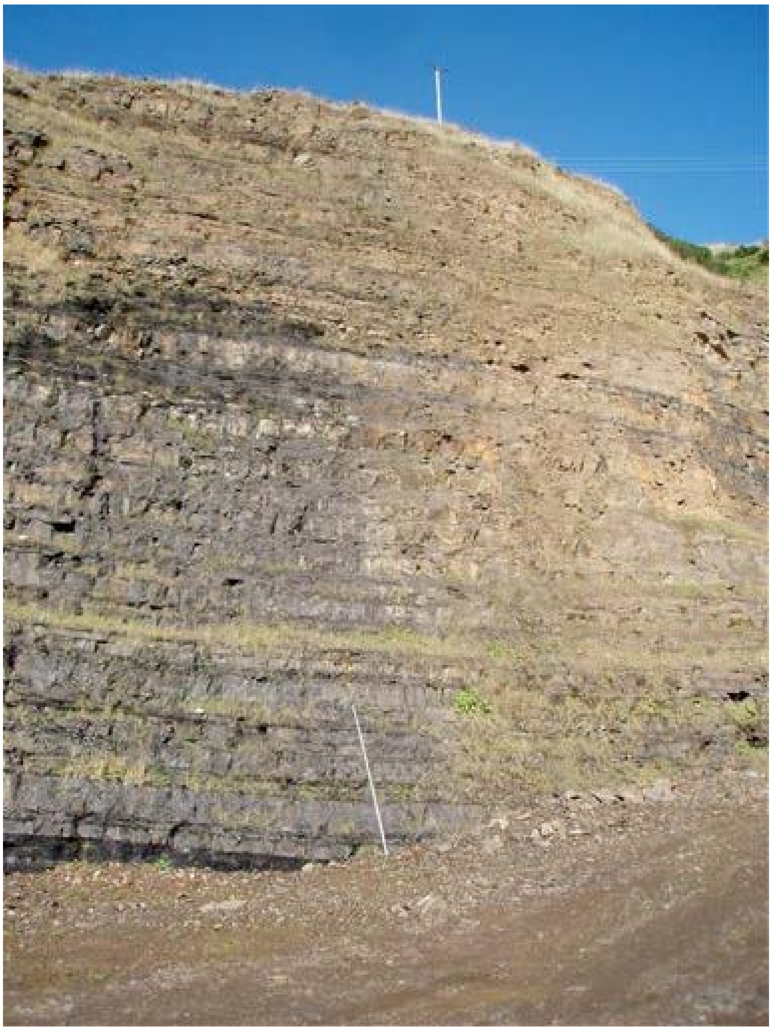


Figure 11 Loughshinny Formation Exposure within IMS Facility

The general succession identified within the former quarry is therefore consistent with the regional sequence and comprises (from oldest to youngest):

- Loughshinny Formation, predominantly an interbedded light-coloured limestone with thin, darker shales;
- Donore Formation, comprising shales, limestones and sandstone units that are transitional between the Loughshinny Formation and overlying Namurian bedrock of the Balrickard Formation;
- Balrickard Formation, comprising thinly bedded and typically intensely fractured and jointed sandstone, shale and rare limestone units; and
- Walshestown Formation, comprising thinly bedded, intensely fractured and jointed black shales, mudstones, siltstones and thin sandstones.

Overall, the geology of the former quarry and its immediate environs is dominated by the Namurian bedrock and, as shown in **Figure 12**, the Namurian bedrock extends further to the south within the IMS facility than is indicated by the regional GSI mapping in **Figure 6**. Exposure of the Loughshinny Formation is restricted to the lowest quarry levels in the southeast of the former quarry footprint. Relevant geological information obtained from the geological logs provided in **Appendix E** for onsite and offsite boreholes installed with the study area is summarised in **Table 3-3**.

On the basis of the data summarised in **Table 3-3**, the outcrop of bedrock and associated structure on the IMS facility is presented in **Figure 12** and the elevation of the contact between the Loughshinny Formation and overlying Namurian bedrock (including the depth of Namurian bedrock) is presented in **Figure 13.**

Borehole BH25 and BH02 are the only locations within the quarry footprint where the Loughshinny Formation outcropped at the quarry surface. Borehole BH25 is situated immediately northeast of the former pond historically present in the southwest of the quarry (now infilled in Cell 6) and gives an elevation for the interface between the Loughshinny Formation and Namurian bedrock of 105.4 mOD. This is consistent with the highest proven elevation of the interface (of 116.1 mOD) at borehole BH10A on the southern site boundary.

The elevation of the contact between the Loughshinny Formation and Namurian bedrock shown on **Figure 13** decreases across the site from south to north in line with the regional structure. Except for the southwest corner of the quarry void (in the vicinity of the former pond), the elevation of the contact declines from c. 95 mOD (at BH18 and BH14) to a minimum of 60.0 mOD at BH32 (the new trial well). In previous studies the variable elevation of the contact between the Loughshinny Formation and Namurian bedrock had been interpreted as due to the presence of an inferred onsite fault shown in **Figure 12**, that is seen in exposure on the walls of the quarry void. The presence of a fault zone was also interpreted from the results of geophysical surveys undertaken in 2010 (Apex, 2010a and 2010b) described below.

The thickness of Namurian bedrock identified across the site is also shown in **Figure 13**. The majority of boreholes constructed in central and northern parts of the quarry identify Namurian strata to significant depths beneath the site.

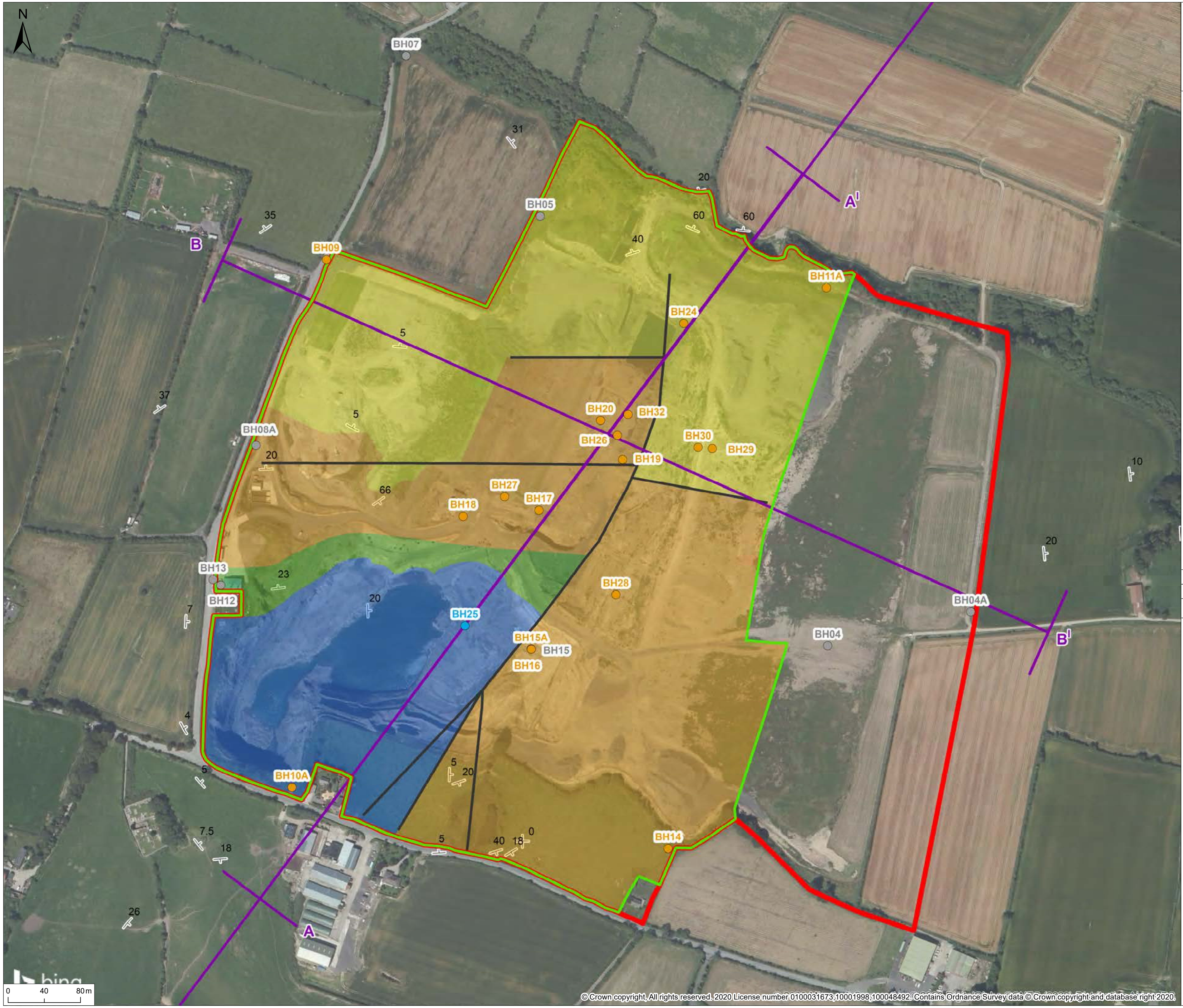
Namurian bedrock exposed in the quarry is characterised by intense weathering in addition to the presence of a densely fractured / jointed structure associated with faulting and folding of the strata.

Consistent with the regional geology, bedrock on the former quarry generally dips to the north, typically at less than 20° (Conodate, 2009) exposing progressively younger units in that direction. A significant fault, bisecting the former quarry with an orientation of north-northeast (NNE), was identified visually in 2009 (Conodate, 2009). Downthrow to the east of this fault was estimated to be 10's of metres and was attributed to the greater depth and prevalence of Namurian bedrock across the site. Borehole evidence of the contact elevation between the Loughshinny Formation and Namurian strata within the site, summarised in **Figure 14**, however does not suggest this magnitude of downthrow is present.

The NNE fault observed on the IMS facility is consistent with the offsite regional structure shown in **Figure 6** that is characterised by the presence of faults and fault-sets to the north and northeast of the site within the study area. The lateral continuity between onsite faults and GSI mapped faults is uncertain, although the onsite geological observations are consistent with the IMS facility being located within a locally significant zone of faulting orientated approximately southwest-northeast with a strike of 034°.

To determine the significance of faulting across the former quarry a geophysical investigation was commissioned by MEHL in 2010 as part of their hydrogeological investigations. The geophysical reports are provided in **Appendix D** (Apex Geoservices Ltd, 2010a and 2010b). The geophysical surveys were interpreted as evidence for the two key faults shown in **Figure 12** that include the NNE trending fault that approximately bisects the site and appears consistent with the orientation of structures observed visually during the site geological survey and an east-west trending fault in the central part of the site, to the south of borehole BH19.

The geophysical survey was interpreted as indicating the downthrow of geological strata to the north and east of these two faults. Consistent with the borehole data this would account for the presence of the Loughshinny Formation in the southwest of the site and Namurian bedrock elsewhere.



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Legend

- 🟥 IMS Facility
- 🟩 Waste Licence Boundary
- — Cross Section Lines

Surface Geology Encountered in Monitoring Borehole

- ● Overburden / Till
- ● Namurian Bedrock
- ● Loughshinny Formation

Bedrock Geology

- 🟨 Balrickard Formation
- 🟧 Walshestown Formation
- 🟩 Donore Formation
- 🟦 Loughshinny Formation (L)
- — Potential Fault

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Drawing Number **Figure 12**

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Legend

🟥	IMS Facility
🟩	Waste Licence Boundary
—	Elevation Contours for the Contact between Namurian Bedrock and Loughshinny Formation (maOD)

Geology of Monitoring Borehole Response Zone

●	Loughshinny Formation
●	Namurian Bedrock
●	Loughshiiny & Namurian Bedrock

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Client Integrated Material Solutions (IMS)

Project Hollywood Great

Title Relationship Between Loughshinny and Namurian Bedrock

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Figure 13	-

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4.3.1 Summary of Geological Model for the Site

On the basis of the results from the site geological survey, geophysical investigations and borehole drilling on the site, a geological model for the IMS facility has been developed and is shown in **Figure 12** and the cross sections provided in **Figure 7**, **Figure 8** and **Figure 9.** The key observations regarding the geological model are as follows:

- Exposure of Carboniferous bedrock of the Loughshinny Formation, Donore Formation, Balrickard Formation and Walshestown Formation within the former quarry void;
- Surface outcrop of the Loughshinny Formation restricted to the southwest corner of the quarry, in the vicinity of the former pond, with a contact between the Loughshinny and overlying Namurian bedrock of above 105 mOD;
- The presence of Namurian bedrock at outcrop in central, northern and eastern parts of the quarry;
- The presence of Namurian bedrock at outcrop in areas external to the quarry void;
- Carboniferous bedrock across the site is typically thinly bedded comprising shales, mudstones, sandstones and limestones units; is intensely weathered and degraded nature, with the presence of a high density of fracturing and jointing throughout each unit; and common presence of structural deformation features including folding;
- Significant faulting of the site, most notably: a north-northeast trending fault that bisects the site; and a potential an east-west trending fault near the centre of the site; and
- An elevation for the interface between the Loughshinny Formation and overlying formations of the Namurian bedrock that declines from above 105 mOD in the southwest of the former quarry to approximately 60 mOD at BH32 in the central/northern part of the quarry.

The geophysics has been interpreted as being consistent with geological downthrow to the east and north of the two discrete faults identified on the site. However, the contact elevation data (between the Loughshinny Formation and Namurian strata) across the site is also consistent with a general decline in elevation to the north, with the lowest elevation of the contact approximately following the north-northeast orientated fault bisecting the former quarry.

This fault zone appears coincident with the off-site regional structure expected within the study area to the north of the IMS facility, although lateral continuity with those off-site structures is difficult to demonstrate. The intensely fractured nature of bedrock observed across the former quarry suggests the that this local fault zone may represent a zone of enhanced permeability that has developed throughout the Carboniferous bedrock geology underlying the site.

4.4 Site Hydrogeology

The hydrogeological assessment presented herein is principally underpinned by the additional works recently commissioned by IMS to address those area of concern and uncertainty outlined in the decision notice for Waste Licence Application W0129-03 (EPA, 2016). These additional works and data sources are listed in **Section 1.6**. Information from the additional works has been augmented by the monitoring undertaken for Waste Licence compliance as described in this section.

The understanding of geology and hydrogeology has largely been informed by the extensive network of boreholes installed in onsite and offsite locations, including:

- Boreholes installed as part of the works commissioned by IMS in 2018, namely onsite trial well BH32 and offsite monitoring well BH31 (see **Appendix C**);
- Boreholes installed in support of planning applications by the previous site operator (MEHL) under the supervision of Arup in 2010 and 2013: Borehole BH15, BH15a, BH16, BH17, BH18, BH19, BH20 and BH24 to BH30;
- Groundwater monitoring infrastructure installed between 1998 and 2008 to fulfil the requirements of EPA waste licence: Borehole BH4a, BH5, BH6, BH8, BH9, BH10a, BH11a, BH12, and BH13;
- Monitoring boreholes installed around the Bog of the Ring wellfield that include:

  - Boreholes in the immediate vicinity of the BOTR production wells that form part of the EPA's national groundwater monitoring network and show a clear influence of the operational pumping regime at the Bog of the Ring wellfield, namely paired wells OW-2D/2S and OW3D/3S.
  - Boreholes situated away from the wellfield, in the direction of the IMS facility, namely: TW10 and TW07.
- Groundwater investigations boreholes installed around the Fingal Landfill Site, situated c. 2 km east of the IMS facility, that were monitored as part of the Waste Licence Application in 2006.

The onsite and offsite groundwater monitoring network used to define the hydrogeology of the IMS facility and its local environs are shown in **Figure 14** and **Figure 15** respectively. These figures identify which geological unit each observation borehole has been installed (where known).

Data for a total of 29 No. boreholes have informed the hydrogeological understanding of the study area presented herein. The key information regarding these monitoring installations summarised in **Table 3-3.**

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Legend

- 🟥 IMS Facility
- 🟩 Waste Licence Boundary

Geology of Monitoring Borehole Response Zone

- ● Loughshinny Formation
- ● Loughshinny & Namurian Bedrock
- ● Namurian Bedrock
- ● No installation / Response Zone

Other Monitoring Boreholes

- ✦ Main Quarry Pond Monitoring Point (MWP)
- ✦ Pond (Pd)

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Project Hollywood Great

Title Onsite Groundwater Monitoring Network

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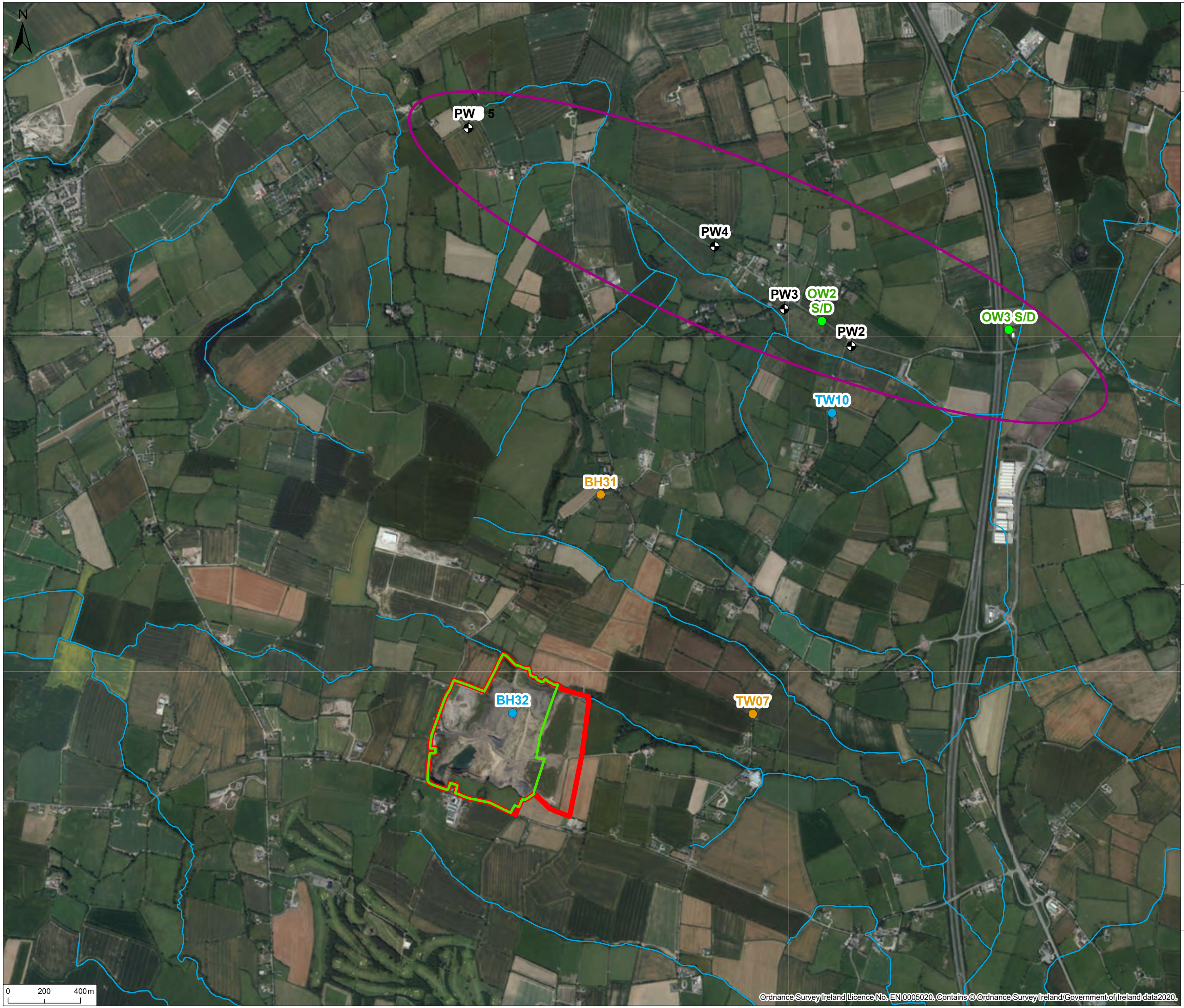

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Legend

🟥 IMS Facility
🟩 Waste Licence Boundary
🟪 Bog of the Ring Wellfield
— Rivers
⊕ Bog of the Ring Abstraction Boreholes

Geology of Monitoring Borehole Response Zone

● Overburden and Loughshinny Formation
● Namurian Bedrock
● Loughshinny Formation

Rev	Description	By	CB	Date

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4.4.1 Groundwater Level Monitoring Dataset

An extended groundwater level monitoring programme has been undertaken by IMS between 2018 and 2022 using the network of onsite and offsite monitoring boreholes shown in **Figure 15** and **Figure 16**. A total of 20 No. boreholes across the IMS facility and 7 No. boreholes in offsite locations have been monitored at different times over this period through a combination of manual dips and data logging using pressure transducers installed in selected monitoring boreholes. Data has also been accessed from EPA for monitoring wells associated with the Bog of the Ring wellfield, namely boreholes OW-2D, OW-2S, OW-3D and OW-3S.

Groundwater monitoring data collected in 2005 in support of the Fingal Landfill Project (RPS, 2006) has also been used. The proposed Fingal Landfill is located approximately 2 km to the east-southeast of the IMS facility within the valley of the Ballough Stream, which flows in southerly direction ultimately discharging to the Rogerstown Estuary. This additional data was sourced from the reports provided in **Appendix D** and provide an improved understanding of groundwater levels at the site in context of the regional flow pattern.

The groundwater level data used in this hydrogeological assessment is tabulated in **Appendix F**. A detailed discussion of groundwater level monitoring data available for the site is provided in letter reports prepared CDM Smith, as presented in **Appendix C,** notably:

- Groundwater Level Monitoring and Aquifer Test Report (CDM Smith, 2020);
- Assessment of On-site Groundwater Levels in the Context of the BOTR Wellfield Pumping (CDM Smith, 2018c); and
- Review of pressure transducer data – June to August 2018 (CDM Smith, 2018b).

4.4.2 Groundwater Flow

The groundwater monitoring undertaken at the site has produced a robust dataset to describe hydrogeological conditions within the Loughshinny Formation across the IMS facility. Typically, the Loughshinny is fully saturated where overlain by Namurian strata and is unconfined in the southern parts of the former quarry where Namurian strata are absent. Groundwater in Namurian bedrock also forms a laterally extensive and inferred unconfined aquifer unit across the IMS facility.

Groundwater level contour maps for the Loughshinny Formation and Namurian bedrock across the IMS facility are presented in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith, 2019) provided in **Appendix C,** using the manually measured groundwater level data collected CDM Smith. These are reproduced below as **Figure 16** to **Figure 19**.

Groundwater contour plots for the 15th November 2018 and 2nd February 2019 have been presented for boreholes with response zones completed in Namurian bedrock. The contour plots confirm an easterly groundwater flow across the IMS facility within the Namurian bedrock. Groundwater contour plots for boreholes completed in the Loughshinny Formation are presented for the 15th November 2018 and 17th December 2018 and indicate a south-easterly flow direction on the IMS facility.

The site-specific groundwater contour plots show that the natural groundwater flow direction on the IMS facility is generally to the east-southeast, placing the western and eastern boundary of the IMS facility in an up-hydraulic gradient and down-hydraulic gradient positions respectively. Under natural conditions there is no evidence to suggest the groundwater flow direction in the Loughshinny Formation or Namurian bedrock is influenced by the inferred orientation of the regional faulting (i.e. south-south east to north-northeast). The active pumping of the Loughshinny Formation did, however, result in the development of a cone of depression (i.e. pumping induced drawdown) that extends in a northerly direction which could reflect some directional control imparted by the localised zone of enhanced permeability.

Figure 16 Interpreted Groundwater Contours – 15 November 2018 – Namurian Wells

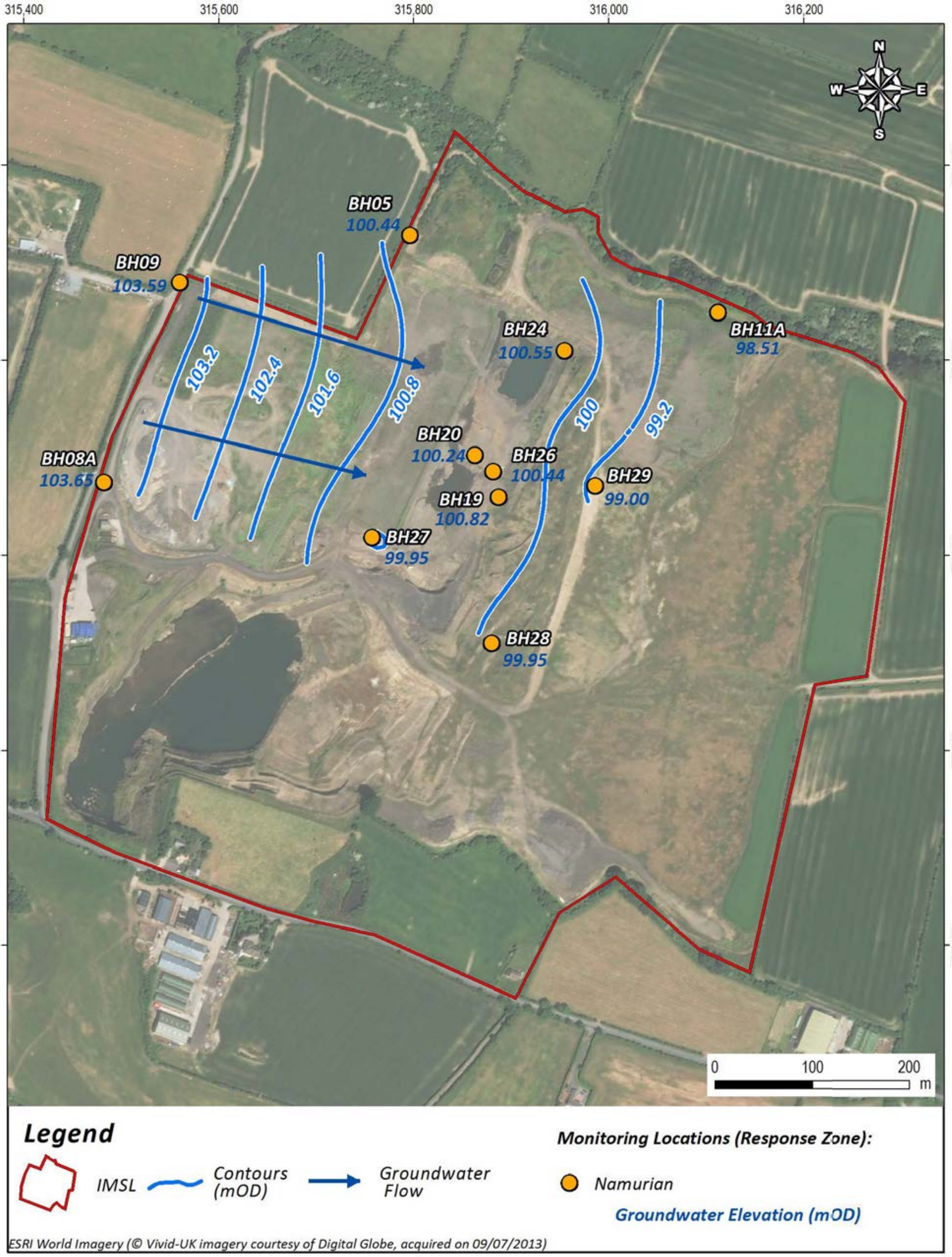

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Figure 17 Interpreted Groundwater Contours – 02 February 2019 – Namurian Wells

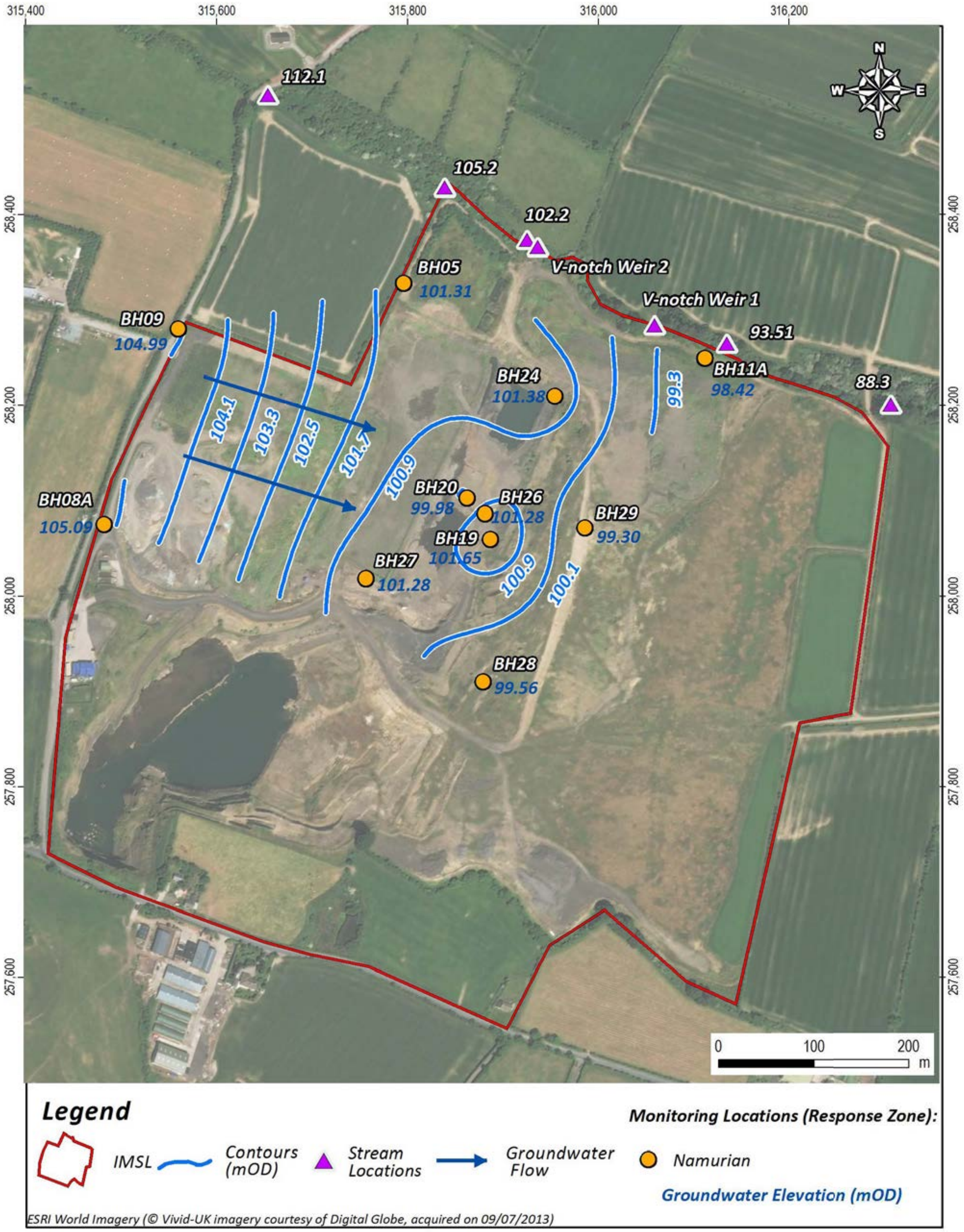

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Figure 18 Interpreted Groundwater Contours – 15 November 2018 – Loughshinny Formation Wells

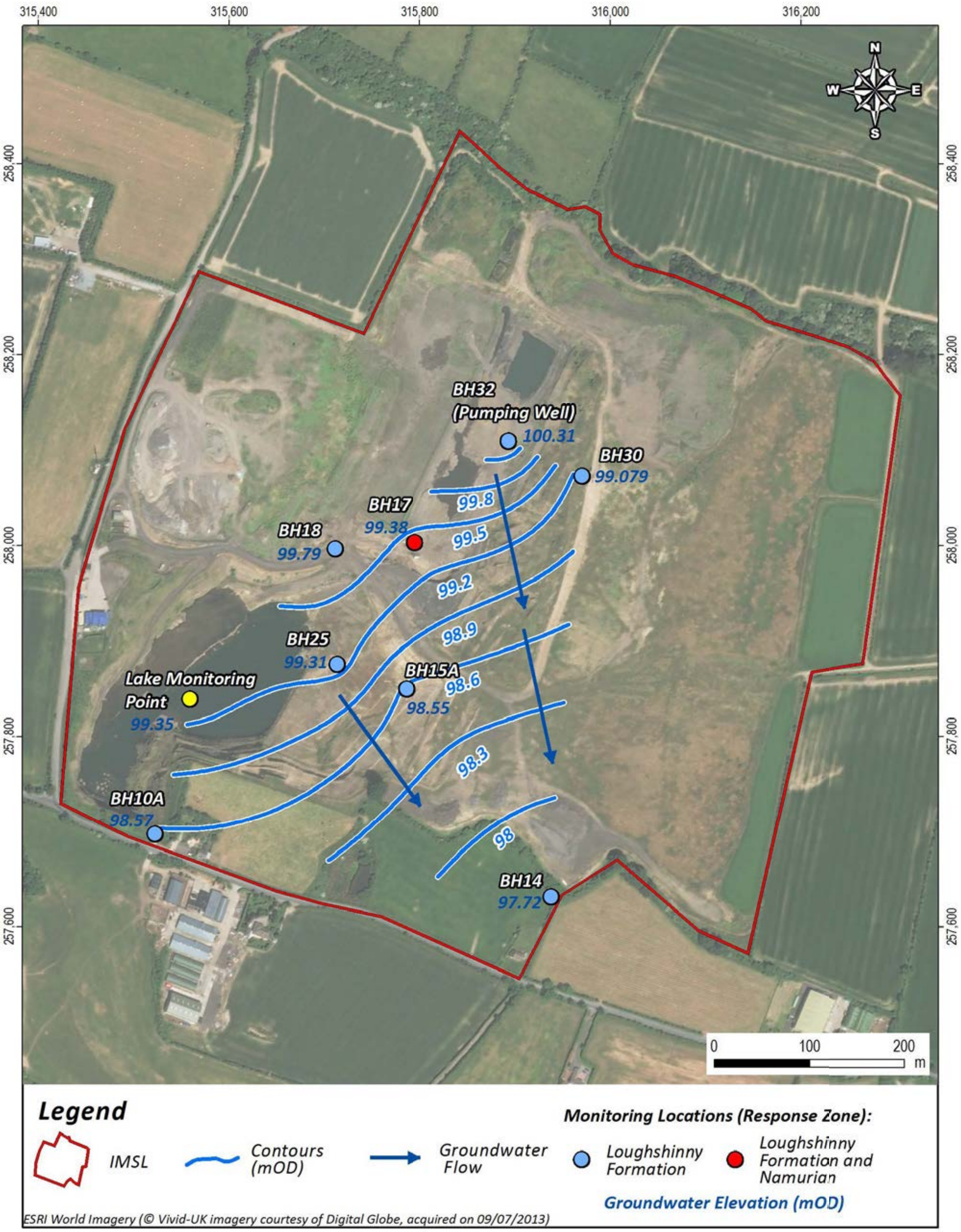

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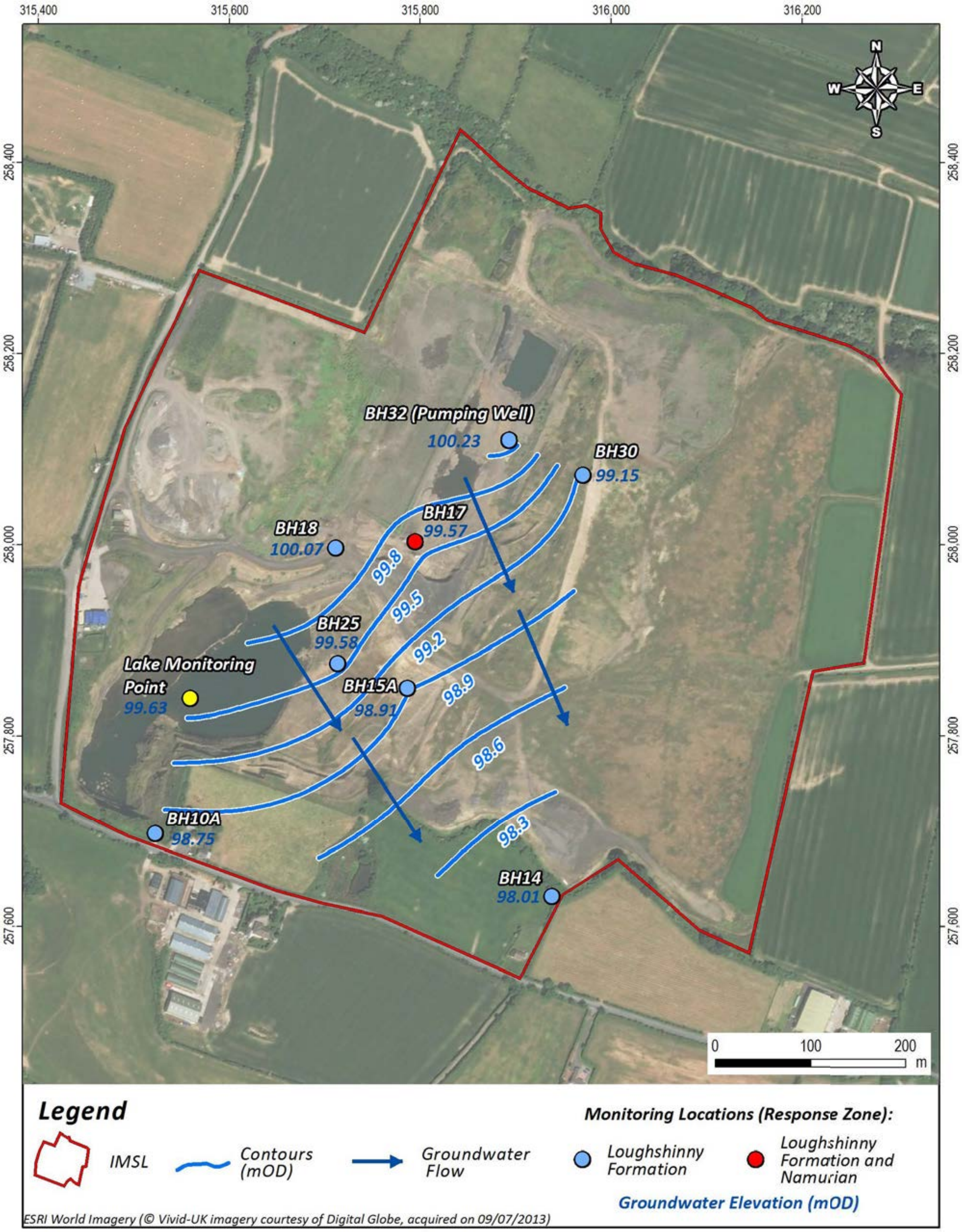
Figure 19 Interpreted Groundwater Contours – 17 December 2018 – Loughshinny Formation Wells



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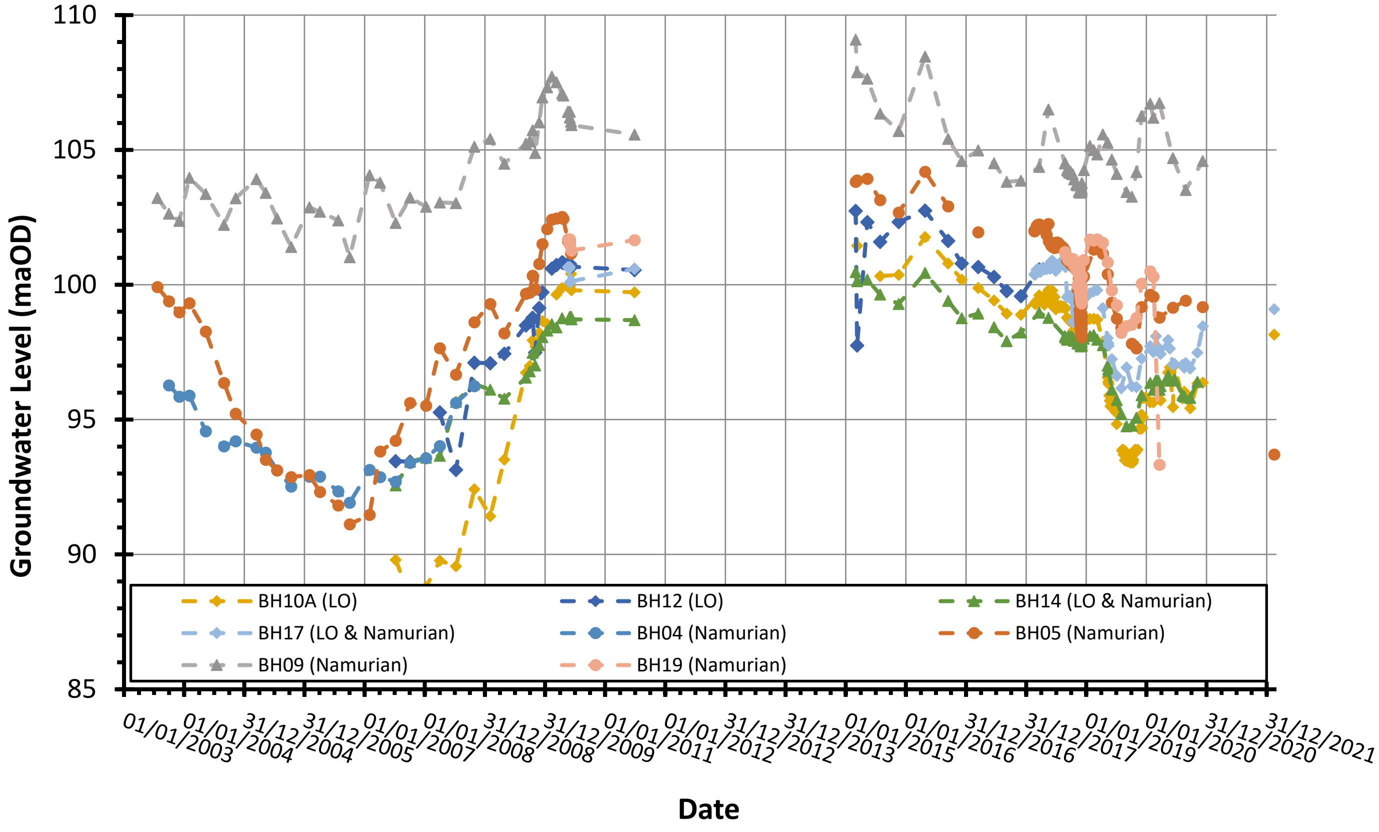
4.4.3 Long-Term and Seasonal Groundwater Level Variability

The long-term groundwater level variability on the IMS facility has been determined from the extended monitoring dataset for Waste Licence boreholes presented in **Graph 2**. The waste licence monitoring dataset has been augmented with the additional monitoring data from 2018 to 2022 for boreholes BH09 and BH14 (See report in **Appendix D**).



Graph 2 Groundwater Levels in selected Waste Licence Monitoring Wells

Graph 2 presents groundwater levels for those boreholes for which an extended dataset is available. From this dataset the following observations can be made:

- The minimum groundwater level on the IMS facility is observed in 2006 and 2007 during quarry dewatering. Groundwater levels were below 93 mOD at boreholes for which data is available;
- Minimum groundwater levels were followed by a subsequent rise in groundwater level that attain a high level by 2010 and remained high over the period between 2015 to 2019, with an elevation typically between 100 mOD and 108 mOD;
- The long-term trend in groundwater level observed in monitoring boreholes completed in the Loughshinny Formation and those completed in the Namurian bedrock are similar;
- The annual range in groundwater level observed at individual boreholes is typically less than 5 m, in comparison to the long-term groundwater level variability observed over the entire monitoring period;
- Groundwater levels within the Loughshinny Formation (LO) are similar to, or lower than, groundwater levels measured in boreholes completed in overlying Namurian bedrock strata;
- The minimum groundwater elevation of below 90 mOD is observed in borehole BH10A and is expedited to reflect correspondingly low water levels in the former main quarry pond on the IMS facility which was pumped at that time;
- The minimum groundwater level of below 95 mOD observed in the long-term dataset is considerably lower than bed level at the upstream of the northern boundary stream (i.e. 105.2 mOD) but may

potentially be greater than the minimum bed level measured at the downstream end of that stream (i.e. 93.5 mOD); and

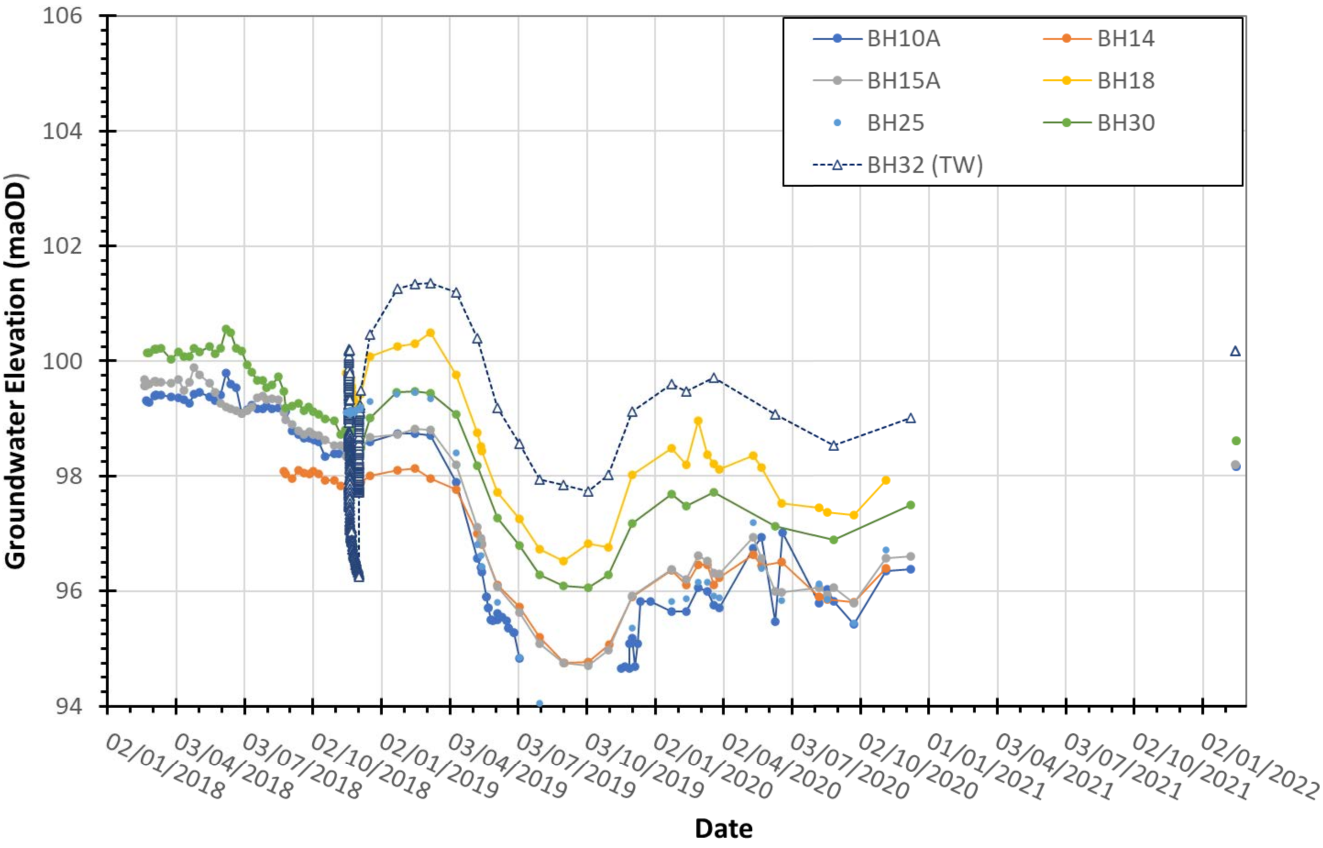
- The maximum groundwater level on the IMS facility that exceeds 105 mOD are observed in borehole BH09, situated along the western boundary of the IMS Facility. That borehole is completed in the Namurian strata with a response zone of between 78.9 mOD and 86.9 mOD.

From the water level dataset for Waste Licence monitoring boreholes it is also noted that artesian groundwater conditions have been observed on occasions in boreholes BH04A, BH06 and BH11. These boreholes are constructed in areas at a low topographic elevation on the IMS facility and /or near the stream forming the northern site boundary.

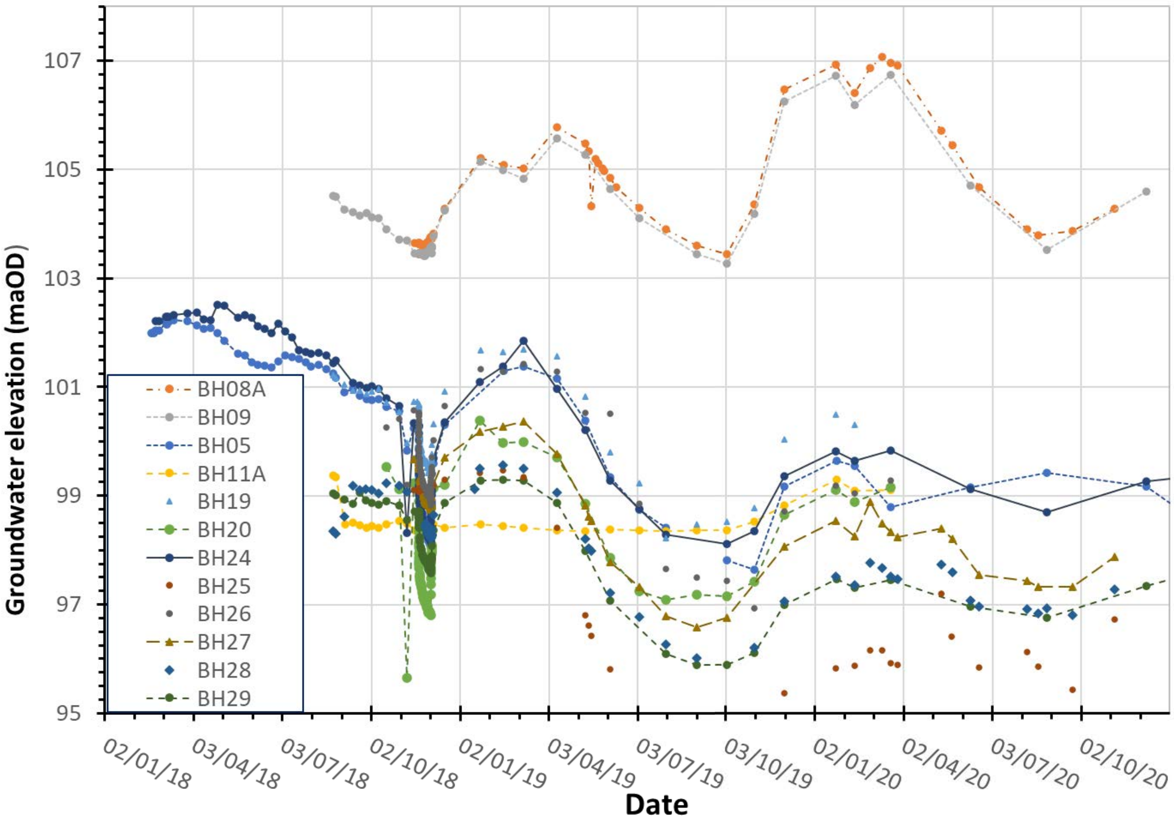
Time series groundwater level data for monitoring wells situated on the IMS facility and monitored between 2018 and 2022 are provided in **Appendix F**. Based on these data, the groundwater level dataset for wells that are completed in the Loughshinny Formation are presented in **Graph 3**.

Although, the time-series dataset presented in **Graph 3** is clearly affected by the pumping test on the borehole BH32 (the new test well) undertaken between the 20th November and 3rd December 2018, groundwater levels in the Loughshinny Formation show similar trends with levels between c. 97 mOD and 101.5 mOD, with an apparent decrease in groundwater levels in boreholes to the south / southeast and lowest groundwater levels observed in BH10A. It is notable that the highest groundwater levels were observed in the BH32 (the trial well) constructed with the deepest response zone within the Loughshinny Formation on the IMS facility of between 44.0 mOD and 49.0 mOD. This suggests semi-confined behaviour of the aquifer.

The corresponding groundwater level dataset for onsite boreholes completed in Namurian bedrock strata are presented in **Graph 4.**



Graph 3 Groundwater Levels in Onsite Monitoring Wells – Loughshinny Formation



Graph 4 Groundwater Levels in Onsite Monitoring Wells – Namurian Bedrock

Graph 4 also shows the clear effect of the pumping test of borehole BH32 in late 2018. The groundwater levels in Namurian bedrock show a similar trend to those observed in the Loughshinny Formation. Elevated groundwater levels are observed in boreholes situated the centre of the quarry void, which may relate to the relative depth of the slotted sections in each monitoring borehole; the proximity to surface water bodies within the quarry at that time (i.e. ponds) and/or the general position in the groundwater flow field. It is notable however that in the central quarry void groundwater levels in the Namurian bedrock range from 95.8 mOD to c. 102.5 mOD which is greater than the range seen in boreholes completed in the Loughshinny Formation. The highest groundwater levels measured in the Namurian bedrock are observed at borehole BH08A and BH09 situated on the western boundary of the IMS facility with elevations generally above 103.5 mOD. This is consistent with the general easterly flow indicated in the contour plots for Namurian bedrock shown in **Figure 17** and **Figure 18**.

4.4.4 Groundwater Level Variability in Offsite Wells

The recent groundwater level for offsite well BH31, TW07, TW10, OW-2D and OW-3D are presented in **Graph 1**. To aid the interpretation of off-site groundwater levels, the groundwater levels for onsite observation boreholes BH30, which is completed in the Loughshinny Formation are provided.

Groundwater levels observed at the new offsite Monitoring Well BH31 over the period of November 2018 to February 2022 are shown **Graph 1**. Groundwater levels at borehole BH31 are affected by intermittent pumping of a proximal agricultural borehole used for industrial vegetable washing. However, the groundwater levels in the saturated Namurian bedrock at this location vary between c. 102.8 mOD to 114.5 mOD and are consistently elevated relative to onsite wells, including trial well BH32, by c. 3.3m to 15.5m over the period monitored. The groundwater level dataset for borehole BH31 confirm the presence of a groundwater divide in the vicinity of Knockbrack Hill high ground and is consistent with the inferred separation of groundwater catchment areas that was presented in in **Figure 10.**

The 'deep' monitoring wells OW-2D and OW-3D are completed in the Loughshinny Formation, one within and the other to the east of the BOTR wellfield (see **Figure 16**). These two boreholes are characterised by groundwater levels that range between 13 to 25 mOD and 31 to 34 mOD respectively in the monitoring period between September 2018 and February 2022. As shown in the regional cross section provided in

Figure 9 these levels are more than 90 m lower than groundwater levels on the IMS facility and 70 m lower than the new offsite monitoring well BH31.

The principal observation regarding groundwater levels observed at offsite borehole TW10 and borehole TW07 are as follows:

- Groundwater levels within the Loughshinny Formation at TW10 range from c. 33 mOD to 40.5 mOD and at least 63.5 m lower than the levels at BH31;
- Groundwater levels in the Namurian bedrock to the east of the IMS facility at TW07 show a small variability of only 0.6 m between September 2018 and February 2022, with a mean groundwater level of c. 61.8 mOD; and
- Groundwater levels at TW10 and TW07 are significantly lower than observed on the IMS facility and in offsite borehole BH31 but remain higher than the groundwater levels observed at the Bog of the Ring wellfield.

Declining groundwater levels from the Knockbrack Hill groundwater divide towards the BOTR are confirmed by the levels in TW07, TW10, OW-2D and OW-3D as shown in **Graph 1** and the regional cross section in **Figure 9**.

The influence of operational pumping at the Bog of the Ring wellfield is evident in the groundwater level dataset for monitoring boreholes OW-2D especially, being located within the wellfield. Of particular significance is a pronounced recovery of groundwater levels (by c. 4.5 m) at OW-2D that commenced on the 20th September 2018 and continued for approximately one week as a consequence of a temporary cessation in pumping from well PW2. As shown in **Graph 1**, the significant and rapid rise in groundwater levels observed during this event was not observed in onsite observation wells, nor were any significant changes in the rate of groundwater rise / natural recession observed. The absence of any groundwater level changes in other monitoring wells as result of this cessation of pumping indicates that the hydraulic influence of pumping and recovery at the BOTR wellfield did not extend to the IMS facility.

Similarly, the significant drawdowns recorded at OW-2D during BOTR wellfield pumping throughout the Irish summer drought of 2018 were undetectable within the monitoring wells located at the IMS facility.

This is consistent with the position of the wellfield within a productive aquifer unit situated at low topographic elevation, in a separate groundwater catchment to the IMS facility as indicated in the regional groundwater contours in **Figure 10**.

4.4.5 Vertical Hydraulic Gradients

The groundwater monitoring dataset provided in **Appendix F** has been used to evaluate vertical hydraulic gradients between the Loughshinny Formation and Namurian bedrock at the IMS facility. The groundwater level (GWL) data for two groups of proximal wells with response zones that were monitored as part of the Constant Rate Test (CRT) have been extracted and reviewed in **Table 4-1**.

The dataset for Group 1 demonstrates a continuous downward hydraulic gradient between boreholes completed in Namurian bedrock in the vicinity of trial well BH32. However, the dataset for Group 2 and the Loughshinny Formation in Group 1, imply an upward gradient from the underlying Loughshinny Formation outside of periods strongly affected by pumping of BH32 (Test Well).

Table 4-1 Vertical Hydraulic Gradients at the IMS Facility

Borehole Reference	**Geological Unit**	**Ground Elevation (mOD)**	**Response Zone**		**Groundwater Level (GWL) (mOD)**			
			Length (m)	Elevation (mOD)	Baseline Rest GWL	Pre-CRT GWL	End-CRT GWL	Post-Recovery GWL
					15/11/18 c.17:00	*20/11/18 c. 08:45*	*03/12/18 c. 08:45*	*17/12/18 c. 10:00*
GROUP 1								
BH19	Namurian	105.1	5	92.1 - 87.1	100.80	100.85	99.55	101.12
BH26	Namurian	105.2	5	87.2 - 81.2	100.54	100.59	98.92	100.74
BH20	Namurian at contact with Loughshinny Formation	104.8	6	67.8 - 61.8	100.23	100.13	97.75	100.23
BH32 (TW)	Loughshinny Formation	105.0	5	49.0 - 44.0	-	100.18	96.35	100.30
GROUP 2								
BH29	Namurian	123.7	7	90.7 - 83.7	-	98.99	97.93	99.22
BH30	Loughshinny Formation	124.2	2.3	67.5 - 65.2	99.06	99.12	97.99	99.30

4.4.6 Hydrogeological Characteristics of the IMS Facility

The groundwater level dataset has been used to the define the key hydrogeological characteristics for the IMS facility in terms of the aquifer conditions (i.e. unconfined or confined); saturated thicknesses in Namurian rock within the site; and the thickness of any unsaturated zone (based on current ground levels). The sitewide variability of these characteristics has been generally determined on the basis of borehole-pairs situated in close proximity as summarised in **Table 4-2**. The dataset upon which this table is based is provided in **Appendix F**.

The maximum groundwater level observed within the centre of quarry void has been shown to be c. 102.5 mOD at BH24 completed in the Namurian strata, based on the available groundwater level data.

As shown in previously in **Figure 13** and cross sections across the IMS facility (**Figure 7**, **Figure 8** and **Figure 9**), the data presented in **Table 4-2** demonstrates that the saturated Namurian bedrock across the majority of the IMS facility commonly exceeds 15 m and is greater than 40 m in places. With the exception of the outcrop in the southwest of the IMS facility, the depth to the LF increases to the north as the Namurian bedrock units become thicker, i.e. the interface between the Namurian strata and the Loughshinny Formation is situated a considerable depth beneath saturated Namurian deposits.

Table 4-2 Aquifer Characteristics Across the IMS Facility

Area	General Hydrogeological Description	Representative Boreholes (Unit)#	LO - Namurian Contact (mOD)	Groundwater Level (mOD)			Approximate Nam Saturated Thickness above LO (m)	Response Zone (mOD)	Vertical Hydraulic Gradient
				Date of Dataset~	Minimum	Maximum			
Southern half of the IMS facility	Loughshinny Formation forms an unconfined aquifer. Unsaturated zone in Namurian bedrock	BH10A (LO)	116.1	Jul. 2007 to Feb 2022	88.39	102.73	-	69.1 – 98.1	-
		BH12 (LO)	101.0	July 2007 to Mar. 2018	93.14	102.75	-	65 – 50 (slotted section)	-
		BH25 (LO)	>105.2	Nov. 2018 to Nov 2020	93.28	99.46	-	80.4 – 87.4	-
Central and northern parts of the quarry void on the IMS facility	Saturated Loughshinny Formation overlain by saturated Namurian Bedrock. Unsaturated zone in Namurian bedrock.	BH27 (Nam)	95.3	Nov. 2018 to Nov 2020	96.58	100.37	1.6 – 5.1	93 – 99	Generally Upward
		BH18 (LO)		May 2010 to Nov 2020	96.52	100.65		89.5 – 95.5	
		BH28 (Nam)	81.9	Aug. 2018 to Feb 2022	96.02	99.56	14.1 – 17.7	85.9 – 91.9	Generally Downward
		BH15A (LO)		April 2010 to Feb 2022	94.70	99.89		75.9 – 80.9	
		Group 1	60.0				c. 37 – 41		Downward through Namurian Upward from deep LO to base of Namurian
		BH19 (Nam)		May 2010 to Mar 2020	98.22	101.69		87.1 – 92.1	
		BH26 (Nam)		Oct. 2018 to Mar 2020	96.93	101.42		81.2 – 87.2	
		BH20 (Nam)		May 2010 to Mar 2020	95.66*	101.02		61.8 – 67.8	
		BH32 - TW (LO)		Nov. 2018 to Feb 2022	96.26*	101.14		44.0-49.0	
		Group 2	< 83.7	Aug. 2018 to Feb 2022	95.89	99.47	12.2 – 15.8	83.7 - 90.7	Upward
		BH29 (Nam)		Feb. 2018 to Feb 2022	96.07	100.56		65.2 - 67.5	
		BH30 (LO)							
		BH24 (Nam)	< 58.05	Feb. 2018 to Feb 2022	98.11	102.51	> 40	58.1 – 65.1	-

*# Unit refers to the geological unit of the borehole response zone where LO denotes Loughshinny Formation aquifer and Nam denotes Namurian bedrock aquifer; ~ Dataset start date of before 2018 denotes Waste Licence monitoring Dataset; * Denotes minimum groundwater level affected by pumping test.*

4.4.7 Hydraulic Properties

The hydraulic properties of groundwater bearing strata has been determined from two pump tests that have been undertaken on the site:

- A pumping test undertaken by Arup on behalf of MEHL in June 2010 - Test pumping of borehole BH17 that comprised: a 180-minute step drawdown test ('Step Test') undertaken on the 31st May 2010; a 48-hour Constant Rate Test (CRT) that commenced on 8th June 2010 and subsequent recovery test following the cessation of the CRT; and
- A pumping test undertaken by CDM Smith on behalf of IMS in 2018 as described in the Groundwater Level Monitoring and Aquifer Test Report provided in **Appendix C** - Test pumping of a new Trial Well TW (BH32) installed in the Loughshinny Formation at a central location on the IMS facility.

The summary of the pumping test undertaken by Arup in 2010 is provided in **Appendix D**. This summary formed an Appendix A14.6 of the Environmental Impact Statement for Chapter 14 produced by Arup in 2010 (2010a). Although the results of the 2010 pumping test have been reviewed, this hydrogeological assessment has placed reliance on the most recent pumping test undertaken by CDM Smith in 2018 as the results of the original test were compromised by the following and generally rejected by the EPA at that time:

- The pumped well (BH17) was open to, and pumped from, both the Namurian bedrock and the Loughshinny Formation and could not therefore provide the necessary information on the degree of hydraulic connection or isolation between the Namurian bedrock and the Loughshinny Formation on the site;
- The duration of the Constant Rate Test (CRT) in 2010 was insufficiently long to reliably evaluate the behaviour of the system and derive aquifer parameters; and
- Limited observation network available on the IMS facility at the time of the original pumping test.

The 2018 aquifer test involved pumping trial well BH32 that was completed solely with the limestones of the Loughshinny Formation and the monitoring of an extensive network of observation wells in both the Loughshinny Formation and Namurian bedrock.

4.4.7.1 2018 Aquifer Test (BH32)

The 2018 aquifer test involved:

- A pre-test trial to determine the likely pumping rate that the BH32 could sustain;
- A 4-stage Step Test undertaken on 19th November 2018 that consisted of four 90-minute steps of pumping rates 172.8 m^3/d, 267.8 m^3/d, 345.6 m^3/d and 527.0 m^3/d;
- A 13-day Constant Rate Test (CRT) undertaken between 10:00am on 20th November 2018 and 10:30am on 3rd December 2018 during which the BH32 was pumped at a rate of 6.13 l/s (equivalent to c. 530 m^3/day); and
- The subsequent recover test following cessation of pumping for the CRT.

The monitoring network used in the pumping test is summarised in **Table 4-3**.

Table 4-3 Details of Observation Boreholes Monitored for CRT in 2018

Borehole Reference	Geological Unit	Radial Distance from BH32	Construction Details		Ground Level / Datum Elevation	Borehole Response Zone as Defined by Open hole or Gravel Pack			Elevation of Contact Between Loughshinny Formation and Namurian		Depth of Namurian Bedrock Identified in Borehole	
		(m)	Source	Date	(mOD)	(mbgl)	(mOD)	Length (m)	(mbgl)	(mOD)	(mbgl)	(mOD)
BH10A	Loughshinny Formation	554.2	Golders Associates	05/03/07	137.1	39-68	98.1-69.1	29	21	116.1	21	116.1
BH15A		280.3	Arup	16-22/04/10	105.9	25-30	80.9-75.9	5	23	82.9	23	82.9
BH18		213.9	Arup	10-24/04/10	110.5	15-21	95.5-89.5	6	15.2	95.3	15.2	95.3
BH25		294.6	Arup	21-22/05/13	105.4	18-25	87.4-80.4	7	Loughshinny Formation present at ground level		-	-
BH30		85.5	Arup	05/06/13	124.2	56.7-59	67.5-65.2	2.3	-		-	-
BH32 (TW)		**0.0**	**CDM Smith**	**11/18**	**105.0**	**56-61**	**49.0-44.0**	**5**	**45**	**60.0**	**45**	**60**
TW10 (offsite)		2421.1	-	1993	-	-	-	-	-	-	-	-
BH08	Loughshinny Formation & Namurian Bedrock	415.8	-	17/08/01	-	-	-	-	-	-	-	-
BH14		479.9	Golders Associates	02/03/07	125.1	23-38	87.1-102.1	15	30	95.1	30	95.1
BH17		142.9	Arup	05/05/10	105.4	22-54	83.4-51.4	32	33	72.4	33	72.41
BH05	Namurian Bedrock	239.6	Glovers SI Ltd	03/09/98	118.2	25-35	93.2-83.2	10	-	-	>35	< 83.2
BH08A		412.0	Glovers SI Ltd	17/08/2001	136.7	13 - 27	109.7-123.7	14	-	-	>27	<109.7
BH09		374.3	Glovers SI Ltd	03/08/2001	128.9	42 - 50	86.9-78.9	8	-	-	>50	-
BH11A		259.9	Golders Associates	02/05/2007	100.0	19 - 30	81.0-70.0	11	-	-	>30	-
BH19		50.1	Arup	21-22/04/10	105.1	13 - 18	92.1-87.1	5	-	-	>18	-

Borehole Reference	Geological Unit	Radial Distance from BH32	Construction Details		Ground Level / Datum Elevation	Borehole Response Zone as Defined by Open hole or Gravel Pack			Elevation of Contact Between Loughshinny Formation and Namurian		Depth of Namurian Bedrock Identified in Borehole	
		(m)	Source	Date	(mOD)	(mbgl)	(mOD)	Length (m)	(mbgl)	(mOD)	(mbgl)	(mOD)
BH20		31.1	Arup	22-27/04/10	104.8	37 - 43	67.8-61.8	6	43	61.8	43	61.84 (Possible contact)
BH24		117.9	Arup	10/06/2013	106.3	41.20 - 48.2	65.1 58.1	7	-	-	>48.2	-
BH26		25.6	Arup	28/05/2013	105.2	18 - 24	87.2-81.2	5	-	-	> 24	-
BH27		163.7	Arup	24-26/05/13	107.0	8 - 14	99.0 - 93.0	6	-	-	>14	-
BH28		199.6	Arup	22/05/13	125.9	34 - 40	91.9 - 85.9	6	-	-	>34	-
BH29		100.3	Arup	29/05/13	123.7	33 - 40	90.7 - 83.7	7	-	-	>40	-
BH31 New offsite Monitoring Well (MW)		1300.9	CDM Smith	30/10 to 2/11/18	128.9	40 - 124	88.9 - 4.9	84	-	-	>124	32.36
TW07 (Offsite)		1326.3	-	1993	-	-	-	-	-	-	-	-

A detailed description of borehole BH32 including geological log, is provided in the technical report in **Appendix C**.

BH32 was drilled to a total depth of 66 mbgl, although it collapsed back to 61 mbgl. Solid well-casing and grouting was successfully installed to a depth of 56 mbgl, within the Loughshinny Formation. The construction of the TW therefore isolates the entire sequence of Namurian strata, giving the TW a 5-metre open section (response zone) across the Loughshinny Formation between 44.0 mOD to 49.0 mOD. The interface between the Loughshinny Formation and Namurian bedrock is located at 60.0 mOD (i.e. 45 mbgl), approximately 11 m above the top of the response zone within the Loughshinny Formation. This represents the lowest elevation for that interface identified on the IMS facility.

During the drilling of BH32, it was noted that both the Namurian bedrock and Loughshinny Formation were extensively fractured throughout. This is consistent with observations made at outcrop within the quarry and observations made during the drilling of other boreholes on the IMS facility (most notably the cored boreholes drilled in 2010 and 2013).

The groundwater level observed in BH32 immediately before the CRT commenced was 100.2 mOD, approximately 40 m above the elevation of the inferred contact between the Loughshinny Formation and Namurian bedrock.

A total of 20 onsite observation wells, including BH32, were monitored during the aquifer test using a combination of automatic data loggers and manual dips.

The water levels in the main quarry pond located in the southwest of the quarry and small attenuation pond in the southern and northern region of the quarry, respectively, were also monitored.

The new offsite monitoring well BH31 was monitored during the pumping test.

The corresponding groundwater level dataset for offsite EPA observation wells near the Bog of the Ring wellfield was obtained and reviewed. Additionally, groundwater level measurements were taken by CDM Smith at the two offsite observation boreholes TW07 and TW10.

4.4.7.1.1 Observations during the CRT

Aquifer Response

The principal observations from the CRT include:

- Boreholes BH05, BH17, BH18, BH19, BH20, BH25, BH26, BH27, BH28, BH29 and BH30 all respond to the pumping of TW. These boreholes are constructed in both the Namurian bedrock and Loughshinny Formation and are located in central and northern areas of the former quarry;
- The central and northern boreholes are characterised by comparable response to pumping and drawdown;
- A rapid development of significant pumping related drawdown area observed in boreholes completed in Namurian strata in central and northern parts of the former quarry despite the high elevation of their response zones relative to open section of the pumped test well (BH32) within Loughshinny Formation;
- The largest pumping-related drawdowns observed during the CRT extend to the north of test well (BH32) and are most notable in borehole BH24 and BH05, the latter being located close to the northern boundary of the IMS facility. This is consistent with a cone of depression developed in both the Namurian bedrock and Loughshinny Formation around the pumped test well (BH32) that principally extends to the north;
- Pumping related drawdowns rapidly decline to the south towards the former main quarry pond in southeast corner of the IMS facility acting as a barrier to drawdown, where natural hydraulic gradients orientated to the southeast are maintained throughout the CRT; and
- No pumping related drawdowns were observed in the new offsite monitoring well BH31.

Unlike the interpretation of the CRT undertaken in 2010 (see **Section 4.4.7.2**) the results for the CRT test undertaken in 2018 do not require reliance on the distribution of inferred discrete faulting across the IMS facility as a key controlling factor defining the spatial development of drawdowns across the site. This conclusion is based on the following observations:

- The storage effect of the main quarry pond present in the southwest corner of the IMS facility, exerts a strong control on aquifer response in the south of the quarry and can account for the limited development of the cone of depression to the south (most notably in BH15, BH18 and BH27);
- A similar drawdown response as seen in BH19 is observed in borehole BH30 and BH29 on opposite sides of the main fault thought to bisect the site, hence the absence of any barrier effects; and
- The observation of small, but very similar, drawdowns in both the Namurian bedrock and the Loughshinny Formation, despite the response zone of the test well (BH32) being located at significant depth in the Loughshinny Formation. This attests to the absence of significant hydraulic separation between these two saturated bedrock units as a consequence of the shared, extensive fracture networks.

It can therefore be concluded from the results of the CRT in 2018 that the extensively fractured nature of Carboniferous bedrock, has developed in the development of widespread enhanced permeability that provide reliable estimates of aquifer parameters for the IMS facility.

Vertical Hydraulic Gradient between Formations

Vertical hydraulic gradients during the CRT can be evaluated form the data presented in **Table 4-1**. That dataset demonstrates that in the vicinity of the Test Well (borehole BH32) a downward vertical gradient was generated in all units, oriented from shallow Namurian bedrock to the response zone in Loughshinny Formation of the Test Well. This was not however seen at greater distance from the test well in Group 2.

Main Quarry Pond Boundary Effects

Rainfall and runoff during the latter part of the CRT resulted in a small increase in water level with the main quarry pond and northern attenuation pond. A total rise in the level of the main pond of c. 0.2 m was observed over the duration of the CRT. As the water level in the main quarry pond reflects the local groundwater level in the Loughshinny Formation aquifer, there was an observed recharge effect as follows:

- The increase in pond level observed after large recharge events most notably the initial large event on the 21st of November;
- Groundwater levels in borehole BH15A and BH25 respond initially to the CRT and then to the rain event induced pond level rise - both are situated in close proximity to the former pond with a response zone in the Loughshinny Formation; and
- The absence of pumping related drawdowns in boreholes located in the southern area of the site.

4.4.7.1.2 Hydraulic Properties

As described in the Groundwater Level Monitoring and Aquifer Test Report (**Appendix C**) the drawdown dataset for the CRT was analysed principally using Theis solution for unconfined aquifers. All boreholes were analysed using the Theis method with the exception of two boreholes (BH26 and BH32) that were analysed using the Neuman solution for an unconfined aquifer characterised by delayed yield. The aquifer parameters derived from the CRT are reproduced in **Table 4-4.**

Table 4-4 Hydraulic Properties Derived from Wells that Responded to the Aquifer Test

Well	Formation	Test	Transmissvity, T (m^2/d)	Storativity	Comment
BH32	Loughshinny Formation	Step Drawdown	219.4	Not Applicable for Pumped Well	Neuman solution yielded good curve fit for T of 173.2 m^2/d
BH32	Loughshinny Formation	CRT	181.7 (C-J) 539.0 (Theis)	Not Applicable for Pumped Well	As above
BH30	Loughshinny Formation	CRT	260.4 (C-J) 225.3 (Theis)	3.34×10^{-3} (C-J) 3.98×10^{-3} (Theis)	-
BH5	Namurian	CRT	193.7 (C-J) 164.8 (Theis)	2.78×10^{-5} (C-J) 5.72×10^{-5} (Theis)	-

Well	Formation	Test	Transmissvity, T (m^2/d)	Storativity	Comment
BH19	Namurian	CRT	241.1 (C-J) 189.4 (Theis)	5.6 x 10^{-3} (C-J) 7.9 x 10^{-3} (Theis)	-
BH20	Namurian	CRT	207.5 (C-J) 165.3 (Theis)	1.68 x 10^{-4} (C-J) 1.00 x 10^{-3} (Theis)	-
BH24	Namurian	CRT	205.8 (C-J) 164.3 (Theis)	4.58 x 10^{-5} (C-J) 1.43 x 10^{-5} (Theis)	-
BH26	Namurian	CRT	308.0 (C-J) 183.6 (Theis)	1.10 x 10^{-3} (C-J) 8.49 x 10^{-3} (Theis)	Neuman solution yielded good curve fit for T of 51.1 m^2/d
BH27	Namurian	CRT	321.1 (C-J) 160.7 (Theis)	3.08 x 10^{-3} (C-J) 7.01 x 10^{-3} (Theis)	-
BH29	Namurian	CRT	258.4 (C-J) 250.8 (Theis)	2.3 x 10^{-3} (C-J) 2.18 x 10^{-3} (Theis)	-
BH17	Namuiran bedrock and Loughshinny Formation	CRT	408.5 (Theis)	2.34 x 10^{-4} (Theis)	Sensitive to Aquifer Thickness

In summary, the Theis solution provided an estimate of transmissivity that ranged from 160 to 539 m^2/day, with an average of 245 m^2/day. A Neuman solution for BH26 and BH32, provided an estimated T value that ranges from 51 to 409 m^2/d, with an average of 195 m^2/d.

Estimated storativity values range from 1.34 x 10^{-5} to 8.49 x 10^{-3} with a geometric mean of 7.53 x 10^{-4}. These values are consistent with the low storage expected in fractured bedrock media behaving as an unconfined / semi-confined system.

4.4.7.2 2010 Aquifer Pumping Test (BH19)

A summary of the pumping test and associated analysis undertaken by Arup on behalf of MEHL in June 2010 is provided in **Appendix D**. Despite this test not being undertaken to ideal standards, as identified by the hydrogeological specialists who reviewed the test on behalf of the EPA (Geosyntec, 2014), some observations do merit inclusion in this hydrogeological assessment.

During the 48-hour CRT performed on BH17, that commenced on the 8th of June 2010, groundwater levels were monitored in 15 onsite observation boreholes that included:

- Six boreholes completed in the Loughshinny Formation, namely BH12, BH4a, BH10A, BH14, BH15a and BH18; and
- Nine boreholes completed within Namurian strata, namely BH5, BH6, BH8a, BH9, BH11a, BH13, BH16, BH19 and BH20.

The notable feature of the pumping test in 2010 was the fact that the test well, BH17, was completed with a response zone situated in both the Loughshinny Formation and the overlying Namurian strata and its short duration. The test well construction prevented the pumping test form determining the hydraulic relationship between the key saturated aquifer units present on the site, regardless of the duration of the pumping test.

During the CRT, pumping related drawdowns were observed in ten observation boreholes. As with the CRT undertaken in 2018, significant drawdown was observed in observation boreholes completed in both the Loughshinny Formation and the Namurian bedrock. The results of the 2010 CRT clearly show the development of a cone of depression around BH17 that extends to the north / northeast, with corrected maximum drawdowns of above 0.6 m recorded in BH18, BH20, BH16 and BH05. Smaller drawdowns were observed at similar radial distances to the east and south (i.e. Borehole BH15a and BH19, respectively).

A pumping related drawdown was absent from three boreholes completed in the Loughshinny Formation (BH12, BH4a and BH14) and two boreholes completed in Namurian strata (BH6 and BH13). The boreholes that did not show any pumping related drawdown were all located at the greatest radial distance from the test well, BH17, of between 389 m and 521 m. On the basis of the corrected drawdowns a reasonable cone of depression was defined across much of the IMS facility including in the south.

Interpretation of the distance-drawdown response observed in 2010 placed significant emphasis of the position of observations wells relative to the discrete faults inferred from the results of geophysics (See **Appendix D**). Arup concluded that:

> '*the distance-drawdown analysis has demonstrated that the north-south fault is acting as a partial barrier to groundwater flow and the east-west trending fault does not act as a barrier to flow*'

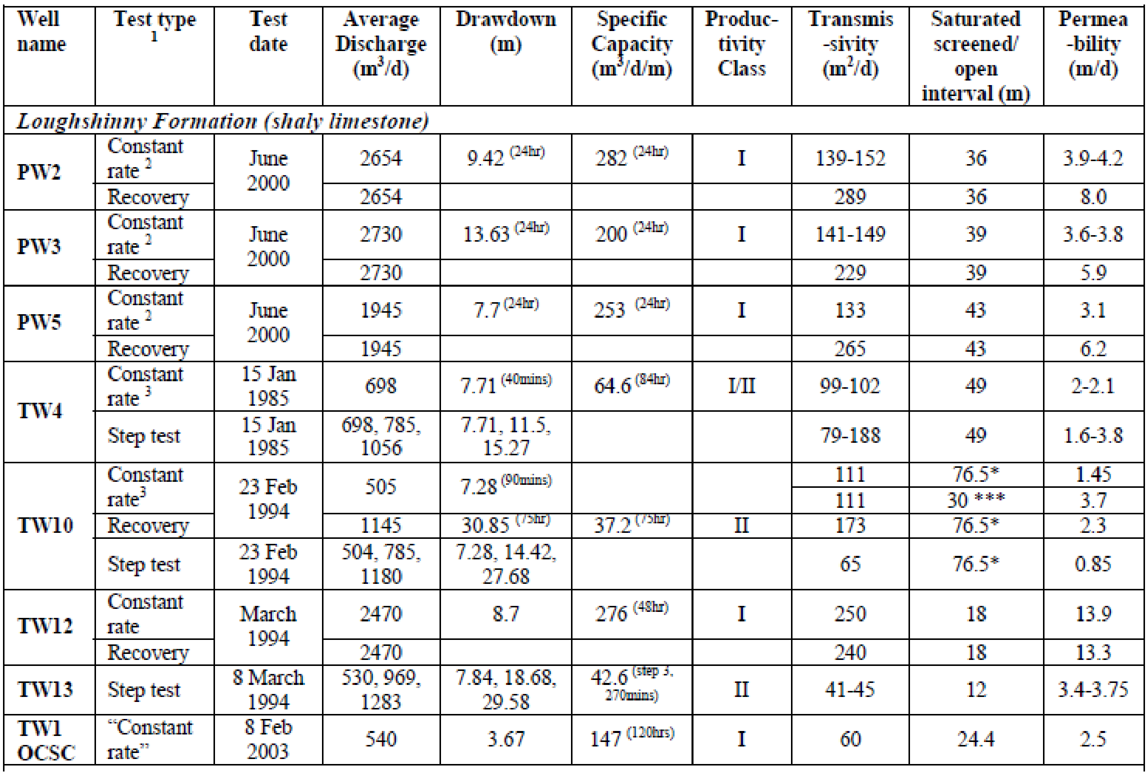
Although it can be argued that the principal north-northeast trending fault could be limiting drawdown development to the east of that fault, it is felt that in general the influence of this fault is given too much weight, particularly when considered in the light of the drawdown response observed during the 2018 CRT. It is felt that the observed distance-drawdown response in 2010 can reasonably considered in terms of widespread permeability enhancement most notably to the in the northern half of the site.

The time-drawdown response for each of observation borehole that demonstrated a significant pumping related drawdown was reviewed by Arup (**Appendix D**). It was thought that as the seven boreholes subject to review were all situated within '*in a fracture zone*' the time-drawdown relationships were best interpreted as indicative of '*confined, densely fractured, consolidated aquifer of the double-porosity (fracture and matrix block) type (Kruseman and deRidder, 2000)*'. However, it is notable that the theoretical curve for such an aquifer body is not distinguishable from the type curve for a simple unconfined aquifer, both being characterised by delayed yield response. Regardless of the conceptual interpretation of the system, the drawdown data was analysed using the analytical solutions of Theis and Cooper-Jacob.

The resulting aquifer hydraulic properties determined for the site are presented in the report in **Appendix D**. However, these results are not reproduced here owing to the severe limitation associated with the pumping test and the reliance placed on the recent pumping test. That said, the derived parameters from the 2010 CRT are broadly consistent with the results presented for the 2018 CRT.

4.4.7.3 Aquifer Test Results for the Bog of the Ring Wellfield

Hydraulic parameters for the Loughshinny Formation are discussed within the Bog of the Ring Groundwater Source Protection Zones project (GSI, 2005). That report states that '*within the Loughshinny and Mullaghfin Formations, transmissivities and permeabilities calculated from 24- to 72-hour constant rate pumping tests, and from step tests, range from 23-290 m^2/d and 0.65-13.9 m/d, respectively*'. In that report the GSI presents the following summary table of derived hydraulic parameters:



Well name	**Test type** [1]	**Test date**	**Average Discharge (m^3/d)**	**Drawdown (m)**	**Specific Capacity (m^3/d/m)**	**Produc-tivity Class**	**Transmis-sivity (m^2/d)**	**Saturated screened/ open interval (m)**	**Permea-bility (m/d)**
Loughshinny Formation (shaly limestone)									
PW2	Constant rate [2]	June 2000	2654	9.42 $^{(24hr)}$	282 $^{(24hr)}$	I	139-152	36	3.9-4.2
	Recovery		2654				289	36	8.0
PW3	Constant rate [2]	June 2000	2730	13.63 $^{(24hr)}$	200 $^{(24hr)}$	I	141-149	39	3.6-3.8
	Recovery		2730				229	39	5.9
PW5	Constant rate [2]	June 2000	1945	7.7 $^{(24hr)}$	253 $^{(24hr)}$	I	133	43	3.1
	Recovery		1945				265	43	6.2
TW4	Constant rate [3]	15 Jan 1985	698	7.71 $^{(40mins)}$	64.6 $^{(84hr)}$	I/II	99-102	49	2-2.1
	Step test	15 Jan 1985	698, 785, 1056	7.71, 11.5, 15.27			79-188	49	1.6-3.8
TW10	Constant rate[3]	23 Feb 1994	505	7.28 $^{(90mins)}$			111	76.5*	1.45
							111	30 ***	3.7
	Recovery		1145	30.85 $^{(75hr)}$	37.2 $^{(75hr)}$	II	173	76.5*	2.3
	Step test	23 Feb 1994	504, 785, 1180	7.28, 14.42, 27.68			65	76.5*	0.85
TW12	Constant rate	March 1994	2470	8.7	276 $^{(48hr)}$	I	250	18	13.9
	Recovery		2470				240	18	13.3
TW13	Step test	8 March 1994	530, 969, 1283	7.84, 18.68, 29.58	42.6 $^{(step 3, 270mins)}$	II	41-45	12	3.4-3.75
TW1 OCSC	"Constant rate"	8 Feb 2003	540	3.67	147 $^{(120hrs)}$	I	60	24.4	2.5

The results for the main production wells (PW) are broadly similar to the transmissivities derived from CRT undertaken on the IMS facility in 2018.

4.5 Site Hydrology

4.5.1 Surface Water Bodies

Surface water bodies present on and near the IMS facility are shown in **Figure 5**. The quarry pond was infilled in late 2019 and early 2020.

The hydrology of the study area is defined by south-easterly flowing streams that drains away from the Nag's Head – Knockbrack high ground to eventually discharge to either the Rogerstown Estuary located c. 9 km to the east-southeast of the IMS facility or to the coast at Balbriggan to the north. Three streams are of relevance to the study area, notably three headwater streams of the Ballough Stream (EPA Waterbody code IE_EA_08B031500). As shown in **Figure 5**, from south to north the related tributaries are:

- The Knightstown Branch of Ballough Stream (EPA Section 08_22) situated immediately to the south of the southern boundary of the IMS facility that drains to the east-southeast, away from Nag's Head to the Ballough Stream;
- The Tooman Branch of the Ballough Stream (EPA Section 08_205) that forms the northern boundary of the IMS facility and flows east-southeast to the Ballough Stream (This watercourse is referred to as the 'northern boundary stream' hereinafter but has been referred to as Bedaragh/Walshestown Stream in historical reporting);
- The small unnamed branch of Ballough Stream (EPA Section 08_377) situated 0.7 km north of the IMS facility that flows to the east-southeast, from the eastern flank of Knockbrack Hill, to the Ballough Stream.

The three branches of the Ballough Stream are situated in Water Framework Directivesub-catchment 08_6 (Ballough Stream) that forms part of the Nanny-Delvin Water Framework Directive (WFD) catchment (IEES_08).

Further to the south, drainage is dominated by another branch of the Ballough Stream and the Ballyboghil Stream, both of which drain to the east.

4.5.2 Surface Water Monitoring

The location of surface water monitoring points is shown in **Figure 20** and includes:

- Seven water quality monitoring stations (SW01-SW07), in compliance with Condition 6 and Schedule C or Waste Licence Reg. W0129-02; and
- Two streamflow locations on the watercourse that forms the northern site boundary of the IMS facility that were measured by CDM Smith in February 2019 (V1/S1 and V2/S2).

The ponds present on the IMS facility have historically been monitored, most recently during the extended pumping test undertaken in 2018.

Water quality in the northern boundary stream is monitored on a 6-monthly basis as a requirement of the Waste Licence at the two locations shown in **Figure 20** (SW01 and SW02). The surface water dataset collected over the period of 2014 to 2022 is provided with other Waste Licence monitoring datasets in **Appendix F.**

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Notes

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Legend

🟥 IMS Facility
🟩 Waste Licence Boundary
— Rivers

Waste Licence Monitoring Points

⬟ Emission Monitoring Point
▲ Leachate Monitoring Point
● Surface Water Monitoring Point

CDM Smith Surface Water Monitoring Locations (2018/2019)

● River Level Monitoring Point
▲ V-Notch Weir

Rev	Description	By	CB	Date

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Client Integrated Material Solutions (IMS)

Project Hollywood Great

Title Surface Water and Other Waste Licence Monitoring

Status	Drawn By	PM/Checked By
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Project Number	Scale @ A3	Date Created
JER1631	1:4,000	MAR 2020

Drawing Number
Figure 20

Rev
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4.5.3 Surface Water Level and Flow

4.5.3.1 Northern Boundary Stream (Tooman Branch of the Ballough Stream)

The Tooman Branch of the Ballough Stream is situated in an incised channel that forms the northern boundary of the IMS facility. The general elevation along the watercourse declines from 112.1 mOD at its upstream end in the north-western corner to of the site, to 88.3 mOD at the downstream corner of the site (c. 750m east). This implies a gradient for this section of the upland / headwater stream of 0.03.

The surface water level and flow within the northern boundary stream were monitored in February 2019 by CDM Smith (2019) at the two v-notch weirs (V1 and V2) and level monitoring points (S1 and S2) shown in **Figure 20**. The purpose was to gain a better understanding of flow rates and responses to rainfall, and to examine if the stream is likely receiving groundwater baseflow. V1/S1 represent the downstream monitoring point whereas V2/S2 represents the upstream monitoring point. The upstream and downstream bed levels at the two v-notch weirs were 105.2 mOD and 93.5 mOD, respectively, with a drop of 11.7 m over a horizontal distance of c. 340 m.

Flow in the northern boundary stream is flashy, responding quickly to rainfall events. Over the streamflow monitoring period, measured flows ranged from 0.4 l/s to 5.79 l/s, with a geometric mean of 2.0 l/s (equivalent to c. 173 m^3/d). The data also indicated that flow is gaining downstream at times of low flow (i.e. no contributions of surface runoff). This implies a groundwater baseflow contribution from the underlying Namurian bedrock which is exposed along the stream bottom (CDM Smith, 2020).

The flow data is consistent with some baseflow (i.e. groundwater – surface water interaction) along the northern boundary stream.

4.5.3.2 Other Surface Watercourses

There are no EPA Hydrometric Gauges associated with the principal watercourses within the Study Area identified above. Two gauging station are situated on watercourse relevant to the study area. These stations are listed below, and both appear to be located on the Ballough Stream:

- Station RS08B031400: Ballough Stream (Br W of the Five Rds) [IE_EA_08B031500] Easting - 318275.44; Northing - 257083.78; and
- Station RS08W130800: which stream? (Br S of Damastown Ho.) [IE_EA_08B031600] Easting - 313923.42; Northing - 257653.57.

4.6 Groundwater – Surface Water Interaction

The northern boundary stream is inferred to receive groundwater baseflow from the Namurian bedrock. As such, the northern boundary stream boundary is likely to constitute a surface water receptor.

This groundwater – surface water interaction to the east of the site down hydraulic gradient, has implications for potential migration of landfill leachate derived pollutants that may enter the water environment unless sufficiently controlled by landfill engineering and leachate management. This potential pollutant linkage is addressed in the accompanying LandSim analysis presented as part of this application.

4.7 Hydraulic Connection to the Bog of the Ring

As described, the IMS facility is situated in a different groundwater catchment than the BOTR wellfield. Groundwater heads at the IMS facility and BOTR are significantly different, by up to 80 m under non-pumping condition at the wellfield. Monitoring wells at the IMS facility do not show a pumping influence and did not respond to the abstraction outage that reduced total pumping from the wellfield and caused groundwater levels to recover locally around the wellfield in the summer of 2018.

Notwithstanding the physical separation, groundwater catchment divide, and difference in heads, hydrogeological evidence has been gathered to conclude that groundwater levels at the IMS facility will not be affected by a scenario in which abstraction at the BOTR wellfield ceases.

5 UPDATED CONCEPTUAL HYDROGEOLOGICAL MODEL

5.1 SPR Model of Environmental Risk assessment

This section provides an updated conceptual hydrogeological model of the IMS facility in context of the planned development and the Source – Pathway – Receptor (SPR) linkages associated with the landfilling of inert and non-hazardous waste at the IMS facility.

5.1.1 Sources

The proposed development involves diversifying the existing inert waste activity to include non-hazardous waste activity on the IMS facility for a period of 25 years. This overview assessment considers the initial construction phase and the ongoing operational phase of the IMS facility.

5.1.1.1 Construction Phase

The limited construction phase (construction of an attenuation pond and leachate storage area only) does have the potential to affect soils, geology and hydrogeology, this includes the accidental emissions and release of potentially hazardous substances during construction that may affect the quality of groundwater and/or soils, most notably associated with cement, concrete materials, temporary oils and fuel particularly where below ground excavations are required.

There is a potential for short-term effects on groundwater quality through the infiltration of surface run-off within or adjacent to construction areas.

It is not planned or anticipated that any of the construction activities will directly intercept groundwater in the aquifer units identified on the site, thereby having a direct effect on the groundwater flow regime in the aquifer units underlying the site.

5.1.1.2 Operational Phase

The operational phase of the proposed development involves the continuation of infilling using a diversified waste stream and restoration of the former quarry with a mix of wastes at a rate not exceeding 500,000 tonnes per annum.

Potential impact on groundwater quality during active infilling through the infiltration of runoff and/or leachate collecting within the waste mass within active cells as a consequence of the time duration extension of active filling. Leachate will be produced where rainwater percolates through the waste (such as an active cell or an uncapped cell), picking up suspended and soluble materials that originate from products of the degradation of waste. The wastes to be landfilled at the Hollywood site will generate leachate and this leachate is controlled by means of a basal liner (to prevent a pathway to ground) and active pumping to a designated collection area with no discharges.

There is potential for increased risk of longer-term localised effect compared to the current licensed operation on the quality of soil and potentially groundwater through the accidental release of hazardous materials, most notably non-waste hazardous substances such as fuels and oils associated with areas of parking, vehicular movements around the site and/or refuelling activities.

5.1.2 Pathways

The environmental pathways associated with the IMS facility are outlined in this section.

Natural groundwater flow is divided in to a southern (i.e. the catchment associated with the site) and northern (i.e. the BOTR groundwater catchment) catchment. In the southern catchment groundwater flow is orientated to the east in the Loughshinny Formation aquifer unit. The Loughshinny Formation Lm aquifer is present at the quarry floor in the southwest of the former quarry (**Figure 6**). Groundwater flows southeast in the saturated Namurian bedrock aquifer. Groundwater flow is orientated towards the valley of the Ballough Stream that flows to the southwards, ultimately discharging to Rogerstown Estuary in the southeast, it is established that the Rogerstown Estuary European Site has direct hydrological connectivity to the Ballough Stream.

Streams in the vicinity of the IMS facility (including the northern boundary stream) likely receive baseflow from the underlying aquifer units (predominantly Namurian bedrock in the study area). At times of prolonged dry weather periods, the headwater streams may become hydraulically disconnected from low groundwater levels.

The Namurian bedrock and Loughshinny Formation both form aquifer units on the IMS facility. These aquifers are characterised by a high degree of hydraulic continuity imparted by a dense fracture network that cuts across both the formations. The combined Namurian bedrock and Loughshinny Formation on the IMS facility can be considered a hydraulically continuous, multi-layered, unconfined aquifer system.

The IMS facility is situated in a recharge area. As such vertical hydraulic gradients in the Namurian bedrock aquifer are mainly downwards.

During active landfilling and during the management period following capping, any leachate that is generated from non-hazardous cells will be collected from the lined landfill and pumped to storage tanks for collection. For inert cells, following the management period, leachate levels will rise to depths that equilibrates infiltration through the capping and leachate leakage through the cell bases. Accordingly, a reduction and then partial restoration of recharge to the underlying strata will occur.

Increases in surface run-off will be created by the cell capping. This will be managed on site and directed via the attenuation pond to the surface watercourses.

5.1.3 Receptors

The potential environmental receptors associated with the IMS facility are outlined in this section.

Groundwater underlying the site within the locally important bedrock aquifer (Lm) of the Loughshinny Formation is not located in a Source Protection Zone. Groundwater within the Namurian bedrock sequence is also a potential environmental receptor. Leachate leaking from site landfill cells will be diluted within a mixing zone within the saturated strata prior to advection off site. Potential pollutants within leachate will thus be diluted and dispersed within groundwater down hydraulic gradient within acceptable concentration limits. This will be demonstrated by a numerical hydrogeological risk assessment for the site.

The soils to the east of the site are moderately drained and/or moderate fertility soils overlying sub-economic extractable mineral resources (i.e. excess overburden, above the Namurian strata which is no longer commercially quarried at the site).

The Bog of the Ring wellfield and groundwater dependent wetland site c. 3 km northeast of the facility that provides locally important potable water source to >1000 homes (< 2500 homes). This well field has been shown to be outside the groundwater catchment for the landfill and therefore beyond possible hydraulic influence. It can therefore be discounted as receptor for the site.

Northern boundary stream: Groundwater level data indicates that the northern boundary stream is likely to be in continuity with the groundwater contained in the underlying strata for much of the time. At times of regional groundwater low, this may not be the case, with the extreme upstream end of the watercourse likely to be perched above underlying groundwater. A similar surface-groundwater relationship is expected for the northern boundary stream is expected for the other easterly flowing streams identified to the north and south of that watercourse.

Private groundwater abstraction wells are a potential receptor to the proposed work at the IMS facility. There are active groundwater abstractions situated down-hydraulic gradient from the IMS facility with the nearest well situated c. 0.7km to the east.

5.1.4 Sites of Environmental Sensitivity

There are no sites of environmental sensitivity in the immediate vicinity of the IMS facility.

The nearest site of environmental sensitivity is the Bog of the Ring, approximately 2.5 km to the northeast of the IMS facility and in a different surface water catchment than the IMS facility. In the Fingal County Development Plan (2005 – 2011), the BOTR is proposed as a National Heritage Area (NHA) under Local Objective HO34 (Site Code: 001204). The site synopsis states the site '*is a flat low-lying area with impeded drainage, showing signs of peat development in its upper horizons. The site was drained about thirty years ago, but still contains pockets of wet and damp ground where marsh vegetation occurs*' and '*marshes are* *few in County Dublin and therefore the site is of interest*'. As described above for the BOTR well field, this site can forthwith be discounted as a receptor for the site.

Rogerstown Estuary Special Area of Conservation (SAC) No. 000208: The site is designated on the basis of habitats including [1130] Estuaries; [1140] Tidal Mudflats and Sandflats; [1310] Salicornia Mud; [1330] Atlantic Salt Meadows; [1410] Mediterranean Salt Meadows; [2120] Marram Dunes (White Dunes); [2130] Fixed Dunes (Grey Dunes)*. These features would only be deemed viable receptors should their surface water quality be adversely affected by leachate impacted groundwater flowing from beneath the proposed landfill.

Although a sensitive receptor, the designated habitats on Rogerstown Estuary SAC are estuarine in nature and not strongly dependent on the regional hydrogeological characteristics of its catchment.

5.2 Summary of Site-Specific SPR Risk Factors

The sources, pathways and receptors assessed in this section are displayed in Error! Reference source not found. and **Figure 21.** using the cross sections outlined in **Section 3.5.3**.

On the basis of hydrogeological review provided in **Appendix H**, the key elements of the hydrogeological conceptual model developed for the study area and the supporting lines of evidence are summarised in Error! Reference source not found. and **Figure 21**.

Table 5-1 Updated Conceptual Hydrogeological Model

Ref.	Aspect of Hydrogeological Model	Key Lines of Supporting Evidence
1.	Two groundwater catchment areas have been defined within the study area:	
	Southern Groundwater Catchment Area Situated to the south the Knockbrack Hill groundwater & surface water divide. Catchment includes the IMS facility and Fingal landfill project area c. 2km east thereof. Includes the Ballough Stream (that flows southward and ultimately discharging to the Rogerstown Estuary) and south-easterly flowing tributaries thereof. The regional geology and associated aquifer units are dominated by bedrock of the Loughshinny Formation and other underlying Carboniferous limestones, which is commonly overlain by quaternary glacial till deposits. The Namurian bedrock forms a saturated aquifer over the majority of the IMS facility with the exception of the southwestern corner, where limestones of the Loughshinny Formation are present at quarry surface (c. 105 mOD). *Northern Groundwater Catchment Area* Situated to the north of the Knockbrack Hill groundwater & surface water divide. Catchment includes the Bog of the Ring Wellfield, Bog of the Ring wetland and the Matt River and tributaries thereof (that flows northwards and discharge to the coast at Balbriggan). The regional geology is dominated by the syncline in the Carboniferous bedrock, resulting in more than 100 m of Namurian bedrock above the Loughshinny Formation beneath the Knockbrack Hill groundwater & surface water divide. The Loughshinny Formation rises back to the ground surface on the northern limb of the syncline at the Bog of the Ring wellfield and headwaters of the Matt River, where it is overlain by localised quaternary superficial deposits. Aquifer units in the northern catchment area are dominated by saturated in the highly fractured Namurian strata beneath and to the north of the Knockbrack Hill divide and the Loughshinny Formation and overlying superficial deposits around the Bog of the Ring wellfield.	Geological and groundwater level dataset for the new offsite monitoring well (borehole BH32) constructed in 2018, as presented in the regional hydrogeological cross section (**Figure 9**) and time-series groundwater levels in **Graph 1**. The groundwater levels for the onsite and offsite monitoring network collected as part of additional works undertaken in 2018 - 2022 and presented the regional hydrogeological cross section (**Figure 9**), time-series groundwater levels in **Graph 1** and summarised in the schematic regional groundwater contour plan provided in **Figure 13**. Regional geology presented in **Figure 9** and regional geological / hydrogeological cross section (**Figure 10**).
2.	Natural groundwater flow in the southern groundwater catchment, that includes the IMS facility, is orientated to the east in the Loughshinny Formation aquifer unit and southeast in the saturated Namurian bedrock aquifer. Groundwater flow is orientated towards the valley of the Ballough Stream that flows to the southwards, ultimately discharging to Rogerstown Estuary in the southeast.	The onsite groundwater dataset collected as part of additional works for IMS and presented in contour plans for the Loughshinny Formation and Namurian bedrock aquifer units in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith 2019) in **Appendix C.** Schematic regional groundwater contour plan provided in **Figure 10** and the regional hydrogeological cross section (**Figure 9**).

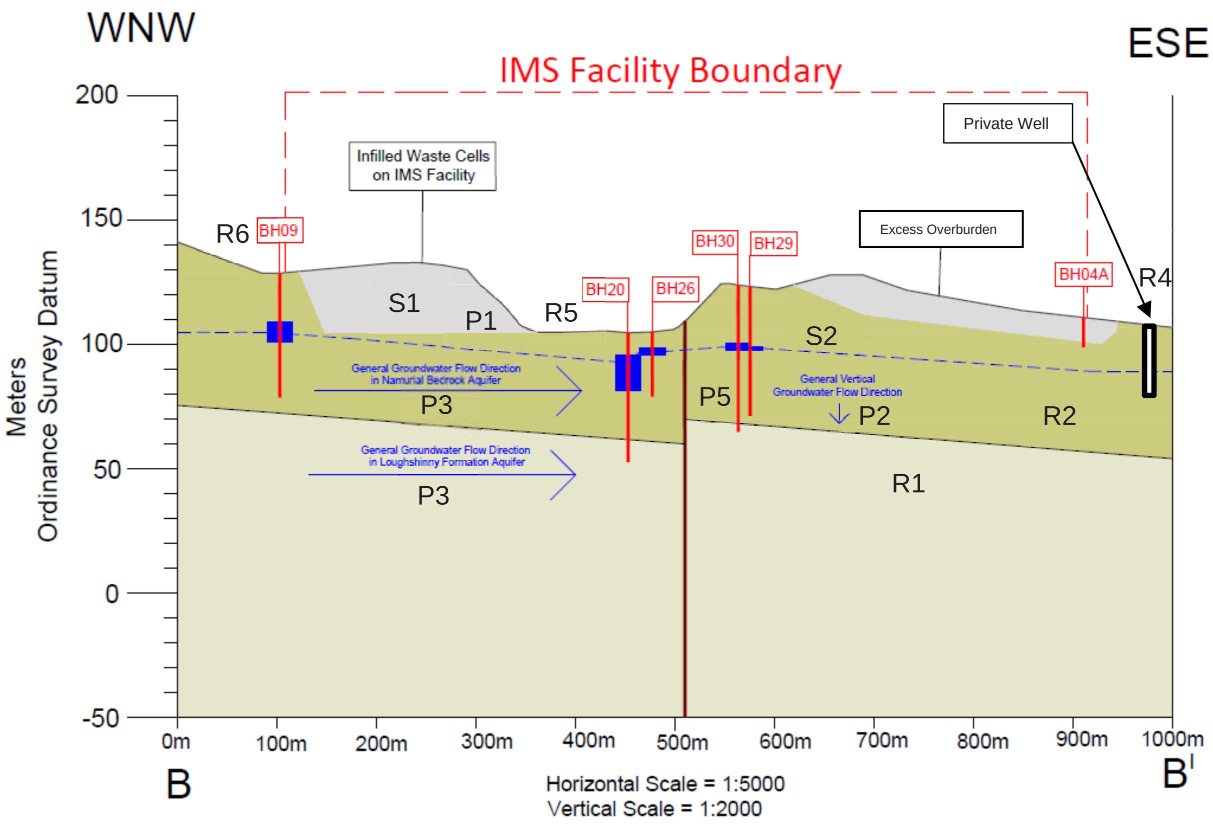
3.	Natural groundwater flow in the thick sequence of saturated Namurian bedrock aquifer beneath the Knockbrack Hill groundwater divide is orientated to the northeast, following declining topography towards the Bog of the Ring wellfield and headwater streams of the Matt River that flows northwards to Balbriggan. Natural groundwater flow around the Bog of the Ring wellfield is locally affected by abstraction, with radial flow in the Loughshinny Formation overlying Quaternary superficial deposits orientated towards the abstraction boreholes.	Groundwater level dataset for the new offsite monitoring well (borehole BH32) constructed in 2018, as presented in hydrogeological cross section **Figure 8** and groundwater levels in **Graph 1**. Schematic regional groundwater contours shown in **Figure 10** and regional hydrogeological cross section (**Figure 9**). Regional geology presented in **Figure 6** and regional geological / hydrogeological cross section (**Figure 9**).
4.	The easterly flowing surface watercourses in the vicinity of the IMS facility (including the northern boundary stream) typically receive baseflow from the underlying aquifer units (predominantly Namurian bedrock in the study area). At times of long-term low groundwater level, the headwater streams may become perched above groundwater in the underlying aquifer units.	The relative elevation of groundwater levels and stream bed elevations along the Northern Boundary Stream during the period of recent groundwater monitoring in 2018 - 2022 by CDM Smith. Long-term water level monitoring dataset gathered for Waste Licence and presented in **Graph 2**.
5.	The Namurian bedrock and Loughshinny Formation both form aquifer units on the IMS facility. These aquifers are characterised by a high degree of hydraulic continuity imparted by extensive weathering and fracturing of both the formations. The combined Namurian bedrock and Loughshinny Formation on the IMS facility can be considered a hydraulically continuous, multi-layered, aquifer. Groundwater flow is expected to occur throughout the aquifers where highly weathered, i.e. Namurian mudstones and shales and restricted where layers are more competent and less fractured, i.e. within the interbedded siltstones.	The rapid and very similar drawdown developed in both aquifer units as observed in the new pumping test pumping test described **Section 1.6.** The fact the regional geology suggests the IMS facility is likely to be located in zone of enhanced permeability relating regional geological (**Figure 6**), observations of onsite geology (**Conodate, 2009**) and results of geophysical investigations (**Arup, 2010**). The results of the pumping test undertaken in 2018 as described in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith 2019) in **Appendix C** and described in **Section 1.6.**
6.	The highly fractured nature of the Namurian bedrock aquifer present on the IMS facility can be represented by an equivalent porous medium (EPM) that share similar hydraulic properties (i.e. T and S). This confirms the Namurian bedrock can be considered as Poor Aquifer being situated in a wide '*local zone*' of enhanced fracture permeability development in accordance with its general hydrogeological designation, **P(l)**.	The uniform and rapid development of the cone of depression in both aquifer units across those areas of the IMS facility unaffected by boundary affects associated water bodies thereon. The results of the pumping test undertaken in 2018 as described in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith 2019) in **Appendix C** and described in **Section 1.6.**
7.	Aquifer parameters derived for the Namurian bedrock and Loughshinny Formation aquifer indicate: an estimated of transmissivity of 160 to 539 m^2/day, with an average of 245 m^2/day; and estimated storativity values that are generally low ranging from 1.34×10^{-5} to 8.49×10^{-3} with a geometric mean of 7.53×10^{-4}. The transmissivity values considered high for the aquifers typically expected in Namurian bedrock and an order of magnitude higher than those typically associated with aquifers depending on fissure porosity alone to convey groundwater flows. This confirms the Namurian bedrock can be considered as Poor Aquifer being situated in a wide '*local zone*' of enhanced fracture permeability development in accordance with its general hydrogeological designation, **P(l)**. This confirms the designation for the Loughshinny Formation ad a Local Important aquifer unit of moderate productivity, **L(m)**.	Results of new pumping test undertaken as part of additional works for IMS. Described in **Section 1.6** and in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith 2019) in **Appendix C.**

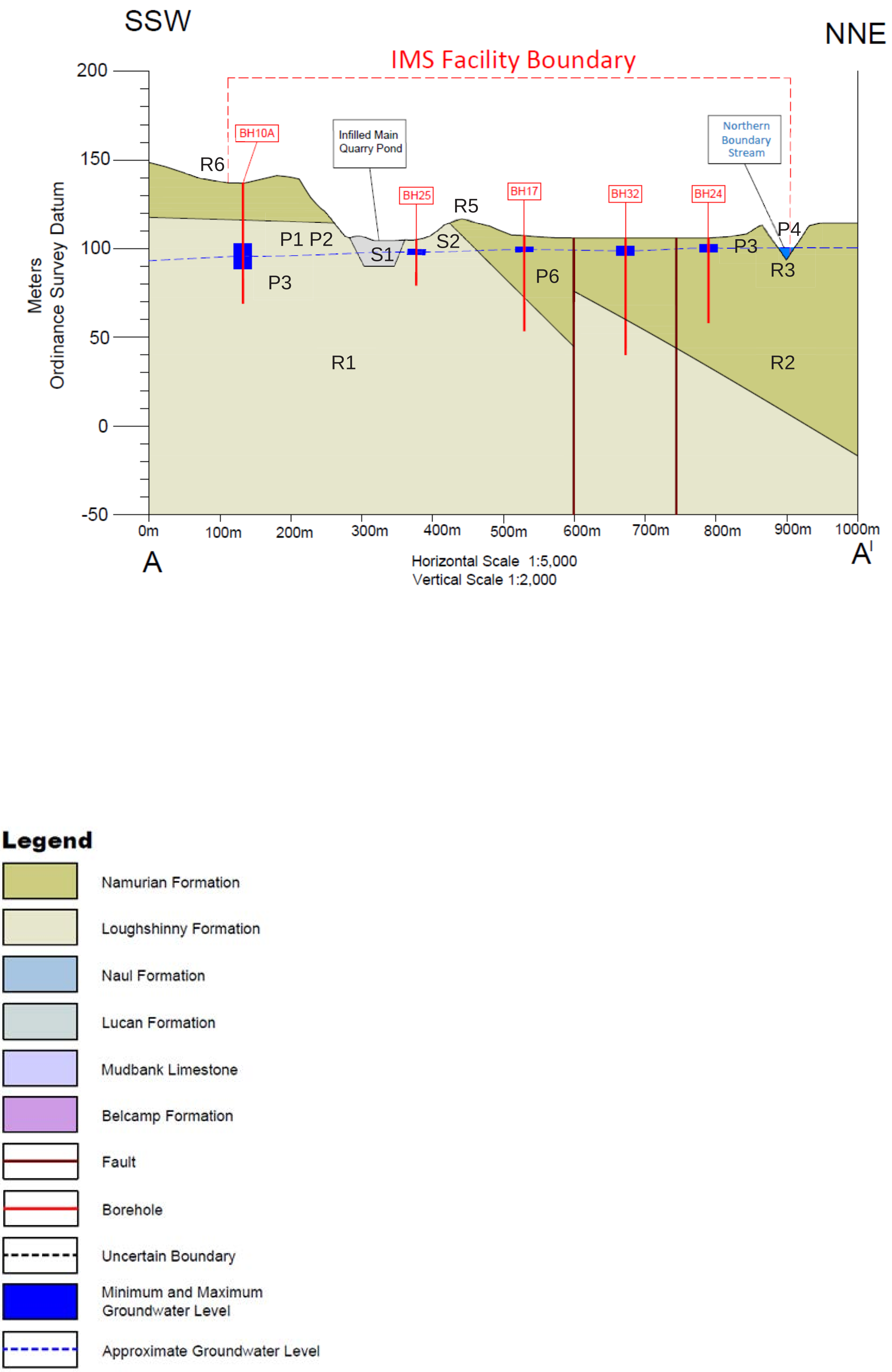
8.	In the north and east of the IMS facility the saturated Loughshinny Formation **L(m)** aquifer unit is typically situated beneath more than 15m (and on occasions more than 40 m) of saturated Namurian bedrock **P(l)** aquifer. The Loughshinny Formation Lm aquifer is present at the quarry floor in the southwest of the former quarry.	Detailed geological information and groundwater levels for the IMS facility as presented in geological / hydrogeological cross sections (**Figure 7**, **Figure 8** and **Figure 9**) and presented in **Table 4-2.**
9.	There is no evidence of the effect of discrete fissures or fracture zones on groundwater flow / hydrogeology of the IMS facility.	Results of new pumping test undertaken as part of additional works for IMS. Described in **Section 1.6** and in the Groundwater Level Monitoring and Aquifer Test Report (CDM Smith 2019) in **Appendix C**. The results of the pumping test provide no evidence of discrete fissures or fracture zones on the development of drawdowns in either unit. The results of the pumping test are consistent with a dense fracture network crossing both units and suggests the aquifer response is consistent with an EPM (**See 5 and 7 above**).
10.	The IMS facility is situated in recharge area in the southern groundwater catchment area. As such vertical hydraulic gradients in the Namurian bedrock aquifer are orientated downwards. The vertical flow directions in the Loughshinny Formation aquifer are more variable but an upward gradient orientated towards the top of that unit or/and the base of the overlying Namurian bedrock sequence is observed.	Groundwater level data for proximal 'borehole pairs' present on the IMS facility as presented in **Table 4-1** and described in **Section 1.6**.
11.	The principal receptors associated with natural easterly / south-easterly groundwater flow on the IMS facility include offsite groundwater in the laterally continuous Namurian bedrock aquifer at the site boundary; groundwater within the underlying Loughshinny aquifer (and transfer therewith); ultimately the headwaters of the Ballough stream 2.75 km to the east of the IMS facility; and any intervening private groundwater abstractions.	Specific west-east hydrogeological cross section for the IMS facility shown in **Figure 7**. Schematic groundwater contours (**Figure 10**) and west-east hydrogeological cross section (**Figure 7**).
12.	Groundwater abstraction at the Bog of the Ring wellfield or changes to the pumping regime thereon is unlikely to have an effect on water levels on the IMS facility.	The IMS facility is situated in a different groundwater catchment area than the Bog of the Ring wellfield (See 1 above). The c. 1-week cessation of pumping at the Bog of the Ring wellfield in September 2018 had no measurable effect on groundwater level or rates of groundwater recession in any monitoring borehole as shown in **Graph 1** and described in **Section 1.6**. Additionally, the drawdown pattern observed the same year was not observed on site. As shown in **Graph 1** and described **Section 1.6** the groundwater levels at the Bog of the Ring wellfield (OW2D) have been shown to be more 80m lower than groundwater levels on the IMS facility and 90 m lower than groundwater levels at the groundwater divide (as measured at the new offsite monitoring well BH31, installed as part of additional works undertaken by IMS). Deep and laterally continuous groundwater body in the fractured Namurian bedrock in the core of the syncline that separates the IMS facility from the Bog of

	the Ring well filed as shown in the regional hydrogeological cross section (**Figure 10**). Consistent with the zone of capture defined for the Bog of the Ring Wellfield source protection zone model (EPA , 2006) provided in **Appendix G.**

Figure 21 Conceptual Hydrogeological Model

Source	Pathway	Receptor
Accidental emissions and release of potentially hazardous substances during construction and operation (S1)	Infiltration of run-off (P1)	Loughshinny Formation Locally Important Bedrock Aquifer (R1)
	Vertical flow within aquifer units (P2)	Walshestown Formation Poor Bedrock Aquifer (R2)
Waste mass leachate within groundwater (S2)	Natural groundwater flow within aquifer units (P3)	Tooman Branch Stream (R3)
		Private groundwater abstraction points (R4)
	Surface watercourse flow (P4)	Nags Head Quarry Geological Heritage Site (R5)
	Flow through fissures and fractures within aquifer units (P5)	Soils on undeveloped areas within the IMS boundary (R6)




SSW
NNE
IMS Facility Boundary
BH10A
Infilled Main Quarry Pond
Northern Boundary Stream
BH25
BH17
BH32
BH24
R6
R5
P1 P2
S1
S2
P3
P4
R3
P6
R1
R2
Meters
Ordinance Survey Datum
200
150
100
50
0
-50
0m
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
A
A'
Horizontal Scale 1:5,000
Vertical Scale 1:2,000
Legend
Namurian Formation
Loughshinny Formation
Naul Formation
Lucan Formation
Mudbank Limestone
Belcamp Formation
Fault
Borehole
Uncertain Boundary
Minimum and Maximum Groundwater Level
Approximate Groundwater Level

6 CONCLUSIONS

An updated conceptual hydrogeological model has been produced for the site using entirely new lines of evidence based on the following:

- Updated groundwater hydrographs for existing groundwater monitoring wells in and around the site including within the Bog of the Ring well field;
- Drilling of new strategically located deep boreholes to widen the understanding of on-site and off-site stratigraphy and ground water elevations and gradients; and
- Execution and interpretation of a full pumping test from a purposefully drilled and installed site borehole within the Loughshinny Formation to allow more definitive assessment of the hydrogeological characteristics, and hydraulic inter-relationships, of the Namurian bedrock and underlying Loughshinny Formation to be determined.

The regional groundwater elevations have been examined, which have confirmed the presence of an east-west oriented groundwater flow divide broadly concurrent with the topographical high ground comprising Knockbrack Hill to the north of the Hollywood site. The elevation of this divide, together with the absence of common aquifer stress responses within monitoring wells across this divide, have provided the hitherto absent evidence to conclude the Bog of the Ring well field is not within hydraulic continuity with the Hollywood site and resides within a separate groundwater catchment and associated flow field.

Accordingly, it can now be stated with confidence that the Bog of the Ring well filed can be dismissed as an environmental receptor and that the pumping regimes at either the Hollywood site of the well field will have no effect on each other.

Following the synthesis of new borehole data, the finding of the pump test interpretation and monitoring well hydrographs, the hydrogeological character of the Hollywood site can be summarised thus:

- The Namurian mudstones and shales are highly weathered and fractured and possess reasonable permeability and sustain a uniform hydraulic gradient to the south east with an approximate of magnitude of 0.005 (0.5%). A downward vertical gradient with the underlying Loughshinny Formation is revealed by some pairs of boreholes installed on site;
- Likely due to a broadly common degree and character of fracturing present, the pump test conducted did not reveal a significantly differing permeability between the two strata at the site and not subject to obvious anisotropy, allowing the saturated bedrock to be considered as an Equivalent Porous Medium;
- This has permitted the construction of a simplified Conceptual Hydrogeological Model to support the development of a LandSim risk assessment capable of being used to predict the likelihood of impact from modelled contaminants of concern within landfill leachates generated at the site over its lifetime;
- This LandSim model has shown the proposed site engineering design and waste streams are not likely at the 90th percentile to result in the measurable release to groundwater of Prohibited Hazardous Substances and will acceptably limit the concentration in groundwater of Non-Hazardous Polluting Substances at the down gradient boundary to within acceptable limits (refer RPS Report MDR1492Rp00015); and
- This shows that the site will not have an unacceptable impact on groundwater resources or groundwater dependant surface waters in likely hydraulic continuity with the site.

It can therefore be concluded that the proposed development at Hollywood Landfill may be operated with acceptable environmental impacts and be compliant with all appropriate waste management and environmental regulations.

GLOSSARY

ABP	An Bord Pleanála
BOTR	Bog of the Ring
CHM	Conceptual Hydrogeological Model
CSM	Conceptual Site Model
DoEC&LG	Department of the Environment and Local Government
EIAR	Environmental Impact Assessment Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (Ireland)
FCC	Fingal County Council
GHS	Geological Heritage Sites
GSI	Geological Survey Ireland
GWB	Groundwater Bodies
IEL	Industrial Emissions Licence
IMS	Integrated Materials Solutions Limited Partnership
IWMF	Integrated Waste Management Facility
mOD	metres above Ordnance Datum
mbgl	metres below ground level
MEHL	Murphy Environmental Hollywood Limited
PWS	Public Water Supply
WAC	Waste Acceptance Criteria
WFD	Water Framework Directive (Directive 2000/60/EC)

REFERENCES

1. CDM Smith 2019. Groundwater Level Monitoring and Aquifer Test Report. March 2019.
2. CDM Smith. 2018a. Hydrogeological review of the EPA's determination (refusal) related to the Naul Landfill application, letter dated 7th February 2018.
3. CDM Smith.2018b. Review of pressure transducer data – June to August 2018, letter dated 20th September 2018.
4. CDM Smith.2018c. Assessment of Onsite Groundwater Levels in Context of Bog of the Ring Wellfield Pumping, letter dated 15th November 2018.
5. GSI & EPA. 1999. Groundwater Protection Response for Landfills (link)
6. GSI. 1999. 1:100,000 scale Bedrock Series geology Map Sheet 13.
7. EPA. 2015D. Report of the Technical Committee on Objections to Licence Conditions re. 'Objection to Proposed Determination for MEHL, Industrial Emissions Licence Register No: W0129-03', EPA, 30 June 2015
8. Mc Connell, B., Philcox, M. and M. Geraghty (2001) A Geological Description to Accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 13, Meath. Geological Survey of Ireland.

APPENDICES

Appendix A

Pre-Application Meeting Questionnaire

MEMO

Date: 05 April 2019
To: Anne Lucey
From: Paul Chadwick
Pages: 13 inc. this page
Regarding: Licence Review for Hollywood Landfill (W0129-02)

Pre-application Questions for Licence Review

In advance of the pre-application meeting on the 11th April 2019 for the Licence Review for Hollywood Landfill, Integrated Materials Solutions Limited Partnership (IMS), as licensee and applicant, has been requested to respond to a series of questions from the EPA on the nature of the proposed development, the supporting environmental documentation and the parallel planning process.

This memo sets out the responses to each of the nine EPA questions to inform the discussions at the pre-application meeting.

We trust the at the information provided is suitable for the EPA requirements but please do not hesitate to contact the undersigned should any further information be required in advance of the meeting. We look forward to discussing the application at the meeting on the 11th April 2019.

Sincerely

Paul Chadwick

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Technical Director - Environment
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1. What type of licence are you planning on applying for and why do you think you need it?

The Hollywood site currently operates under a Waste Licence (Reg No. W0129-02) which was granted in May 2008. Condition 1.5 of the licence states that:

> *No alteration to, or reconstruction in respect of, the activity or any part thereof which would, or is likely to, result in:*
>
> *(i) a material change or increase in:*
>
> - *The nature or quantity of any emission,*
> - *The abatement/treatment or recovery systems,*
> - *The range of processes to be carried out,*
> - *The fuels, raw materials, intermediates, products or wastes generated, or*
>
> *(ii) any changes in:*
>
> - *Site management infrastructure or control with adverse environmental significance,*
>
> *shall be carried out or commenced without prior notice to, and without the agreement of, the Agency.*

IMS now proposes to develop and operate a series on non-hazardous cells at the site in conjunction with the ongoing inert waste landfilling licensed under W0129-02. As the range of processes to be carried out, types of waste to be accepted, and site waste management infrastructure will be materially altered a Licence Review is considered likely.

Under the revised First Schedule to the EPA Act 1992, as amended, the following class of activity is relevant to the proposed development:

Class 11.5: Landfills, within the meaning of section 5 (amended by Regulation 11(1) of the Waste Management (Certification of Historic Unlicenced Waste Disposal and Recovery Activity) Regulations 2008 (S.I. No. 524 of 2008)) of the Act of 1996, receiving more than 10 tonnes of waste per day or with a total capacity exceeding 25,000 tonnes, other than landfills of inert waste.

As a consequence, under Section 76A of the Waste Management Act, it is anticipated that the proposed development will require an Industrial Emissions Licence.

2. What Class(es) of activity apply to your operation and why? (Current licence & future application).

Part 1 of the current licence (W0129-02) includes for the following classes of activity at the Hollywood site with the main class of activity highlighted in bold. The proposed development will also include all of the classes of activity listed below in the Licence Review application in addition to the new classes highlighted in grey in the table. This additional class relates to the potential for the following activities at the site to be addressed in the application

- Processing of Incinerator Bottom Ash prior to landfill
- Stabilisation of wastes prior to landfill
- Treatment of leachate on site

Activity	Class	Description
Disposal	Class 1.	Deposit on, in or under land (including landfill).
	Class 5.	**Specially engineered landfill, including placement into lined discrete cells, which are capped and isolated from one another and the environment.**
	Class 7.	Physico-chemical treatment not referred to elsewhere in this Schedule which results in final compounds or mixtures which are disposed of by means of any activity referred to in this Schedule.
	Class 13.	Storage prior to submission to any activity referred to in a preceding paragraph of this Schedule, other than temporary storage, pending collection, on the premises where the waste concerned is produced.
Recovery	Class 3.	Recycling or reclamation of metals and metal compounds.
	Class 4.	Recycling or reclamation of other inorganic materials.
	Class 13.	Storage of waste intended for submission to any activity referred to in a preceding paragraph of this Schedule, other than temporary storage, pending collection, on the premises where such waste is produced.

MEMO

Date: 04 April 2019
Regarding: Licence Review for Hollywood Landfill (W0129-02)

Under the revised First Schedule to the EPA Act 1992, as amended, the following classes of activity are relevant to the proposed development.

Class	Description
Class 11.1	The recovery or disposal of waste in a facility, within the meaning of the Act of 1996, which facility is connected or associated with another activity specified in this Schedule in respect of which a licence or revised licence under Part IV is in force or in respect of which a licence under the said Part is or will be required.
Class 11.4	(a) Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving one or more of the following activities (other than activities to which the Urban Waste Water Treatment Regulations 2001 (S.I. 254 of 2001) apply): (ii) physico-chemical treatment; (iv) treatment of slags and ashes; (b) Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tonnes per day involving one or more of the following activities, (other than activities to which the Urban Waste Water Treatment Regulations 2001 (S.I. No. 254 of 2001) apply): (iii) treatment of slags and ashes;
Class 11.5	Landfills, within the meaning of section 5 (amended by Regulation 11(1) of the Waste Management (Certification of Historic Unlicenced Waste Disposal and Recovery Activity) Regulations 2008 (S.I. No. 524 of 2008)) of the Act of 1996, receiving more than 10 tonnes of waste per day or with a total capacity exceeding 25,000 tonnes, other than landfills of inert waste.
Class 13.6	Independently operated treatment of waste water (to which the Urban Waste Water Treatment Regulation 2001 do not apply) and discharged by an installation to which Part IV applies.

:

3. What waste types are proposed to be accepted and what is the proposed annual tonnage? Include List of Waste Codes.

The total annual tonnage proposed at the site will remain at 500,000 tonnes per annum as per Schedule A.1 of the current licence (W0129-02). The breakdown between the inert and non-hazardous fractions is not known at present but both streams combined will be subject to the above annual limit.

The proposed development will comprise of the following waste streams to be incorporated into the inert landfill cells. All waste streams are currently permitted under Schedule A.2 of the current licence (W0129-02). Note that this list is not exhaustive and further waste streams may be added in the application.

Description	Typical Source	EWC	EWC Definition
Waste Resulting from Quarrying and Physical Treatment of Minerals	Quarrying wastes	01 01 02	Wastes from mineral non-metalliferous excavation
		01 04 12	Tailings and other wastes from washing and cleaning of minerals other than those mentioned in 01 04 07 and 01 04 11
		01 04 09	Waste sand and clays
		01 04 99	Wastes not otherwise specified
Construction and Demolition Wastes	Construction/development sites	17 01 01	Concrete
		17 01 02	Bricks
		17 01 03	Tiles and ceramics
		17 01 07	Mixture of concrete, bricks, tiles and ceramics
		17 02 02	Glass
		17 03 02	Bituminous mixtures
		17 05 04	Soil and stones
		17 05 06	Dredging spoil
		17 06 04	Insulation materials
		17 09 04	Mixed construction and demolition wastes
Other Inert Wastes	Construction/development sites	10 10 06	Casting cores and moulds which have not undergone pouring
	Water treatment plants	19 09 02	Sludges from water clarification
	Industrial	19 09 04	Spent Activated Carbon
Other compatible inert waste streams may be agreed with the Agency			

MEMO

Date:	04 April 2019
Regarding:	Licence Review for Hollywood Landfill (W0129-02)

The proposed development will comprise of the following waste streams to be incorporated into the non-hazardous landfill cells. Note that this list is not exhaustive and further waste streams may be added in the application.

Description	Typical Source	EWC	EWC Definition
Bottom ash, boiler ash and other ash/dust deemed to be non-hazardous	Power stations/combustion plants	10 01 01	Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)
		10 01 02	Coal fly ash
		10 01 03	Fly ash from peat and untreated wood
	EfW facilities	19 01 02	Bottom ash and slag other than those mentioned in 19 01 11
		19 01 04	Fly ash other than those mentioned in 19 01 13
		19 01 16	Boiler dust other than those mentioned in 19 01 15
		19 03 07	Solidified wastes other than those mentioned in 19 03 06
Soils (low-level contamination)	Construction/development sites	17 05 04	Soil and stones other than those mentioned in 17 05 03
Dredge spoil & drilling muds	Dredging of waterways	01 05 04	Freshwater drilling muds and wastes
		17 05 06	Dredging spoil other than those mentioned in 17 05 05
Sludges	Water/Wastewater treatment plants	06 05 03	Sludges from onsite effluent treatment other than those mentioned in 06 05 02
		19 08 05	Sludges from treatment of urban waste water
		19 08 12	Sludges from biological treatment of industrial waste water other than those mentioned in 19 08 11
		19 02 06	Sludges from physico/chemical treatment other than those mentioned in 19 02 05
Inert waste processing 'fines'	Waste treatment	19 12 12	Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11
Plaster Waste	Casting of nonferrous pieces	10 10 08	Casting cores and moulds which have undergone pouring, other than those mentioned in 10 10 07
Waste from the shredding of ELV'S & White Goods	Waste management facilities	19 10 04	Fluff-light fraction and dust other than those mentioned in 19 10 03
Stable Non-Reactive Hazardous Wastes (SNRHW)	Construction Material Containing Asbestos (CMCA)	17 06 05*	Construction materials containing asbestos
Other compatible non-hazardous waste streams may be agreed with the Agency			

4. Briefly, what is the nature of the waste activity proposed? What emissions are there likely to be?

The nature of the waste activity will be as per the existing licensed landfilling operation. Waste transport, acceptance protocols, lining, infilling and capping will all generally follow the existing operation. The annual throughput at 500,000 tonnes per annum and the landfill footprint are also unchanged in the proposed development.

The key change from a licensing perspective is the inclusion of the non-hazardous waste streams with the existing inert operation. This change will require the following:

- Specific waste acceptance procedures for the non-hazardous and stable non-reactive waste streams.
- A pre-treatment process for wastes prior to landfilling.
- A revised cell layout across the site with a series of designated inert and non-hazardous cells.
- Specific sub-cells for the Stable Non-Reactive Hazardous Wastes (SNRHW) to be landfilled separate from other wastes.
- A specifically designed composite clay and geo-membrane liner installed on the base and side walls of the proposed cells for non-hazardous waste.
- A leachate collection and management system for the non-hazardous leachate.
- A revised phasing plan for simultaneous infilling of both inert and non-hazardous waste streams.
- Specific capping requirements for the non-hazardous cells in line with the EPA Landfill Manual.

The likely emissions to the environment over and above the existing operation may be summarised as follows:

Groundwater - The Waste Acceptance Criteria (WAC) leaching limit values for non-hazardous waste (as set out in Council Decision 2003/33/EC) are higher than the corresponding leaching limit values for inert wastes and hence the introduction of non-hazardous wastes poses a potential greater risk to groundwater. Given the concerns raised by the EPA in the previous licence application (Ref. W0129-03) in 2016, IMS has modified the proposed development to resolve the concerns in two ways:

1. IMS is committed to now eliminating the acceptance and landfilling of hazardous waste from the site thereby eliminating the “source” characteristics for hazardous leachable substances. Stable non-reactive hazardous wastes which have no hazardous leachable substances will be included as is permitted under the Landfill Directive (REF Section).
2. A detailed set of additional groundwater investigations, monitoring and a groundwater pump test have been undertaken in 2018 and 2019 to delineate the extent of connectivity, if any, between the Bog of the Ring (BOTR, public water supply) and the groundwater bodies underlying the site. The investigations have concluded definitively that the position of the groundwater flow divide is not significantly influenced by the likely drawdown zone of influence of the BOTR well field. In short, there is a clear groundwater divide between the site and the Bog of the Ring which can resolve this concern raised by the EPA in the previous application.

IMS is satisfied that the information gaps and concerns cited by the EPA in the 2016 refusal will be fully resolved by the omission of hazardous waste from the proposed development coupled with the more definitive understanding of the hydrogeological regime in the area. In this regard, a robust evidence base will be provided in the Waste Licence application to ensure that the EPA may be fully satisfied that there will be no adverse impact to hydrogeology from the proposed development.

Emissions to Surface Water – As per the existing operation, surface water run-off from the landfill will be treated prior to discharge to the stream so there will be no net change in impact from this source. Should the leachate management option be to treat leachate on site and then discharge to the Ballough Stream that bounds the site to the north, there is potential for impact to surface water.

Emissions to Sewer – Currently there are no emissions to sewer. In the event that the leachate management option is to discharge to the local sewer network then this new additional discharge would be included in the licence. Flows and emission limit values will be agreed with Irish Water as part of the consultation and licence application process.

Air - The infilling of non-hazardous wastes in conjunction with inert wastes may result in a risk of increased dust generation at the site. Current levels are low and the dust mitigation plan will be developed to ensure that levels of dust deposition will not breach the prescribed limits in the revised licence.

Noise - No significant additional noise will be generated on site from the proposed development as operations will remain unchanged. Any intensification from simultaneous infilling in the inert and non-hazardous cells will be maintained within the prescribed noise limits.

Waste – No additional waste will be generated on site from the proposed development.

Resource Use – As above, the proposed development will have no significant impact on resource and energy use at the site.

5. What is the receiving environment?

The site is located in Hollywood Great, Nag's Head, Naul, Co. Dublin, approximately 3km west of the M1 and approximately 14km north of Dublin Airport.

The site was a former quarry which operated until 2007 and is now a licensed (W0129-02) engineered landfill site. IMS ownership of the site expands to 54.4 hectares with the current Waste Licence covering an area of 39.8 hectares.

The site is accessed via the LP-1090 local road which bounds the west of the site and the LP-1080 local road (also known as Sallowood View and the Nevitt Road) which bounds the south of the site and links the R108 with the R132.

The land use is in the vicinity of the site is typically agricultural with the surrounding fields employed for a mixture of pasture and tillage uses. In addition, a small number of commercial operations are also located within the area including a haulage contractor to the north west of the site.

The human environment in the area consists mainly of residential properties located along the local roads including the LP-1090 (west), LP-1080 (south), Tooman Road (east) and Rowans Road (north). The nearest residential property to the site is the bungalow located at the southern site boundary along the LP-1080 to the east of the junction with the LP-1090. There is a primary school located circa 3km east of the site at the Five Roads but this is located circa 40 metres from the existing haul routed employed.

The north of the site is bounded by the Bedaragh/Walshestown Stream which flows from west to east to feed the Ballough Stream (also known as the Corduff River) to the south east and ultimately the Ballyboghil River which discharges at the Rogerstown Estuary circa 9km east of the site.

The site is underlain by a complex geological and hydrogeological setting consisting of several geological formations and a series of faults. The Source Protection Area for the Bog of the Ring collection of groundwater wells to the north east of the site lies approximately 1 km from the site with the actual wells used for drinking water circa 2.5 km north east of the site. The sensitivity of this receiving environment is largely the reason behind the EPA refusal of the previous Licence Review Application in January 2016.

The topography of the site is varied with a topographic high of 148mAOD in the west of the site at the site entrance. The areas of the site under the licence boundary have large stepped and steep depressions that represent the land awaiting infill and restoration, the remainder of the site owned by IMS dips at a consistent rate in an easterly north easterly direction. The quarry restoration will restore the south west of the site to the highest point at 148mAOD, the rest of the site will shallowly decline concentrically away from this point, predominantly towards the east tying in with the surrounding landscape. The lowest proposed level is 98mAOD in the north east of the site approaching the stream.

Under the Fingal Development Plan 2017-2023, the area around the site is zoned as HA 'High Amenity' to protect and enhance high amenity areas. Furthermore, the entirety of the LP-1080 along the southern boundary of the site and a section of the LP-1090 along the western boundary are designated to preserve the view highlighting the sensitivity of the landscape in the area.

6. Have you screened for EIA? Do you need EIA? If not why?

Recital 27 of the EIA Directive (Directive 2014/52/EU) states that the screening procedure should ensure that an environmental impact assessment is only required for projects likely to have significant effects on the environment. Given the historic groundwater concerns raised at the site, coupled with the Appropriate Assessment Screening outcome (see response to Question 7), it is determined that the proposed development has potential for significant effects on the environment. In this regard the application is screened in for EIA and an Environmental Impact Assessment Report (EIAR) is being prepared to accompany the Licence Review application.

The EIAR will be prepared in accordance with the requirements of the European Union (Planning and Development) (Environmental Impact Assessment) Regulations 2018 (S.I. No. 296 of 2018). These Regulations specifically apply to the planning process by amending the Planning and Development Act 2000, the Planning and Development (Housing) and Residential Tenancies Act 2016, the Planning and Development (Amendment) Act 2018 and the Planning and Development Regulations 2001. While not strictly applying to the EPA function for a Licence Review application, the requirements of these Regulations are applied *in lieu* of any specific licensing EIAR regulation.

7. Have you screened for appropriate assessment? Do you need a full appropriate assessment? If not why?

Screening for Appropriate Assessment (AA) in line with the requirements of Article 6(3) of the EU Habitats Directive (EC 92/43/EEC) on the Conservation of Natural Habitats and of Wild Fauna and Flora; the Planning and Development (Amendment) Act 2010; and the European Union (Birds and Natural Habitats) Regulations 2011 as amended, has been undertaken.

The site is located within the Nanny-Delvin WFD Catchment, adjacent to the Ballough River, which flows along the northern boundary of the site. The Ballough is a small tributary stream that rises at a small upstream distance of the site and enters the Rogerstown Estuary circa 9km downstream.

The Rogerstown Estuary is a designated SAC (Site Code 000208) and SPA (Site Code 00415).

Pollutants resulting from on-site construction practices as well as operational activities could potentially impact upon these European sites via the hydrological connection. This could directly impact habitats and/or indirectly impact species through habitat alterations such as loss of food source (e.g. deterioration of vegetation).

Because of this hydrological connection between the site and the Rogerstown Estuary SAC/SPA, it is concluded that the proposed development has potential for significant effects on these two European Sites and that an Appropriate Assessment is required.

A Stage 2 Natura Impact Statement will accompany the Licence Review Application.

8. What is the planning status?

The current operations are permitted by the following:

- The site was first granted a 15-year permission by Fingal County Council (FCC) in June 1988 (Reg. Ref. 88a/32) to infill, restore and reinstate the portion of the quarry that was excavated to that date.
- In 2004, planning permission from FCC (Reg. Ref. F04A/0363) was granted to infill the existing quarry with waste materials within engineered cells at a rate of 340,000 tonnes per annum as part of the restoration and reinstatement of the quarry.
- Subsequently in 2007 a further planning permission (Reg. Ref. F07A/0262) was granted by FCC to amend the 2004 consent to permit an extended area to be infilled and to permit the continued infill of the quarry at a rate of 500,000 tonnes per annum. These consents allow the current infilling operation to continue up to October 2019 at which point the permission expires.

In February 2019, IMS sought planning permission from FCC (Reg. Ref. F19A/0077) from for the continued infilling of the former quarry with construction and demolition waste material at a rate of 500,000 tonnes per annum permitted under Reg. Refs. F07A/0262 and F04A/0363 for a further 15 no. year period from the date of expiration of the existing permissions in order to enable the lands to be fully restored to the original ground level.

For the proposed development under consideration in this Licence Review, An Bord Pleanála (ABP) granted a 25 year permission under Section 37E of the Planning and Development Act, 2000, as amended (Strategic Infrastructure Development – SID), for an integrated waste management facility at the site in June 2011 (Case reference: PL06F.PA0018). The 2011 permitted development consists of a series of engineered landfill cells for inert, non-hazardous and hazardous wastes and associated infrastructure.

This proposal was the subject of a Licence Review (Ref: W0129-03) by the former site owner, Murphy Environmental Hollywood Limited (MEHL) in December 2010. In January 2016, the EPA refused the application on two grounds, i.e.

- The activities that are the subject of the licence review application, and
- The status of the applicant as a fit and proper person.

IMS is now seeking to proceed with the SID development permitted under PL06F.PA0018, with alterations, and is now engaging with ABP the Section 146B process. ABP will ultimately make a determination to do one of the following:

- Make the alterations as requested which would provide planning consent for the application,
- Make a different alteration to that sought (but which would not, in the opinion of the Board, represent, overall, a more significant change to the terms of the development than that which would be represented by the latter alteration). Again, this would constitute planning consent for the proposed development.
- Refuse to make the alteration in which case a new application would be submitted to ABP.

In short, the proposed development does not currently have planning permission but this process is ongoing through engagement with ABP to determine the appropriate planning application route.

9. Any specific questions for discussion?

There are two specific questions from IMS for consideration in the meeting on the 11th April 2019 as follows:

1. Hydrogeology

Hydrogeology was a fundamental issue in the refusal of the previous Licence Review at the site in 2016 (Ref. W0129-03). In the first instance IMS has sought to alleviate EPA concerns through the omission of hazardous waste cells from the proposed development to reduce the “source” risk. However, much of the reasons behind the EPA refusal related to the failure by the then applicant to provide a clear understanding of the conceptual hydrogeology underlying the site and the connectivity to the wider environment (e.g. the Bog of the Ring water supply). IMS has undertaken a series of detailed hydrogeological investigations, monitoring regimes and modelling exercises to provide a more robust representation of the hydrogeological regime in the area. IMS wishes to discuss how best to engage with the EPA (or the EPA’s consultants) on these matters as part of the Licence Review application process.

2. Leachate Treatment

IMS is currently undertaking an option analysis of leachate management for the non-hazardous cells. In the event that an on-site treatment option is proposed with a discharge of treated effluent to the Ballough Stream, what will be the EPA requirements for such a discharge?

Appendix B

Groundwater Protection Responses

Groundwater Protection Responses for Landfills

Background

Groundwater in Ireland is protected under European Community and national legislation. Local authorities and the Environmental Protection Agency (EPA) have responsibility for enforcing this legislation. The Geological Survey of Ireland (GSI) in conjunction with the Department of Environment and Local Government (DoELG) and the EPA have developed a methodology for the preparation of groundwater protection schemes to assist the statutory authorities and others to meet their responsibility to protect groundwater (DoELG/EPA/GSI, 1999). This methodology incorporates land surface zoning and groundwater protection responses.

These groundwater protection responses are concerned with the site selection process for landfills and the associated design, operation and monitoring of landfill sites. These responses outline the likely acceptability of landfills in each groundwater protection zone (as described in *Groundwater Protection Schemes* (DoELG/EPA/GSI, 1999)) and the recommended level of response/restriction, which depends on the groundwater vulnerability, the value of the groundwater and the contaminant loading.

In general terms this guidance is for the siting of landfills for non-hazardous wastes. The principles involved may also be applied to the selection process for landfill sites for hazardous and inert waste.

A significant factor in siting all landfills is the protection of groundwater, which is an important resource and source of water supply in Ireland, particularly in rural areas.

The geology and hydrogeology of any region have a major bearing on: (i) the availability of suitable areas for landfill sites; (ii) the level of natural protection for groundwater from contamination by landfill leachate; and (iii) the design, operation and monitoring of landfills.

Groundwater protection schemes, supported by detailed investigations, provide hydrogeological information for landfill site selection. They are used to identify areas where landfills should normally be excluded and areas where they are less likely to pose a risk to groundwater. The groundwater protection responses outlined here require that new landfills should not generally be developed on regionally important aquifers.

Developers of landfills should have regard to both the resource potential and the vulnerability of the underlying and adjacent aquifers. The groundwater protection responses combine both of these factors in a matrix which facilitates rational decisions on the acceptability or otherwise of a landfill from a hydrogeological point of view.

The risk to groundwater from the landfilling of waste is mainly influenced by:

- the nature of the waste;
- the leachate composition;
- the volume of leachate generated;
- the groundwater vulnerability;
- the proximity of a groundwater source;
- the value of the groundwater resource;
- the landfill design; and
- the landfill operation and management practices.

In general the pollution risk is greatest in source protection areas and on regionally important aquifers.

The topsoil and subsoil, depending on their type, permeability and thickness, play a critical role in preventing groundwater contamination and mitigating the impact of many potential pollutants. They act as a protecting filtering layer over groundwater.

Guidance presented in these responses should be used to assist in the selection, design and management of landfill sites, and is based on the precautionary principle. The concept of risk management should be used in the decision making process for the selection of new landfill sites.

These groundwater protection responses should be read in conjunction with *Groundwater Protection Schemes* (DoELG/EPA/GSI, 1999).

Landfilling of Waste: a Hazard for Groundwater

The generation of leachate is one of the main hazards to groundwater from the disposal of waste by landfilling. Good site selection, design and operation assists in minimising the risk of pollution. Leachate from landfills for non hazardous waste is a highly polluting liquid and its composition is dependent on the nature of the waste within the landfill. The pollution potential can be evaluated by calculating the volume and predicting the composition of leachate that will be generated.

The volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and the effectiveness of the capping. It is essential that the volume of leachate generated be kept to a minimum. The design and operation of the landfill should ensure that the ingress of groundwater and surface water is minimised and controlled.

Leachate composition varies due to a number of different factors such as the age and type of waste and operational practices at the site.

The conditions within a landfill vary over time from aerobic to anaerobic thus allowing different chemical reactions to take place. Most landfill leachates have high BOD, COD, ammonia, chloride, sodium, potassium, hardness and boron levels. Ammonia is a contaminant which may be used as an indicator of contamination, particularly in terms of surface water, as it can be toxic to fish at low concentrations (1 mg/l). Chloride is a mobile constituent which is often used as an indicator of contamination. The leachate from landfills for non-hazardous waste may produce reducing conditions beneath the landfill, allowing the solution of iron and manganese from the underlying deposits.

Leachates from landfill sites for non-hazardous waste often contain complex organic compounds, chlorinated hydrocarbons and metals at concentrations which pose a threat to groundwater and surface waters. Solvents and other synthetic organic chemicals are a significant hazard, being of environmental significance at very low concentrations and resistant to degradation. Moreover, they may be transformed in some cases into more hazardous compounds.

Landfills have the potential to produce leachate for several hundred years.

Groundwater Protection Response Matrix for Landfills

The reader is referred to the full text in *Groundwater Protection Schemes* (DoELG/EPA/GSI, 1999) for an explanation of the role of groundwater protection responses in a groundwater protection scheme.

The siting, design, operation and monitoring of landfills must comply with the guidelines outlined in the EPA's Landfill manuals except where such facilities hold a waste licence issued by the EPA. A Waste Licence is required for all landfills.

From the point of view of reducing the risk to groundwater, it is recommended that all landfills be located in, or as near as possible to, the zone in the bottom right hand corner of the matrix.

The appropriate response to the risk of groundwater contamination is given by the assigned response category (**R**) appropriate to each protection zone (Table 1).

Response Matrix for Landfills

VULNERABILITY RATING	SOURCE PROTECTION AREA		RESOURCE PROTECTION Aquifer Category					
			Regionally Important (R)		Locally Important (L)		Poor Aquifers (P)	
	Inner	Outer	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	R4	R4	R4	R4	R3[2]	R2[2]	R2[2]	R2[1]
High (H)	R4	R4	R4	R4	R3[1]	R2[1]	R2[1]	R1
Moderate (M)	R4	R4	R4	R3[1]	R2[2]	R2[1]	R2[1]	R1
Low (L)	R4	R3[1]	R3[1]	R3[1]	R1	R1	R1	R1

In all cases standards prescribed in the *EPA Landfill Site Design Manual (EPA, 1999)* or conditions of a waste licence will apply.

R1 Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

R2^{1} Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down-gradient of the site and to the projected future development of the aquifer.

R2^{2} Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence.

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down-gradient of the site and to the projected future development of the aquifer.
- Groundwater control measures such as cut-off walls or interceptor drains may be necessary to control high water table or the head of leachate may be required to be maintained at a level lower than the water table depending on site conditions.

R3^{1} Not generally acceptable, unless it can be shown that*:*

- the groundwater in the aquifer is confined; or
- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

R3^{2} Not generally acceptable, unless it can be shown that:

- there is a minimum consistent thickness of 3 metres of low permeability subsoil present;
- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

R4 Not acceptable***.***

Regionally Important Aquifers

The siting of landfills on or near regionally important aquifers should only be considered:

- Where the hydraulic gradient (relative to the leachate level at the base of the landfill) is upwards for a substantial proportion of each year (confined aquifer situation).
- Where the proposed landfill is located in the discharge area of an aquifer. In this case surface water may be more at risk.
- Where a map showing a regionally important aquifer includes low permeability zones or units which cannot be delineated using existing geological and hydrogeological information but which can be found by site investigations. Location of a landfill site on such a unit may be acceptable provided leakage to the permeable zones or units is insignificant.
- Where the wastes types are restricted and the waste acceptance procedures employed are in accordance with the criteria specified by the EPA.

Investigations

Special attention should be given to checking for the presence of more permeable zones, such as faults, particularly in fractured bedrock aquifers. Geophysical surveys may be used to identify zones which should be investigated further by drilling to determine their vertical and lateral extent. Hydrogeological tests should also be carried out to define the local and regional effects of the zones. Investigations should be carried out in accordance with the EPA's Landfill Manual *Investigations for Landfills, 1995*.

References

DoELG/EPA/GSI, 1999. Groundwater Protection Schemes. Department of the Environment and Local Government, Environment Protection Agency and Geological Survey of Ireland.

EPA, 1995. Landfill Manual: Investigations for Landfills. Environmental Protection Agency.

EPA, 1995. Landfill Manual: Landfill Monitoring. Environmental Protection Agency.

EPA, 1997. Landfill Manual: Landfill Operational Practices. Environmental Protection Agency.

EPA, 1999. Landfill Manual: Landfill Site Design. Environmental Protection Agency.

Appendix C

CDM Smith Reporting

Integrated Materials Solutions Ltd

IMS Hollywood Landfill, The Naul, Co. Dublin

Groundwater Level Monitoring and Aquifer Test Report

May 2019

Document Control Sheet

Client	Integrated Materials Solutions Limited			
Project	IMS Hollywood Landfill, The Naul, Co. Dublin			
Project No:	118113			
Report	Groundwater Level Monitoring and Aquifer Test Report			
Document Reference:	118113/40/DG/18			
Version	**Author**	**Checked**	**Reviewed**	**Date**
1	C McCabe H Moe	R O'Carroll	J Hunt	9 May 2019

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Abbreviations

ABP	An Bord Pleanala
BH	Borehole
BOTR	Bog of the Ring
C-J	Cooper-Jacob
EPA	Environmental Protection Agency
GSI	Geological Survey Ireland
IMSL	Integrated Management Solutions Ltd
LF	Loughshinny Formation
mOD	Metres above Ordnance Datum
OSI	Ordnance Survey of Ireland
PWS	Public Water Supply
TW	Trial Well

Limitations

CDM Smith Ireland Ltd. (CDM Smith) has prepared this report for the use of Integrated Material Solutions Limited (IMSL) in accordance with the Agreement under which our services were performed.

Data sourced from previous reports undertaken by third parties have been incorporated into this report. These data have been assumed to be correct for the purposes of this assessment. No responsibility is taken by CDM Smith for inaccuracies in the data supplied by any other party.

Section 1 Introduction

1.1 Background

Integrated Materials Solutions Limited (IMSL) holds an EPA Waste Licence (W0129-02) for the operation of an inert landfill at Hollywood Great, Nag's Head, The Naul, Co. Dublin (the site). IMSL previously sought an application to operate a hazardous waste landfill which was approved by An Bord Pleanala (ABP) but was refused by the Environmental Protection Agency (EPA). In their Final Determination[1], the EPA expressed concerns that:

- *"The Groundwater Protection Responses for Landfills …. indicate that the installation of the proposed activity in the geological setting, as proposed, is generally not acceptable. The conditions in which the proposed activity would be acceptable have not been demonstrated to exist".*
- *"The groundwater beneath the landfill site, as proposed, is vulnerable to contamination from the proposed activity"*
- *"The abstraction of groundwater at the Bog of the Ring (public water supply) may influence the groundwater levels beneath the landfill site, as proposed. Consequently, if the water abstraction at the Bog of the Ring were to reduce significantly or cease altogether, this may result in a rebound of groundwater levels beneath the landfill site, as proposed. This scenario would present an unacceptable risk to groundwater because the rising groundwater levels would have the potential to undermine the integrity of the landfill.*

In reaching their decision, the EPA cites the technical review by Geosyntec Consultants (2014) which highlights gaps in the understanding of the site hydrogeology and potential risks to the BOTR wellfield. The site and BOTR locations are shown in Figure 1.

1.2 Project Objectives

The current report addresses two specific questions that arose from the Geosyntec review:

- Are groundwater levels at the site affected by pumping at the BOTR wellfield?
- What is the degree of hydraulic connectivity between groundwater in the Namurian rocks and the Lougshinny Formation at the site?

Addressing these questions frames the objectives of the current report. The first question is related to the EPA's concern that future rising groundwater levels (as a result of reduced pumping at the BOTR wellfield) could undermine the integrity of the landfill. The second question is linked to groundwater susceptibility to contamination at the site. Specifically, Geosyntec questioned the results of the previous test pumping of existing well BH17, noting that BH17 was open to, and pumped groundwater from, both the Namurian and Loughshinny Formation (LF). As a result, it was stated that the test pumping of BH17 could not be relied on to

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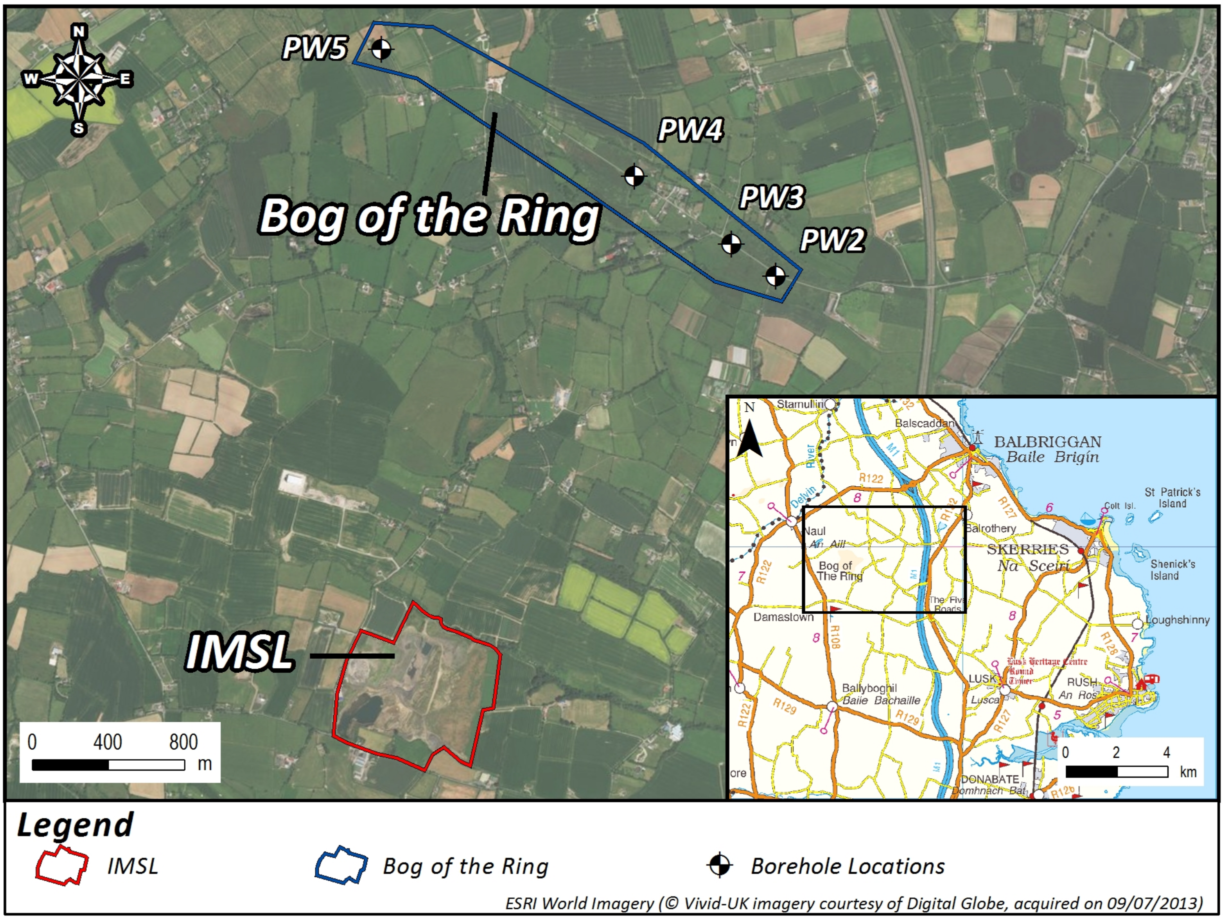
[1] EPA Final Determination dated 6 January 2016 entitled "Notification of Decision of the Agency to Refuse and Industrial Emissions Licence Under Section 83(1) of the Environmental Protection Agency Act 1992, as Amended".

evaluate the degree of hydraulic connection (or isolation) between the Namurian and LF at the site.



ESRI World Imagery (© Vivid-UK imagery courtesy of Digital Globe, acquired on 09/07/2013)

Figure 1: Locations of the IMSL Site and the Bog of the Ring Wellfield

1.3 Scope of Work

CDM Smith Ireland Ltd provided technical services to IMSL as follows:

- Conducting long-term groundwater level monitoring data in onsite and offsite wells; and
- Conducting a long duration aquifer test of the LF at the site whilst monitoring responses to pumping in onsite and offsite monitoring wells.

The associated data were subsequently analysed and assessed to:

- Identify if BOTR pumping affects groundwater levels at the site;
- Confirm groundwater flow directions at and near the site;
- Check the hydraulic connectivity between the Namurian and LF at the site; and
- Obtain reliable estimates of transmissivity and storativity of the Namurian rocks and LF at the site.

The technical work involved:

- Dipping onsite and offsite monitoring wells periodically (bi-weekly or monthly) over a 1-year period between February 2018 and February 2019;
- Equipping a subset of onsite and offsite monitoring wells with pressure transducers to record groundwater levels continuously and automatically over the same period;
- Drilling and installing a new onsite trial well (BH32) for aquifer testing purposes and which is open to the LF only;
- Drilling and installing an offsite monitoring well (BH31-OS) which is open to the Namurian rocks only at a location between the site and the BOTR wellfield;
- Implementing an aquifer test of the LF by pumping BH32 continuously over a 13-day period whilst measuring groundwater levels in the onsite and offsite monitoring wells;
- Installing a rain gauge at the site to support the interpretation of hydrographs and the aquifer test;
- Taking flow measurements of the small stream which runs along the northern boundary of the site;
- Surveying all new wells and stream elevations to Irish Grid and Ordnance Datum (OD) (Malin Head); and
- Downloading and reviewing groundwater level data from existing observation wells at the BOTR wellfield which are available through the EPA national groundwater monitoring network database on the EPA’s Hydronet (https://www.epa.ie/hydronet/).

1.4 Report Structure

The current report is structured as follows:

- Section 2 – Overview of existing wells referenced from the current report;
- Section 3 – Description and assessment of the long-term monitoring which examines the potential hydraulic influence of BOTR pumping on groundwater levels at the site;
- Section 4 – Presentation of groundwater flow directions and gradients at the site;
- Section 5 – Description and presentation of the newly drilled wells BH31-OS and BH32;
- Section 6 – Description of the aquifer test of the LF with trial well BH32;
- Section 7 – Analysis of the aquifer test of the LF based on data from all available monitoring wells;
- Section 8 – Concluding remarks; and
- Section 9 – References.

All related appendices are included as Volume 2 of this report.

Section 2 Overview of Existing Wells

Existing onsite and offsite monitoring wells which were accessed and used for the current study are summarised in Table 1 and their locations are shown in Figure 2 (onsite) and Figure 3 (offsite). The logs and details of most of these wells are presented in past study reports related to IMSL's application for a hazardous waste landfill and are therefore not reproduced in the current report. The wells were accessed and used for the purposes of groundwater level monitoring.

Eight onsite and one offsite well reflect groundwater conditions in the LF. The onsite wells include BH32 which was installed in November 2019 for purposes of aquifer testing, as described in Sections 5 through 7.

Eleven onsite and two offsite wells reflect groundwater conditions in the Namurian. The offsite wells include BH31-OS which was installed in November 2019 for the purposes of confirming groundwater levels in the offsite area between the site and the BOTR wellfield.

Existing onsite well BH17 is screened across both the Namurian and LF and was rejected by Geosyntec in terms of being a suitable well for aquifer testing purposes. Existing onsite well BH08 is partly screened across overburden materials but is also screened in the Namurian.

In addition to the wells listed in Table 1, the BOTR wellfield comprises four active production wells, PW2, PW3, PW4 and PW5. These range in depth from 53 to 91 m. Each well is completed in, and pumps groundwater from, the LF although wells PW2 and PW3 are also screened across shallow gravels which contributes groundwater to respective wells.

Observation wells OW-2D is located in the centre of the wellfield between PW2 and PW3 and monitors the LF. Well OW-2D is particularly helpful in that it provides data on groundwater levels in the LF at the wellfield location. Adjacent well OW-2S is screened across shallow sand and gravel deposits which overlie the LF. Both wells are equipped with pressure transducers and form part of the EPA national groundwater level monitoring network.

Table 1: Existing Monitoring Wells Used and Referenced for Study Purposes

Well	Easting (Irish Grid)	Northing (Irish Grid)	Reference Point Elevation (mOD)	Formation/ Response Zone
BH10A	315522.0	257697.0	136.985	Loughshinny
BH14	315938.0	257631.0	125.064	
BH15A	315786.3	257849.6	106.134	
BH18	315711.0	257996.4	110.403	
BH25	315713.0	257875.5	105.182	
BH30	315970.4	258072.5	123.979	
BH32 ("Pumping Well")	315893.0	258108.9	106.027	
TW10 (offsite)	317657.6	259767.2	52.478	
BH05	315796.0	258328.0	118.615	Namurian
BH08A	315482.3	258074.7	136.687	
BH09	315560.0	258280.0	128.759	
BH11A	316112.0	258249.0	99.96	

Well	Easting (Irish Grid)	Northing (Irish Grid)	Reference Point Elevation (mOD)	Formation/ Response Zone
BH19	315887.1	258059.1	105.52	
BH20	315862.6	258102.3	104.178	
BH24	315954.5	258209.5	106.039	
BH26	315881.3	258086.0	105.15	
BH27	315756.7	258018.2	106.321	
BH28	315879.6	257909.7	125.88	
BH29	315985.9	258071.2	123.415	
BH31-OS	316379.4	259315.7	128.427	
TW07 (offsite)	317219.5	258103.3	69.32	
BH17	315794.7	258003.1	105.295	Loughshinny and Namurian
BH08	315479.0	258069.0	136.748	Overburden / Shallow Namurian

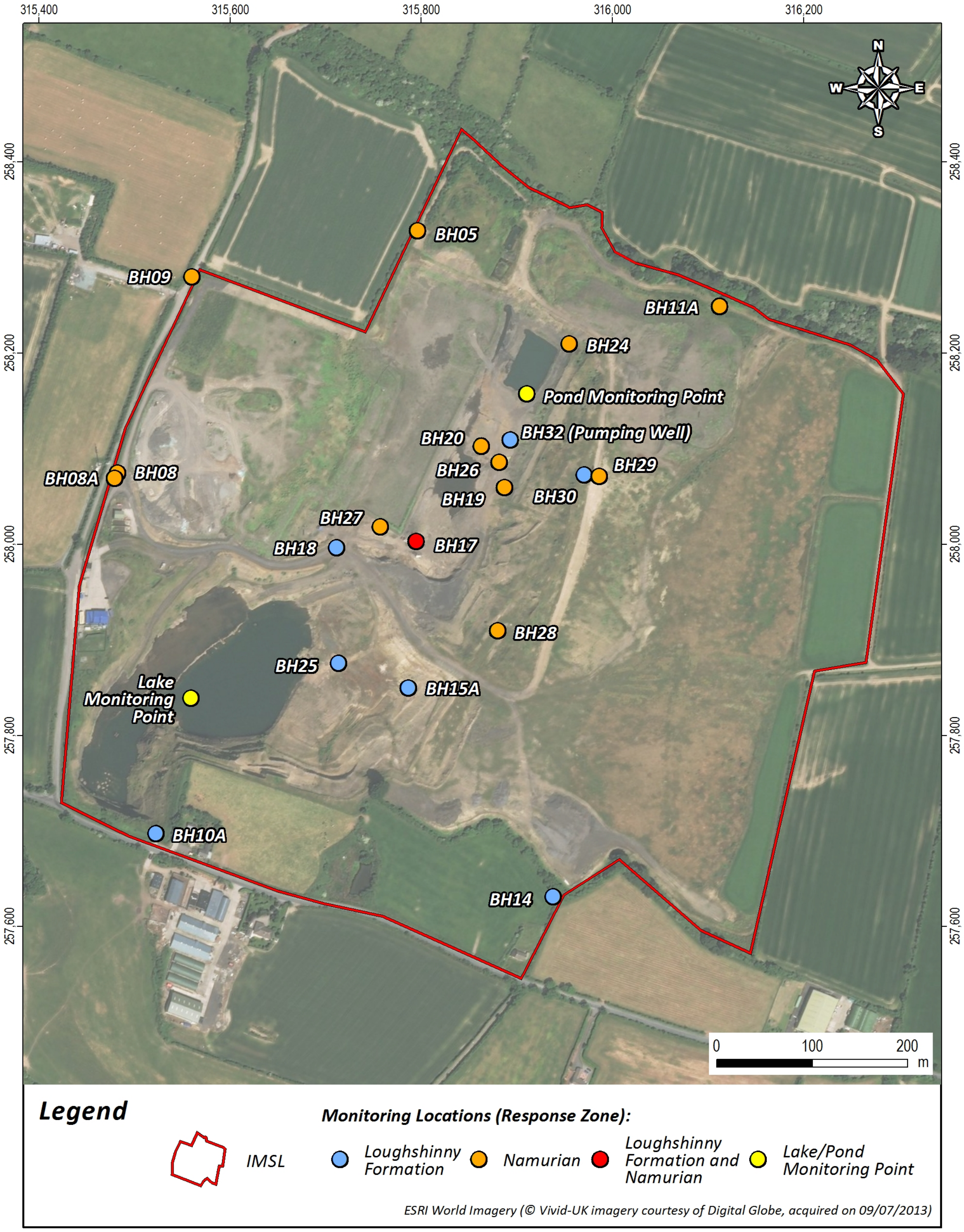


Figure 2: Locations of Onsite Wells Used for Aquifer Test and Long-Term Monitoring Purposes

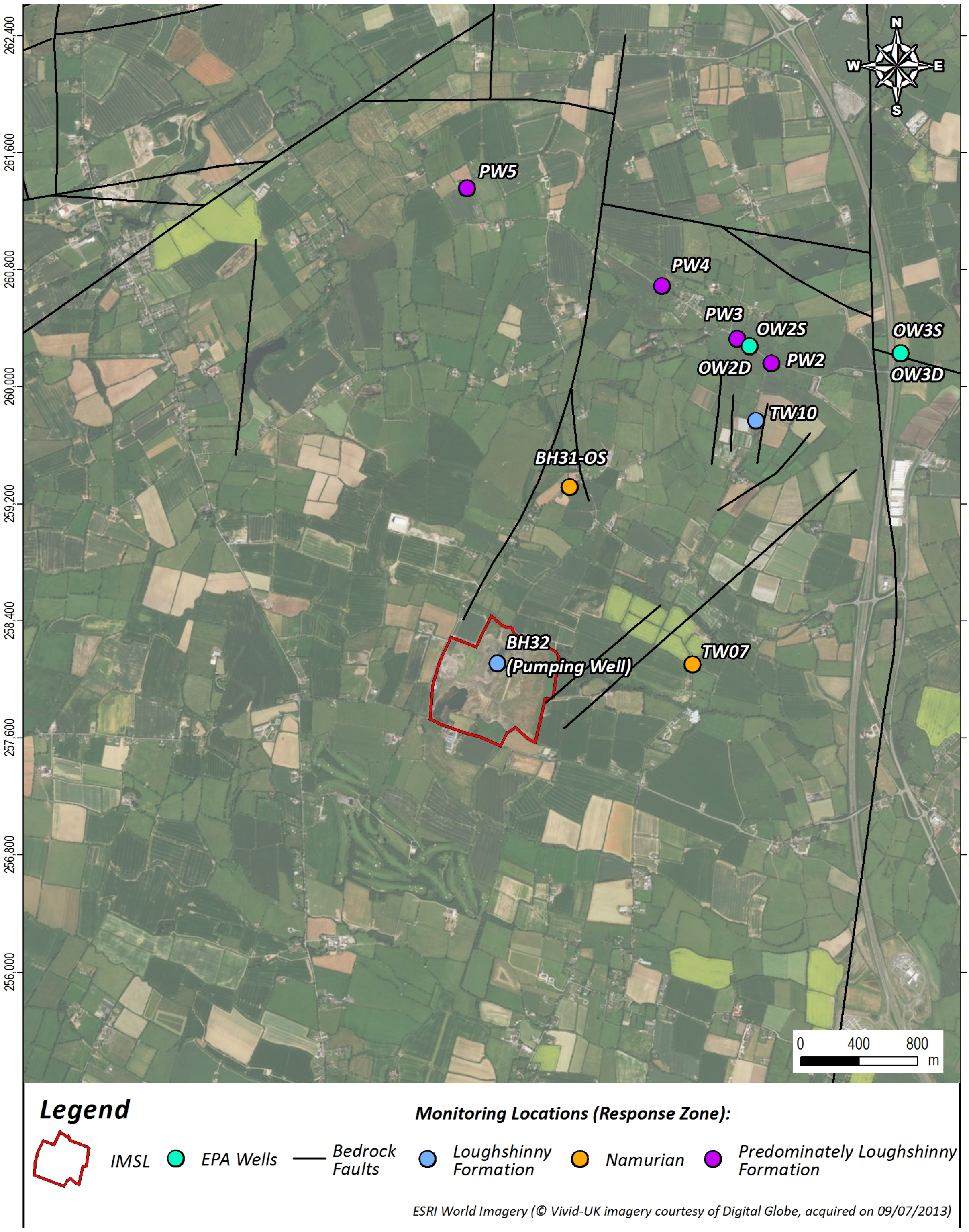


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Figure 3: Location of Offsite Wells Used for Monitoring Purposes and BOTR Production Wells

Section 3 Long-Term Groundwater Monitoring

Based on pressure transducer installations and manual groundwater level measurements, groundwater hydrographs were collated, processed and reviewed from mid-February to mid-October 2018. This period included, and was characterised by, a prolonged dry summer season (commonly referred to as the "2018 drought" which affected the whole country). Based on data from Irish Water, the BOTR production wells were operating at maximum to meet water demands and total wellfield production rates were maintained at approximately 2,700-2,800 m^3/d over the drought period.[2]

The groundwater level data from the drought period provide the best possible opportunity to ascertain if the hydraulic influence of wellfield pumping extends to the site. This is because the zone of influence of BOTR pumping would be greater during drought conditions as groundwater recharge does not occur and groundwater is being pumped from storage in the fractured bedrock aquifer.

The examination of groundwater levels at the BOTR wellfield relied on data from monitoring well OW-2D. As mentioned in Section 2, well OW-2D monitors groundwater levels in the LF which is the same geological formation that is pumped by the BOTR production wells.

At the site, pressure transducers were installed to record groundwater levels in:

- Wells BH5 and BH24, both screened/open to Namurian rocks;
- Wells BH10A and BH15A, both screened/open to the LF;
- Well BH17 which is screened/open to both Namurian and LF rocks; and
- Well BH20 which is mainly screened in the Namurian (the well was drilled into the LF but this section was reportedly grouted up).

The data from each of the onsite wells were corrected for barometric pressure. Data sequences were adjusted to account for discontinuities in the time series which arose when the pressure transducers were periodically removed from the wells for downloading purposes and subsequently reinstalled.[3]

The hydrographs of OW-2D and landfill wells are presented in Figure 4. The OW-2D hydrograph shows:

1. Seasonality (higher groundwater levels in the winter season compared to the summer season); and
2. Temporal changes in the pumping regime and pronounced effects of production wells turning on and off (drawdown and recovery responses).

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[2] Irish Water operates a full SCADA system at the wellfield. Detailed records were requested from Irish Water but were not obtained and must be requested through the Freedom of Information Act.

[3] The adjustments required to generate continuous hydrographs introduce minor inaccuracies relative to mOD. However, the adjustments do not affect hydrograph shape and trends and, therefore, do not affect interpretations of hydrograph responses.

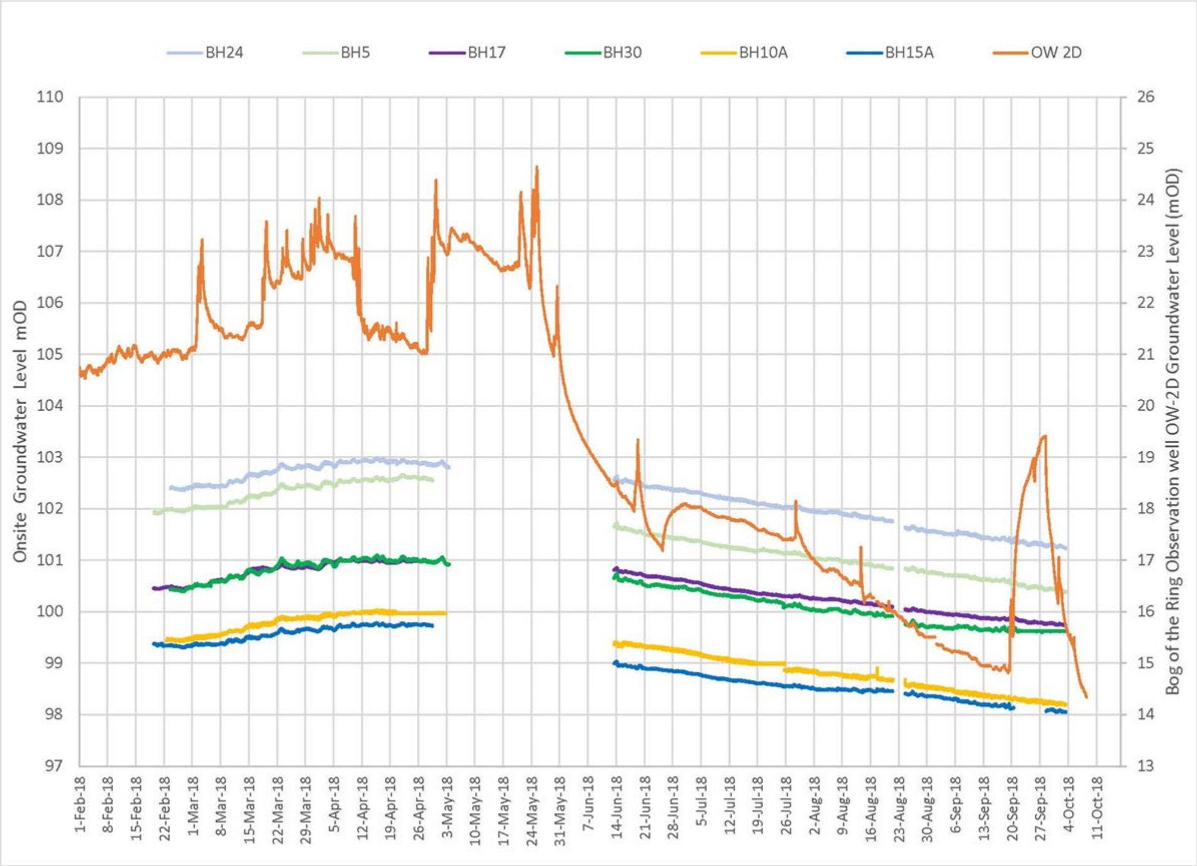

Figure 4: Measured Groundwater Level Response in OW-2D and Onsite Wells

The drawdown and recovery responses are superimposed on the seasonal (winter/summer) response. The steep and prolonged drawdown observed through May and June 2018 (especially) reflects the low to no rainfall period between late April and August 2018 and is highlighted in Figure 5.[4] The steeper observed drawdown gradient in OW-2D in August compared to July is attributed to gradual resource depletion (groundwater removed from storage in the LF) during the summer drought.[5]

The hydrographs of landfill wells show seasonality only, with a gentle groundwater level rise in the winter season and a gradual lowering (shallow gradient) in summer. Drawdown and recovery cycles are absent. Minor (cm-scale) fluctuations in measured water levels during the monitoring period are linked to tidal and/or barometric pressure effects.

None of the landfill wells responded to BOTR wellfield operations during the extended monitoring period, including the 2018 drought.

- The onsite hydrographs did not respond to the variable BOTR pumping regime in March and April 2018 (as displayed by OW-2D).

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[4] Daily rainfall data obtained from Met Eireann for Dublin Airport

[5] BOTR pumping rates were reportedly steady and at maximum through the summer period.

- The onsite hydrographs also did not respond to the significant recovery event which is observed in OW-2D on 19 September 2018, and which is followed by an equally significant drawdown event which began on 28 September 2018.

Unlike the onsite wells, the late-September recovery/drawdown event was observed in offsite wells TW-7 and TW-10 during the available period of record in these wells (28 August - 3 October 2018). Both wells are located between the wellfield and the site (Figure 6). TW-10, which is closer to the wellfield and monitoring groundwater levels in the LF, responded by approximately 1.5 m. TW-7, which is further from the wellfield and monitoring the Namurian, responded less than 0.25 m.

The recovery event on 19 September 2018 was caused by a pump outage in turn caused by a widespread ESB outage in the region. Based on information received from Irish Water, this outage put BOTR production well PW2 out of commission, and the total production dropped from 2,700 m^3/d to 2,100 m^3/d. Well PW2 came back online and full operations were restored on 28 September 2018 which explains the subsequent drawdown response.

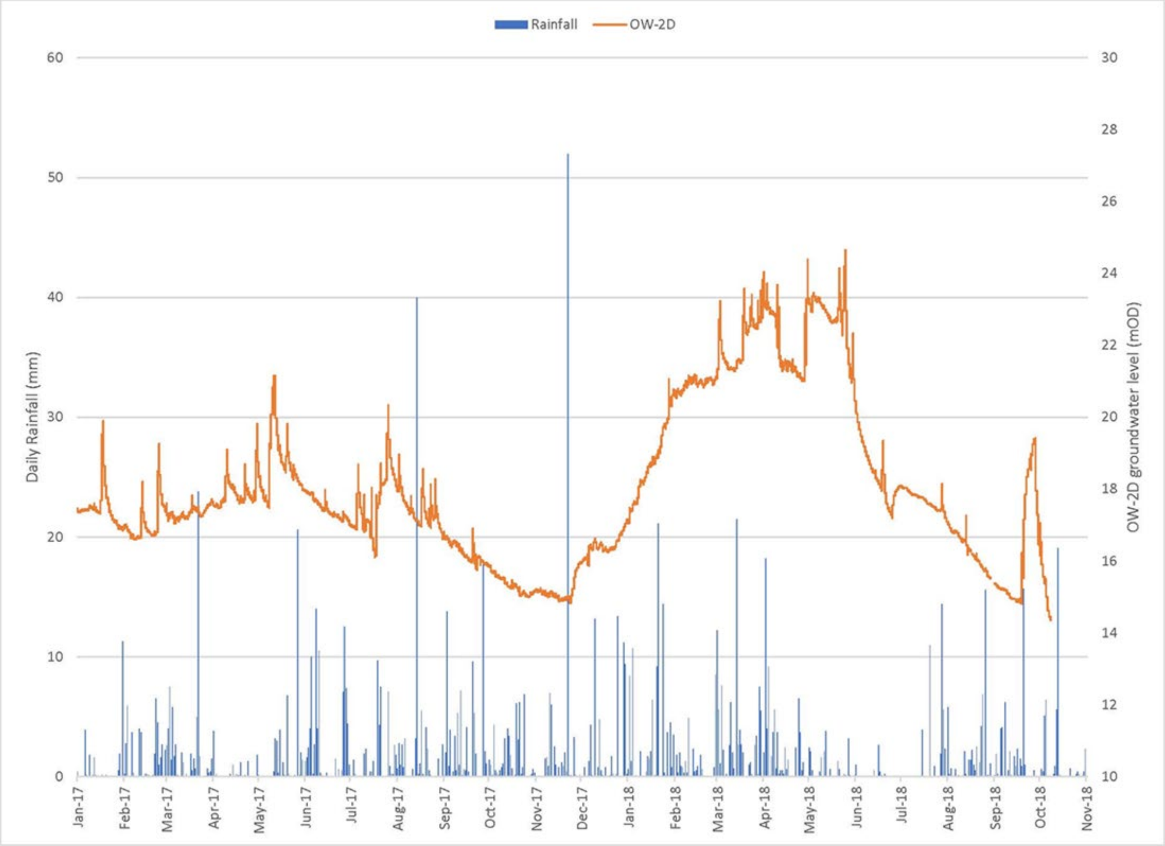

Figure 5: Daily Rainfall at Dublin Airport and Measured Groundwater Level Response in OW-2D

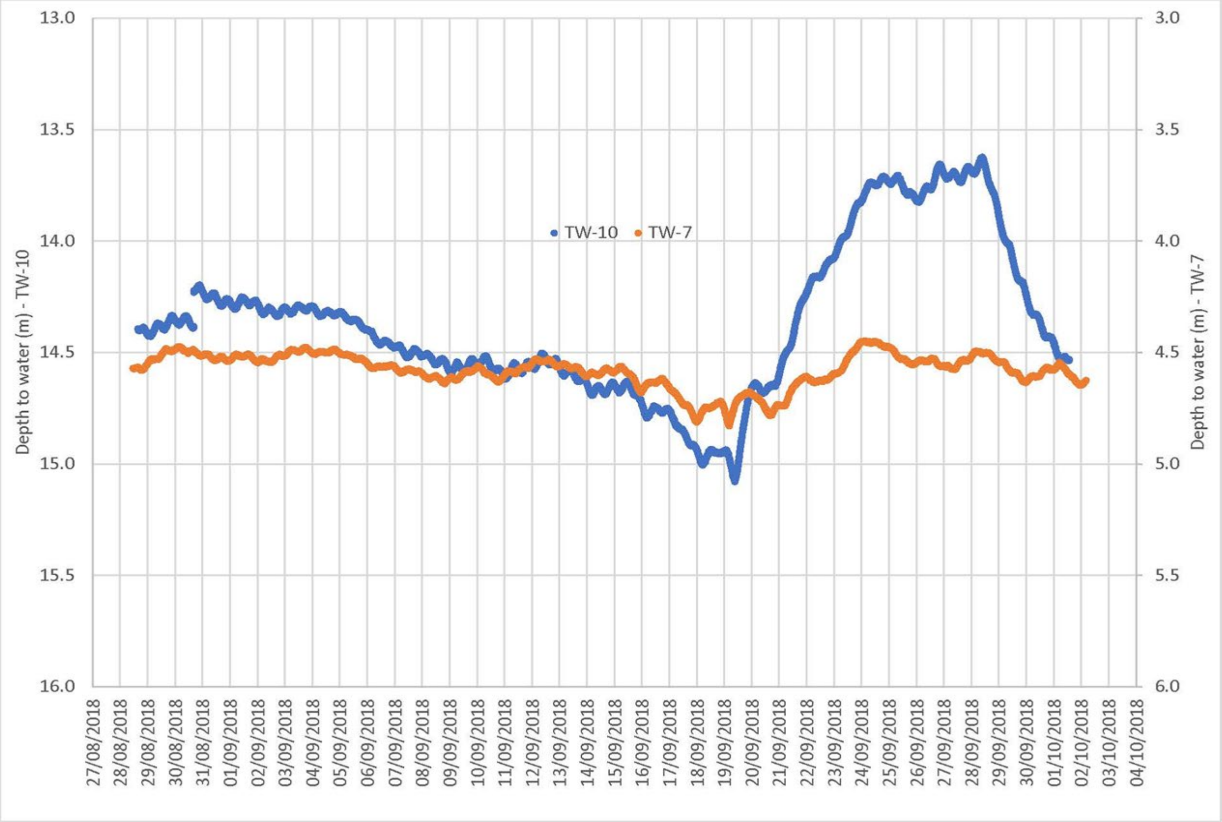

Figure 6: Measured Groundwater Level Response in TW-7 and TW-10

Section 4 Groundwater Flow Directions

4.1 Introduction

Groundwater contour maps were prepared using manually measured groundwater level data (**Appendix 1**). For wells that monitor groundwater in the Namurian rocks, groundwater contours show an overall easterly flow gradient (Figure 7 and Figure 8). For wells that represent the LF, groundwater contours show an overall southeasterly flow gradient (Figure 9 and Figure 10). Note that in the LF maps, the water body in the southwestern corner of the site reflects the groundwater level in the LF. The lake is up to 10 m deep in an area where LF rocks have been excavated. The groundwater mounding that is evident in the centre of the site (Figure 9) is likely related to shallow ponds near BH19 and BH24. The ponds are clay-lined but there may be leaks. When the pond fills up a narrow excavated drainage channel is unable to empty into the pond which would further add to the mounding potential of shallow groundwater in this area.

As shown in Table 2, data from adjacent paired wells BH29/BH30 (Namurian/(LF) as well as BH26/BH32 (Namurian/LF) indicate that hydraulic heads in the LF are generally higher than in the Namurian at the site.

Table 2: Groundwater Levels in Paired Namurian/LF Wells

Date	Groundwater Elevation (m OD)			
	Pair 1		Pair 2	
	Namurian	LF	Namurian	LF
	BH29	BH30	BH32	BH26
15/11/2018	98.72	98.81	100.53	100.57
17/12/2018	98.87	99.01	100.46	100.65
22/01/2019	99.29	99.46	101.26	101.33
15/02/2019	99.30	99.47	101.34	101.28
08/03/2019	99.28	99.44	101.36	101.42
11/04/2019	98.87	99.07	101.20	101.29

Finally, groundwater levels in the new offsite well BH31-OS are higher in elevation than groundwater levels at the site. Thus a flow vector exists back towards the site from well. This demonstrates that a groundwater divide also exists between the site and the BOTR wellfield.

4.2 Groundwater Contribution to Stream

A small stream flows from the west to the east along the northern boundary of the site (Figure 8). The streambed elevation drops from 112.07 mOD to 88.319 mOD at the surveyed locations (Figure 8). Namurian groundwater levels exceed the streambed elevation in the eastern half of the site. Therefore, the stream would receive groundwater baseflow along the eastern section of the site boundary. To confirm this, streamflow measurements were taken in February 2019. Two V-notch weirs and water level data loggers were installed at upstream and downstream locations (Figure 10 and Figure 11) between 4 and 21 February 2019. The logger data were converted to flows based on the relationship between water levels and flow established from field measurements. Two additional loggers were placed in the stream at surveyed locations away from the V-notch weirs to record water levels (Table 3).

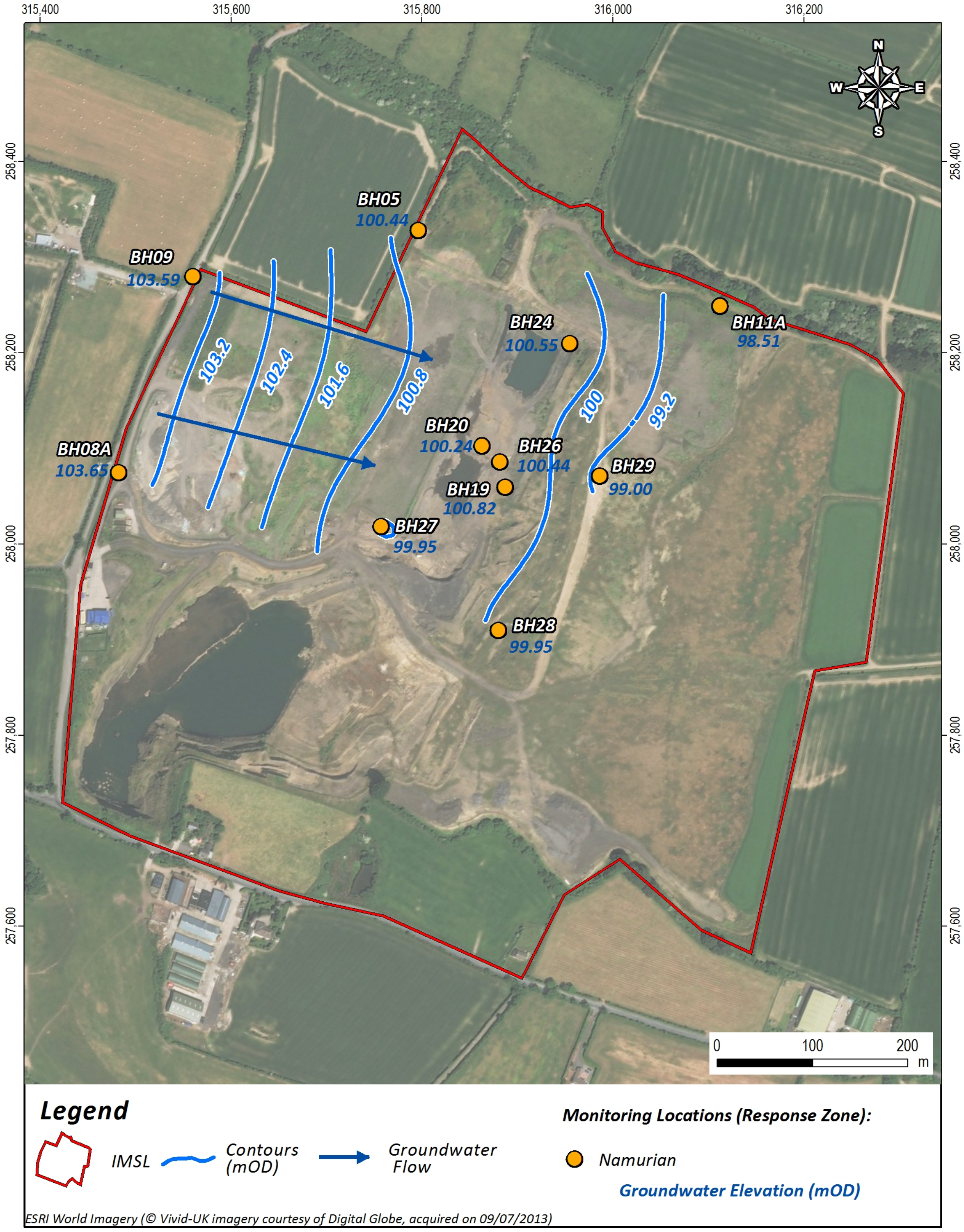

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Figure 7: Interpreted Groundwater Contours – 15 November 2018 – Namurian Wells

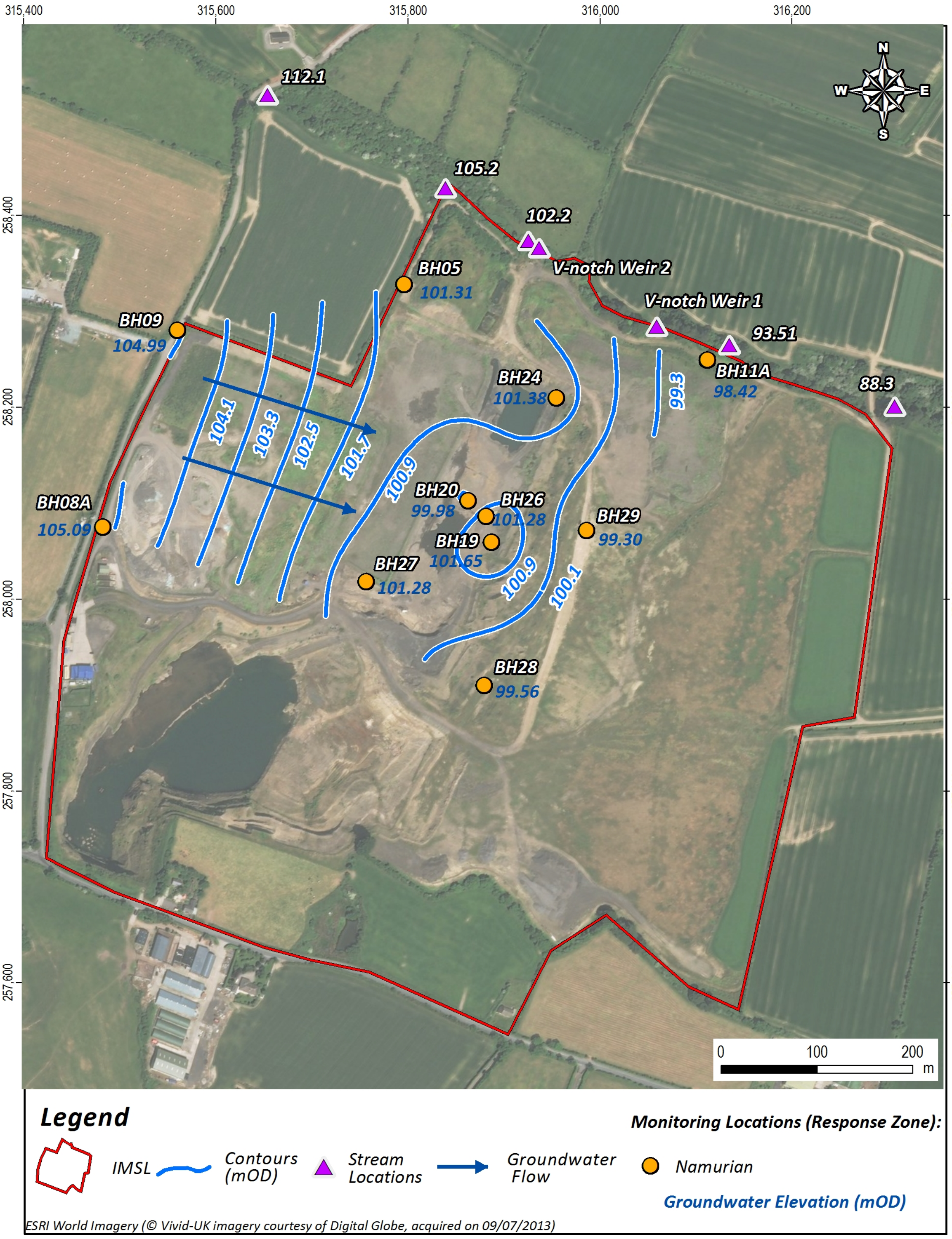
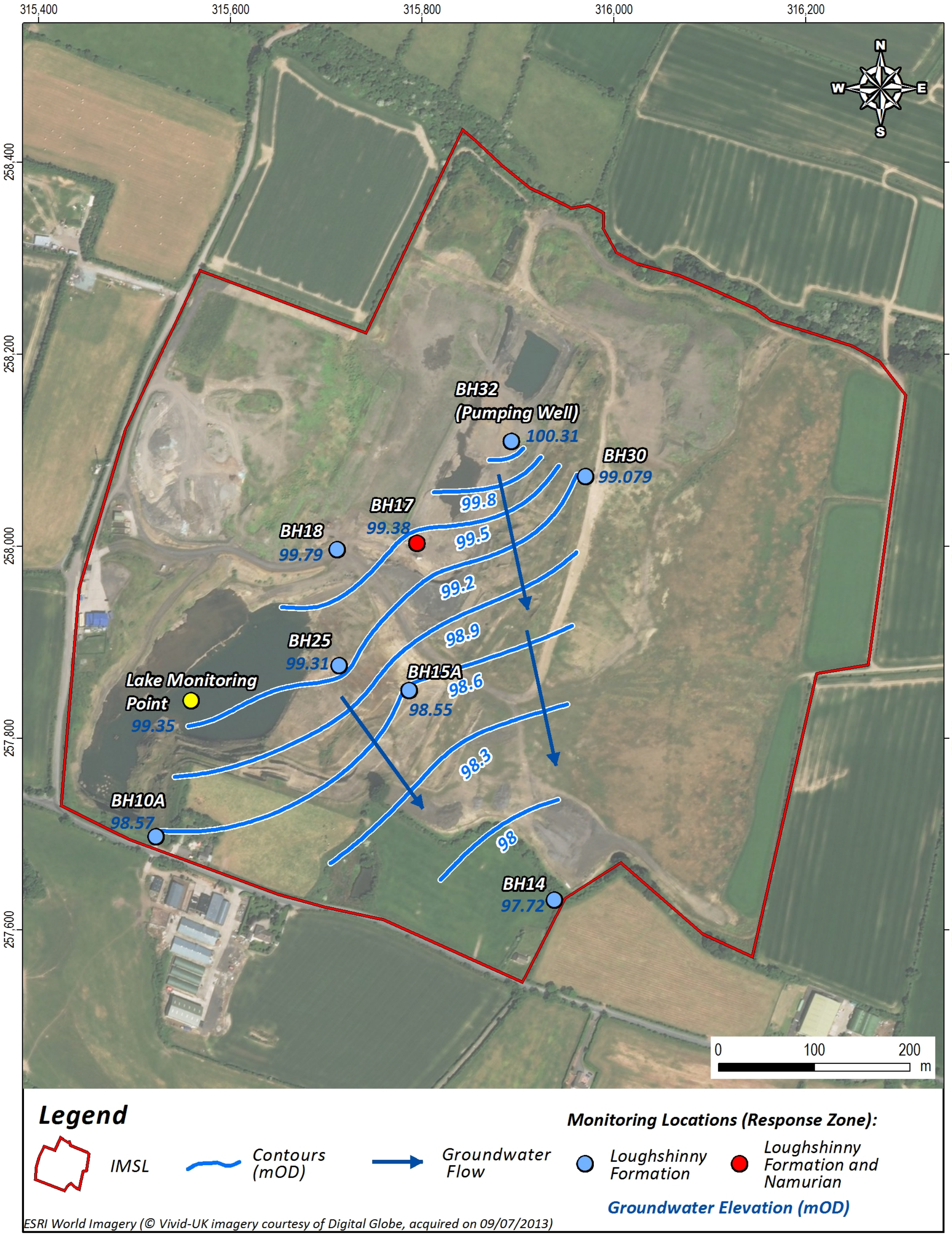


Figure 8: Interpreted Groundwater Contours – 02 February 2019 – Namurian Wells



ESRI World Imagery (© Vivid-UK imagery courtesy of Digital Globe, acquired on 09/07/2013)

Figure 9: Interpreted Groundwater Contours – 15 November 2018 – Loughshinny Formation Wells

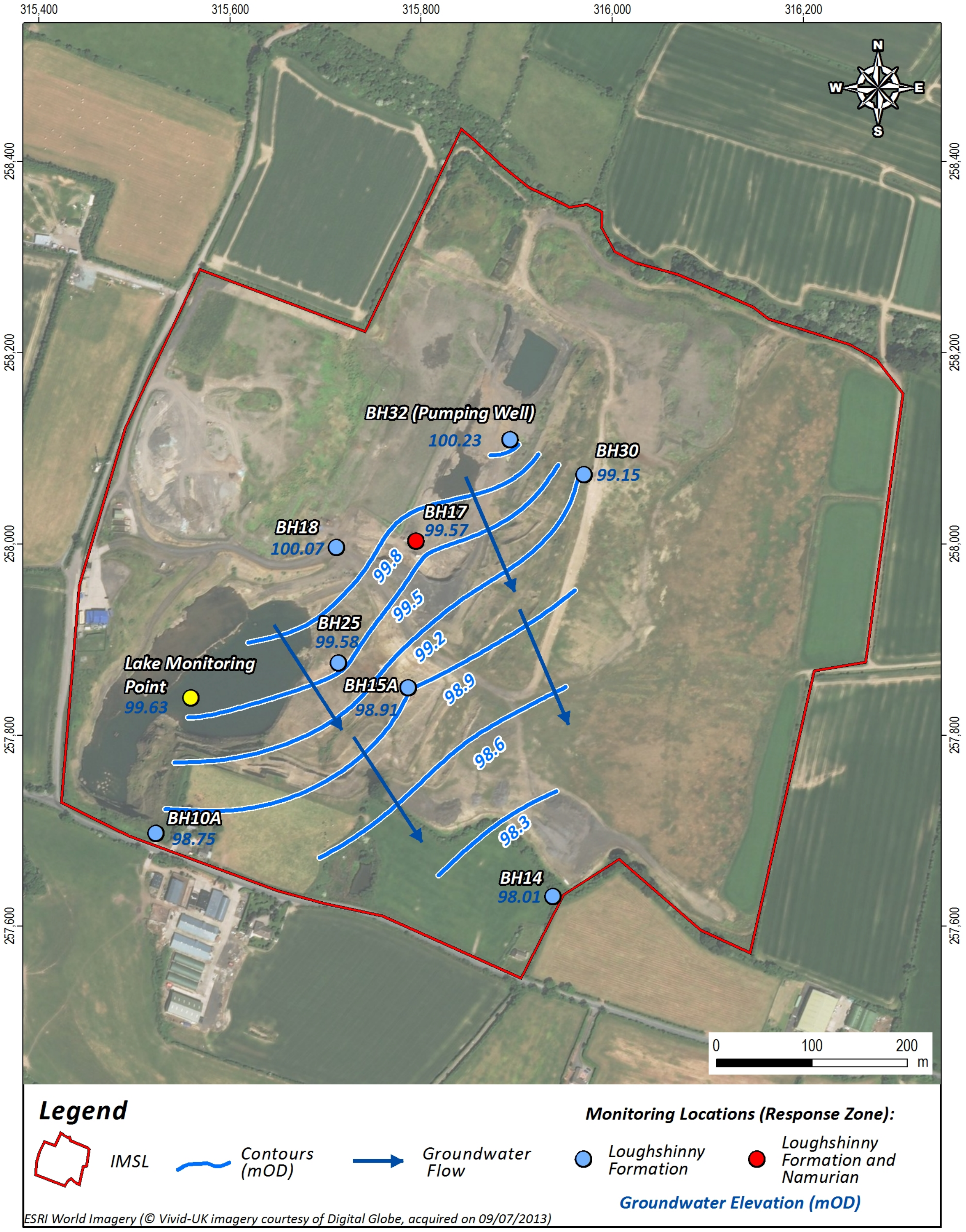


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Figure 10: Interpreted Groundwater Contours – 17 December 2018 – Loughshinny Formation Wells

Figure 11: V-notch Weir 1 (left) and V-notch Weir 2 (right)

Table 3: Stream Survey Points

Point ID	Easting (Irish Grid)	Northing (Irish Grid)	Reference Point Elevation (mOD)	Purpose
SB1	315653.8	258525.3	112.066	Streambed Elevation
Weir 2 (downstream)	315839.4	258428.6	105.200	Logger Location/ Elevation
SB2	315925.4	258373.7	102.242	Streambed Elevation
Weir 1 (upstream)	316135.1	258265.03	93.51	Logger Location/ Elevation
SB3	316307.3	258200.7	88.319	Streambed Elevation

Despite minor undercutting and bypass of water at the weirs, reasonable streamflow measurements were possible due to the low-flow conditions that prevailed at the time of monitoring. Manually measured streamflows during the deployment period ranged between 0.4 and 5.79 litres per second (l/s), with a geometric mean of 2.0 l/s. The flows over the downstream weir on dry days (i.e. no overland flow contribution from adjacent fields) were slightly higher than the upstream weir (e.g. 2.1 vs 2.9 l/s on 4 February 2019), indicating that the stream may be gaining as it passes the site.

The water level data for the two weirs are presented in Figure 12 (Weir 1) and Figure 13 (Weir 2) along with daily rainfall measured at the site for the period between 22 January and 16 February 2019. The hydrograph suggests a relatively flashy response to rainfall.

There is a dominant east-west drainage pattern near the site which follows parallel topographic ridges and valleys (Figure 14).

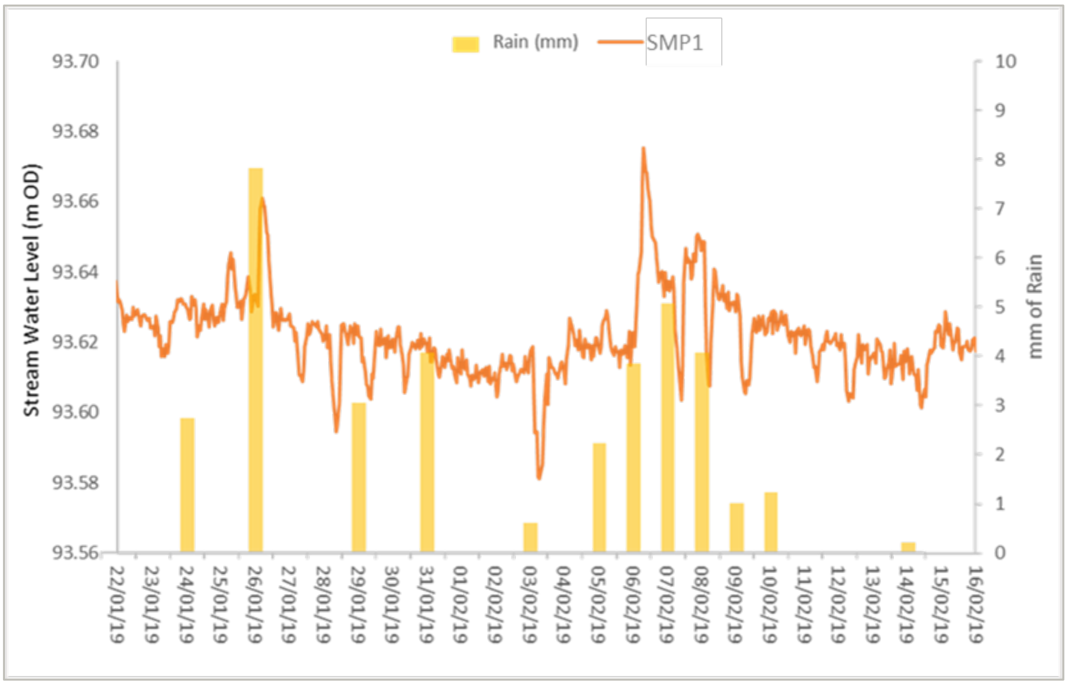

Figure 12: Weir 2 (upstream) Water Levels and Site Rainfall Data

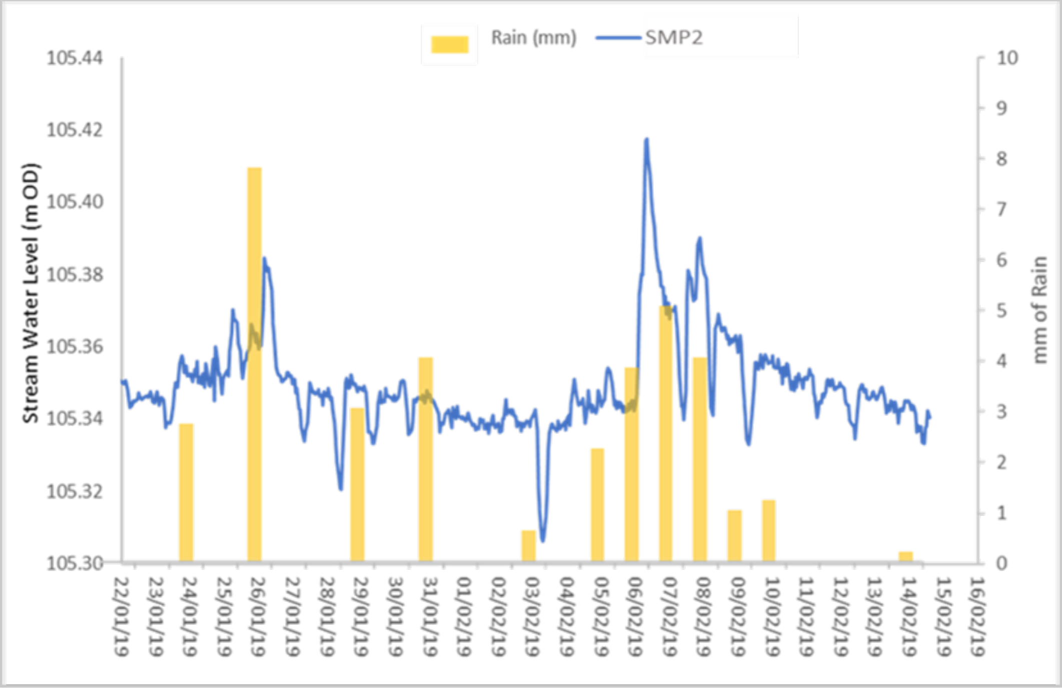

Figure 13: Weir 1 (downstream) Water Levels and Site Rainfall Data

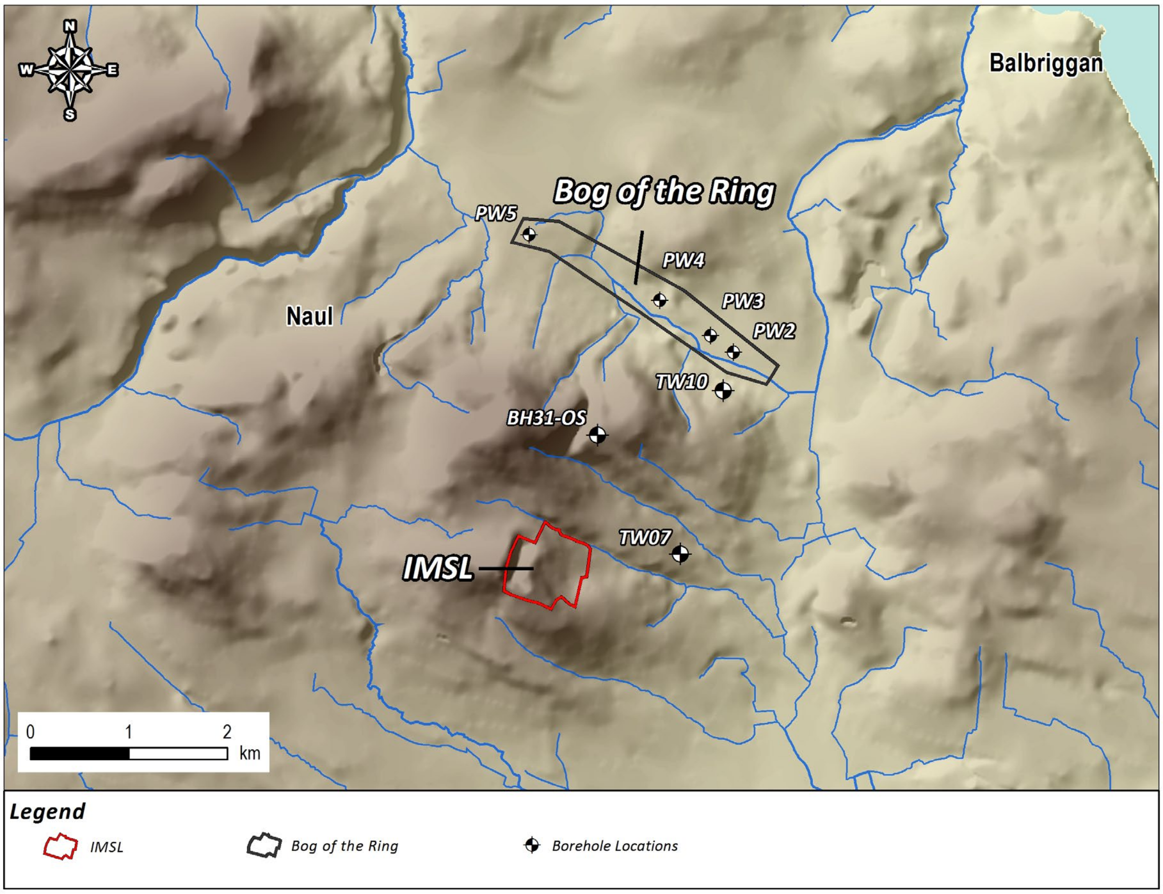

Figure 14: East-West Surface Water Drainage in the Site Area

Section 5 Well Drilling and Installation

Two new wells were drilled and installed as part of the updated technical assessment for the site, as follows:

- BH32 – an onsite trial; and
- BH31-OS – an offsite monitoring well.

5.1 BH32 (Trial Well)

The purpose of the trial well was to serve as a test pumping well of the LF at the site. The well was purposefully constructed such that the Namurian sequence rocks were cased and grouted off. The target location was on or immediately adjacent to a N-S trending fault which has been mapped across the site.

A well summary is presented in Table 4. Well construction and hydrogeological logs are shown in **Appendix 2**.

Table 4: Summary of Well BH32

Item	Description or Value	Comments
Drilling contractor	Patrick Briody & Sons Ltd	Drilling foreman - Aidan Briody
Owner's representative	CDM Smith Ireland Ltd	Supervising hydrogeologist – Conor McCabe
Well location	Holywood, Naul, Co. Dublin	Located within the site
Well coordinate	E 315892.9, N 258108.8	
Ground level elevation (mOD) – surveyed	105.031	
Reference point elevation (mOD) – surveyed	105.811	Top of steel casing
Working period	5 – 9 November 2018	
Drilling method	Air percussion from 0 to 36 mbgl Symmetrix from 36 to 48 mbgl Air percussion from 48 to 66 mbgl	
Total drilled depth (mbgl)	66	Borehole collapsed from 61-66 mbgl. Total measured depth upon completion was 61 mbgl.
Drilled diameters (mm)	381 from 0 to 6 mbgl 304.8 from 6 to 36 mbgl 203.2 from 36 to 48 mbgl 190.5 from 48 to 56 mbgl 152.4 from 56 to 66 mbgl	
Well casing (mbgl)	12-inch steel casing from 0 to 6 mbgl 8-steel casing from 0 to 51 mbgl 5-inch uPVC casing from 51 to 56 mbgl	
Diameter of inner 5-inch uPVC casing at wellhead	126.6 mm ID, 140 mm OD	
Well screen (mbgl)	Open borehole 56-66 mbgl	Screen not installed
Casing grouting	0 to 30 mbgl and 37 to 56 mbgl.	

Item	Description or Value	Comments
Wellhead details	Wellhead consists of a concrete plinth and a 0.78 m stick-up length of a 12-inch steel casing which is fitted with lockable steel cap.	Concrete plinth is protected by bollards
Static water level after well completion	5.5 metres below top of uPVC casing	Measured at 10:00 hrs on 15 November 2018.
Key geological observations	The Namurian rocks are extensively fractured. The Loughshinny Formation consists of fractured black shaley limestone.	
Key hydrogeological observations	Initial recorded water strike occurred 15 mbgl. There was a gradual increase in blow yield with depth. A significantly large void/fracture occurred between 60 and 61 mbgl. At total depth, 12 to 15 l/s was continually air-surged to the surface.	A change in the pH of the discharge water was noted during air surging between the Namurian and Loughshinny groundwater - pH 6.35 at 15 mbgl and pH of 8.31 at 61 mbgl.

The trial well was installed in the Loughshinny Formation. The completed open borehole was isolated from the Namurian rocks by the cement grouting of two sets of casing (8- and 5-inch diameters). Successful grouting was demonstrated by unchanged water levels outside the 8-inch steel and inside the 5 inch uPVC casing during the grouting operations, whilst water was displaced upwards between 8 inch steel casing and 5 inch uPVC casing. There was no emergence of grout inside the 5-inch uPVC casing.

Both the Namurian and underlying limestone are extensively fractured which caused difficulty during drilling, particularly with respect to losses of circulation. The main water-bearing interval in the completed well is 60-61 mbgl. The final borehole depth is 61 m. The open borehole between 61 and 66 mbgl collapsed due to the unstable nature of the fractured limestone rock.

Despite only being open across a 10 m section of borehole (56-66 mbgl, with the lower 5 m having collapsed), approximately 12-15 l/s was discharged at the surface during air surging. Accordingly, the objective of installing a productive well in the LF was accomplished.

5.2 BH31-OS (Observation Well)

The purpose of this borehole was to explore the geology and hydrogeology of the Namurian rocks, mainly the Walshestown Formation, in the centre of the GSI-mapped synform structure to the north of the site. The goals were:

- To verify the base level/elevation of the Walshestown Formation, which is predicted to be 15 m below sea level based on the existing geological model of the Dublin Basin published by GSI;
- To examine if, or the extent to which, Namurian rocks exhibit fracture permeability at the offsite location; and
- To install a deep monitoring well that could be used for groundwater level monitoring purposes.

A well summary is presented in Table 5. Well construction and hydrogeological logs are shown in **Appendix 2**.

Table 5: Summary of Well BH31-OS

Item	Description or Value	Comments
Drilling contractor	Patrick Briody & Sons Ltd	Drilling foreman - Aidan Briody
Owner's representative	CDM Smith Ireland Ltd	Supervising hydrogeologist – Conor McCabe
Well location	Knockbrack, Naul, Co. Dublin	Located on land currently owned by Fingal County Council.
Well coordinate	E 316379.9, N 259315.7	Irish Grid
Ground level elevation (mOD) – surveyed	128.363	
Reference point elevation (mOD) – surveyed	128.427	Top of uPVC casing
Work Period	30 October – 2 November 2018	
Drilling method	Air Percussion	
Total drilled depth (metres below ground level, mbgl)	126	At this depth, further advancement of the borehole became difficult and drilling was ended in agreement with the drilling contractor due to inherent risks of borehole collapse and getting the drill bit stuck.
Drilled diameters (mm)	374.65 from 0 to 6 mbgl 304.8 from to 6 to 18 mbgl 203.2 from to 18 to 126 mbgl	
Casing diameters	12-inch steel from 0 to 6 mbgl 8-inch steel from 0 to 18 mbgl 5-inch uPVC from 0 to 126 mbgl	Risk of sidewall collapse was deemed high. The uPVC casing/screen string was installed as a precautionary measure to allow well to be used for monitoring purposes in the future. Slotted casing was installed from 40 to 124 mbgl.
Diameter of inner 5-inch uPVC casing at wellhead	126.6 mm ID, 140 mm OD	
Slot size	0.5 to 1 mm	Manually slotted
Wellhead details	Wellhead consists of a concrete plinth and a 0.5 m stick-up length of a 12-inch steel casing which is fitted with lockable steel cap.	Concrete plinth is protected by bollards.
Static water level after well completion	25.57 metres below top of uPVC casing	Measured at 15:30 hrs on 15 November 2018.
Key geological observations	The Walshestown Formation is mainly a mudstone which is extensively weathered to 21 mbgl. Interbedded siltstones and sandstones become more frequent beneath 96 mbgl, and may represent the transition to the Balrickard Formation	
Key hydrogeological observations	Initial recorded water strike occurred 42 mbgl, and the estimated blow yield was 0.5 litres per second (l/s). There was a gradual increase in blow yield	Namurian sequence at this location has fracture permeability.

Item	Description or Value	Comments
	with depth. The main water strike occurred 84 mbgl and the estimated incremental blow yield was 2 l/s. The final blow yield at total depth was 5 l/s.	

The borehole reached a total depth of 126 m. This roughly corresponds to sea level which is 15 m above the predicted base elevation of the Walshestown Formation in GSI's geological model of the Dublin Basin (GSI, 2016). At 96 mbgl, a lithological transition appears to take place, whereby the proportion of siltstone and sandstone cuttings (relative to mudstone cuttings) increased. This may represent a transition to the Balrickard Formation but this was not confirmed.

The Namurian rocks that were encountered have fracture permeability. Incremental water strikes were recorded during drilling, and the largest water strike (estimated 2 l/s) is attributed to an interval 84 mbgl. The deepest water strike in the borehole occurred 101 mbgl.

Groundwater levels in the completed monitoring well represent mainly the Walshestown Formation. The measured water levels in the new offsite monitoring well are at a higher elevation than groundwater levels in onsite monitoring wells. This means that a groundwater divide exists and is maintained at an offsite location, i.e. between the site and the BOTR wellfield.

Although it is not installed in the Loughshinny Formation, the new monitoring well measures piezometric heads at the same structural elevation as the BOTR production wells. Thus, the deep monitoring well installation (40 to 126 mbgl) will enhance the continued monitoring of groundwater levels in the area between the site and the BOTR wellfield.

Section 6 Aquifer Test Implementation

6.1 Introduction

Well BH32 was test pumped between 16 November and 3 December 2018 to:

- Demonstrate if, or the degree to which, groundwater in the LF and the shallower Namurian rocks are hydraulically connected; and
- Derive representative hydraulic properties of the rock formations onsite, especially the LF.

To meet these objectives, the aquifer test involved the following sequence of work:

- Preparations for the test;
- An initial pre-test, to determine the likely pumping rates that the BH32 could sustain;
- A step drawdown test, to examine well performance (efficiency) and establish a suitable pumping rate for the subsequent constant rate test; and
- A long duration constant rate test.

6.2 Aquifer Test Preparation

In preparation for the aquifer test, all onsite wells were visited to determine if they could be used as observation wells. The accessible onsite wells are those shown on Figure 1. Of these, thirteen are screened/open only in Namurian rocks and seven are screened/open in the LF (Table 1). The reference point elevations that are tabulated in Table 1 are the surveyed top of uPVC or steel casing elevations that apply to water level measurements taken during the testing. Previously pumped well BH17 was also monitored, and in this case, the well is screened across both the Namurian rocks and the LF. Additional preparatory items were:

- Installation of a rain gauge onsite for measurement of rainfall. The onsite rainfall data for the test duration are shown in Figure 15. Daily rainfall ranged from 0 to 25 mm/day over the test period.
- Installation of a barometric pressure gauge for measurement of barometric pressure. The related data are also shown in Figure 15. During the test, a low pressure event occurred which was accompanied by rainfall on certain days. This is discussed further below.
- Installation of a staff gauge for measurement of water levels in the pond in the northern part of the site (Figure 2). The pond collects surface runoff. Measured water levels rose by approximately 60 cm during the test monitoring period (Figure 16).
- Installation of a slotted PVC with fixed concrete base for measurement of water levels in the lake in the southern part of the site. Lake levels rose by approximately 20 cm during the test monitoring period (Figure 17).
- Manual groundwater level measurements in existing wells using a water level metre (“dipper”). These are presented in **Appendix 1**.

- Installation of pressure transducers in each well for automatic recording of water levels during the test sequence, including recovery. Transducer data were corrected for barometric pressure. Individual hydrographs are presented in **Appendix 3**. It should be noted that wells BH28 and BH14 were not located during the initial survey of the existing monitoring wells. However, they were uncovered during the test implementation period, and pressure transducers were thus deployed for a shorter period of time.

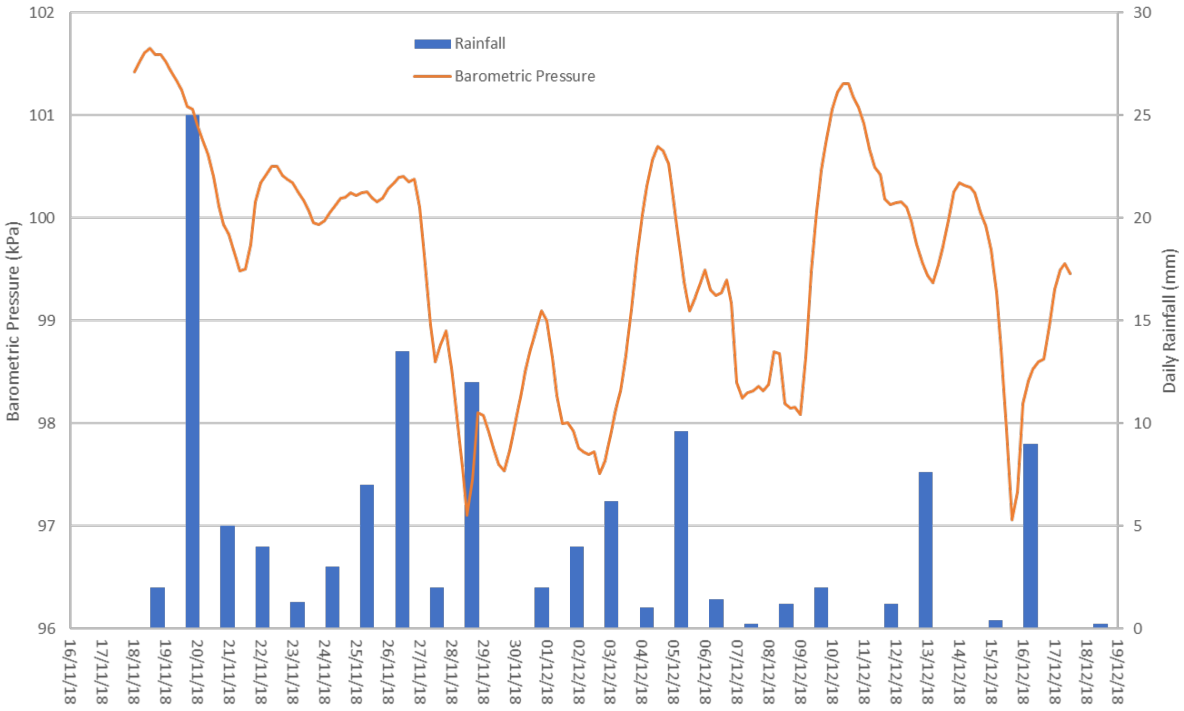

Figure 15: Rainfall and Barometric Pressure During the Aquifer Test Period

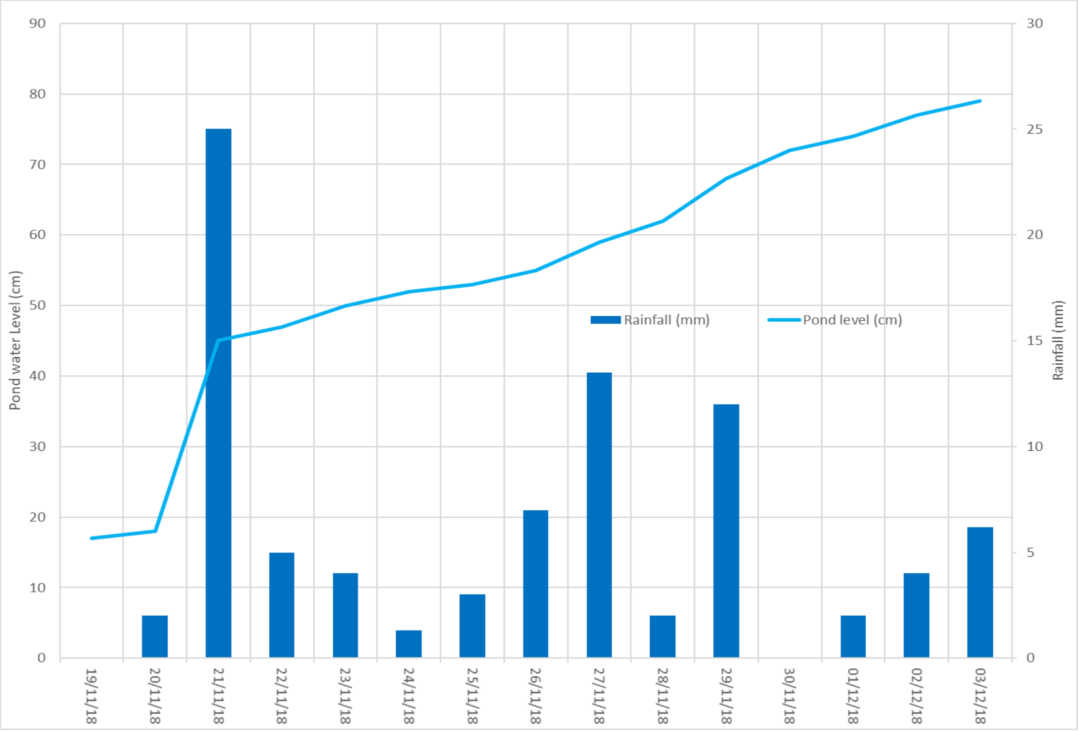

Figure 16: Rainfall and Pond Level During the Pumping Phase of the Aquifer Test

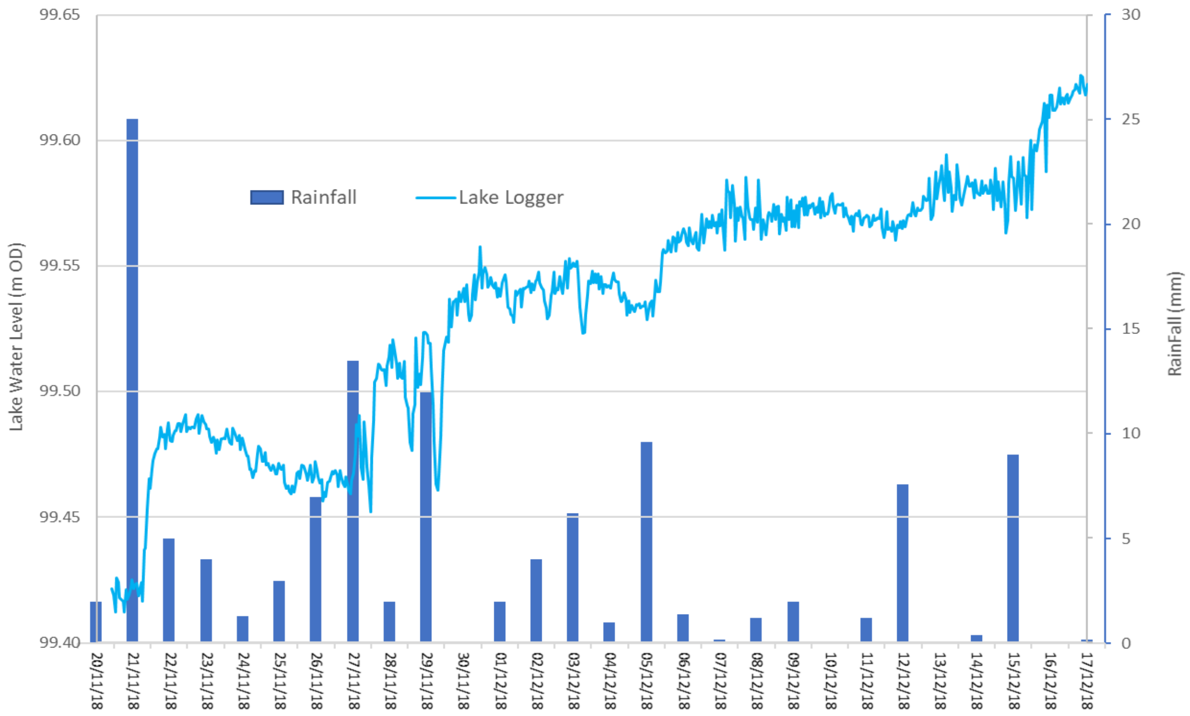

Figure 17: Rainfall and Lake Level During the Aquifer Test Period

Finally, two existing offsite wells (TW7 and TW10) which serve as monitoring wells for the BOTR wellfield, and the new offsite deep monitoring well BH31-OS were also included in the monitoring programme. Each of these wells were equipped with pressure transducers for the test sequence duration. Groundwater levels in TW10 represent the LF whilst data from TW7 and the new offsite monitoring well represent the Namurian (inferred Walshestown Formation).

6.2.1 Equipment Used

Well BH32 was fitted with a 4-inch variable speed submersible pump (Lowara model 16GS55R) with a duty point of approximately 384 m^3/d at 85 m head (at maximum pumping efficiency).[6] A similar pump had been used during the test pumping of BH17 in 2010, which produced approximately 520-540 m^3/d from the set-up in that well.

The submersible pump intake was set 56 mbgl, i.e. immediately above the open borehole section, and the target pumping rate for the aquifer test was 500 m^3/d. This was a practical limit of pumping, constrained by the 5-inch diameter uPVC casing which accommodated the 4-inch pump. The yield of this well is likely much higher. Air surging during drilling and well development produced an estimated discharge in excess of 12 l/s, equivalent to 1,036 m^3/d, which is twice the target pumping rate for the aquifer test. The ability to pump at higher rates would have required a larger pump inside a larger diameter well. The drilling of a larger diameter well was considered during project planning and was partly guided by the test pumping experience of BH17 in 2010 where a pumping rate of approximately 500 m^3/d was deemed sufficient for the aquifer test objectives.

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[6] The pump was sourced and installed by Seamus Kelly Well Drilling Ltd, who provided fulltime suprvision of the test equipment during the aquifer test.

Pumping rates were recorded manually and with an electromagnetic flow meter. The variable speed drive meant pumping rates could be adjusted and maintained easily by the pump operator. The discharge pipe was fitted with a non-return valve. The discharge water was directed approximately 210 m away to two existing settling ponds (Figure 18) from where the water flowed through an overflow pipe, via gravity, to a stream to the north which flows along the northern property boundary.

Figure 18: Settling Pond 1 (Overflow Pipe Below Water Level)

6.3 Pre-Test Monitoring

Pre-test groundwater levels for selected onsite monitoring wells are presented in Figure 19. Groundwater trends were steady in the days immediately preceding the step drawdown test which was conducted on 19 November 2018. The drawdown that is observed in wells BH05 (Namurian) and BH30 (LF) between 5 and 10 November 2018 reflect the drilling and air surging of new trial well BH32. The reaction of BH05 to the drilling of BH32 (a well completed in the LF) is an indication of potential hydraulic interaction between the Namurian and LF groundwater flow systems.

6.4 Pre-Test

The pre-test of BH32 was carried out on 15 November 2018. The pump was briefly turned on at full capacity with the gate valve open to observe the drawdown response in BH32 and get an indication of the pumping rates that might apply for the subsequent test sequence.

The pumping rate that was achieved at full capacity was 578 m^3/d, but only for short duration, with a measured drawdown after 0.5 hours of only 1.89 m. Nonetheless, initial measurement showed that the test pumping objectives could be met with a longer-term pumping rate in excess of 500 m^3/d being achievable.

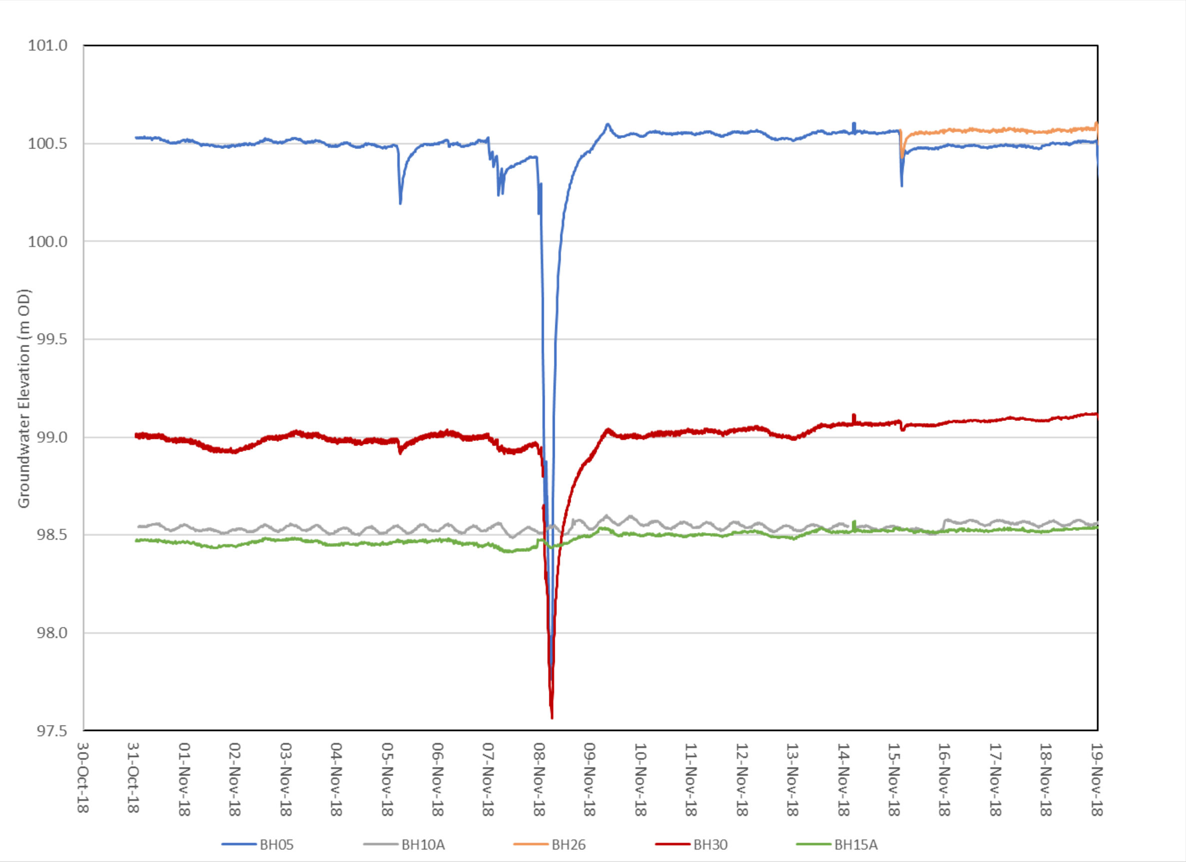

Figure 19: Onsite Groundwater Levels Prior to Test Pumping Sequence

6.5 Step Drawdown Test

The step drawdown test was conducted on 19 November 2018. Each step lasted 90 minutes without recovery between steps. The four successive pumping rates were 172.8, 267.8, 345.6 and 527.0 m^3/d. Measured drawdowns are presented in Figure 20. The data were used to estimate well efficiency using the Hantush-Bierschenk method. Based on Figure 21, linear and non-linear head loss coefficients B and C were derived as follows:

- B = 0.0038 d/m^2
- C = 1.40 x 10^{-6} d^2/m^5

Based on this, the calculated well efficiency at the maximum pumping rate of 527 m^3/d is 84%, implying that a hydraulically efficient pumping well was installed.

6.6 Constant Rate Test

The constant rate test was implemented between 10:00 on 20 November and 10:30 on 3 December 2018, followed by recovery. The pumping phase lasted 13 days. Recovery was measured for 9 days. As shown in Figure 22, a maximum and constant pumping rate of 6.13 l/s, equivalent to 530 m^3/d, was maintained during the constant rate test. There were two brief interruptions to the pumping:

- 17 minutes on 23 November 2018 at 01:37 (the generator cut out).

- 3 minutes on 23 November 2018 at 10:00 (the generator cut out).

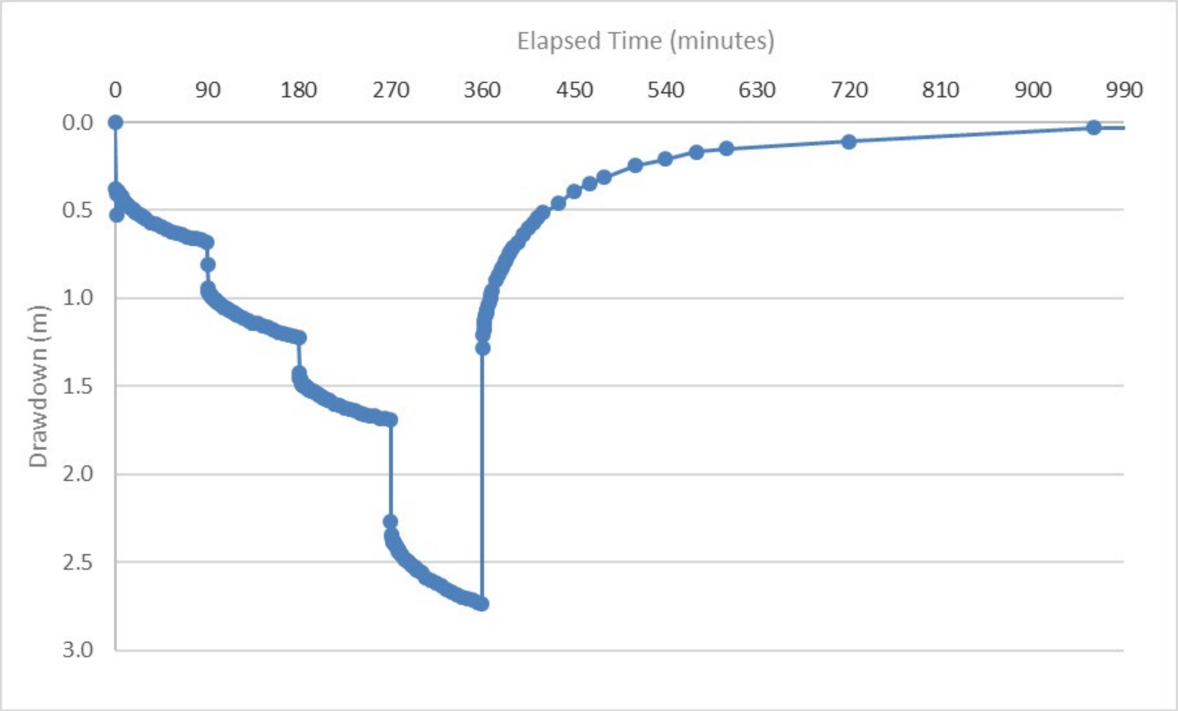

Figure 20: Measured Water Levels During Step Drawdown Test

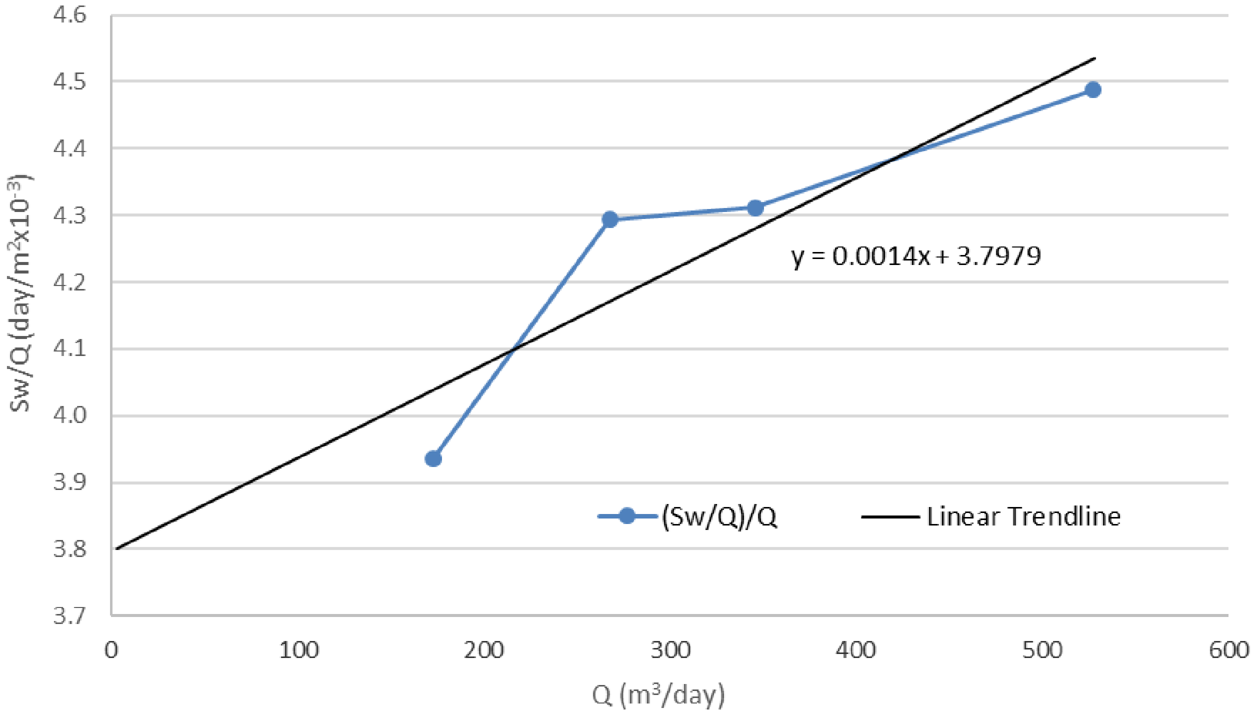

Figure 21: Specific Discharge vs. Discharge (Hantush-Bierschenk method)

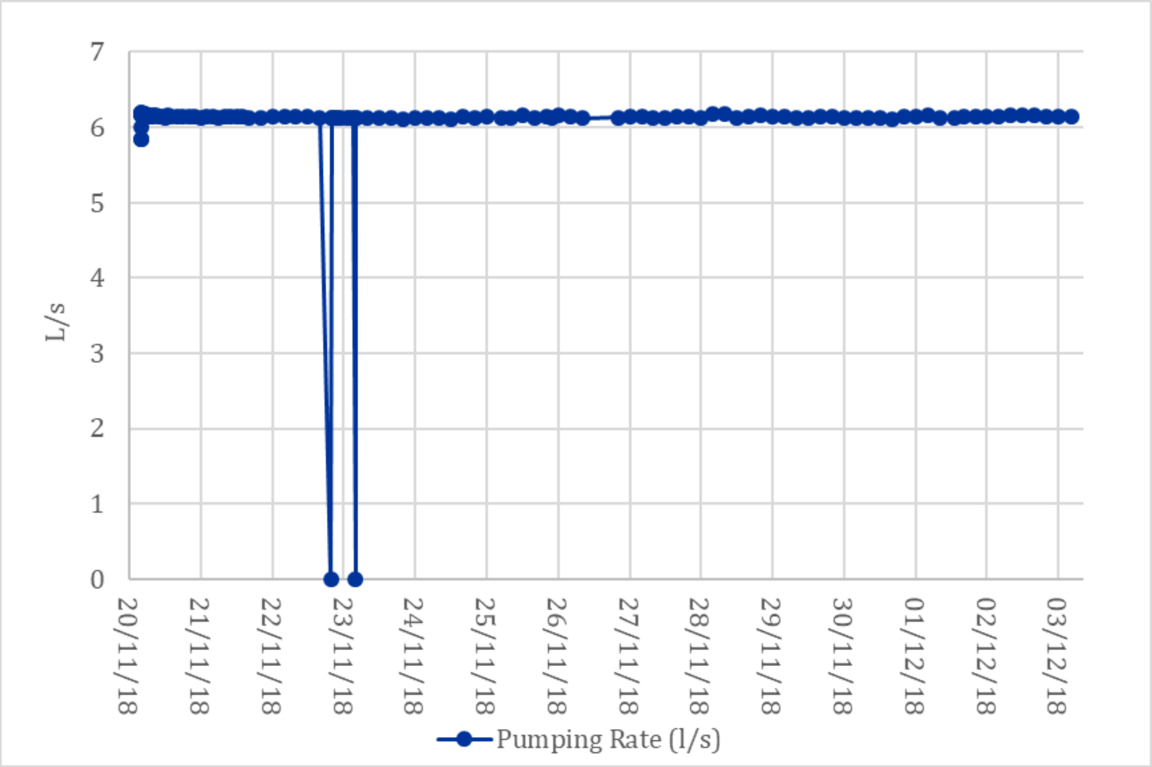

Figure 22: Pumping Rate During Constant Rate Test

Hydrographs for all monitored wells during the constant rate test are presented in **Appendix 3** (hydrographs were separated to provide better vertical resolution for review purposes). There are three basic hydrograph responses that can be discerned:

- Response 1: Wells that responded to the pumping in well BH32 - BH05, B17, BH18, BH19, BH20, BH24, BH25 BH26, BH27 BH28, BH29, BH30.
- Response 2: Wells that did not respond to the pumping in well BH32 but responded to water level changes in the lake at the southern end of the site - BH10A, BH11A, BH14, BH15A, BH25. It should be noted that BH15A responded initially to pumping, showing a drawdown of 0.1 m after 6 days of pumping, but the well then began to recover and its response was masked by the lake level response to rainfall events. Thus, BH15A was placed in this second group of wells.
- Response 3: Wells that responded independently of both - BH31-OS, TW7, TW10, and BOTR monitoring wells.

The wells that fall into Response 1, those which responded to the pumping of the BH32, show clear drawdown and recovery curves (Figure 23). They are all located in the central and northern parts of the site and incorporate wells that are screened or open to Namurian rocks and the LF, respectively. The data from these wells were used for aquifer test analyses.

The wells that fall into Response 2, those which responded to the lake levels only are located in the southern part of the site and are open/screened below the lake level elevation. Two example hydrographs (BH15A, BH25) are presented in Figure 24.

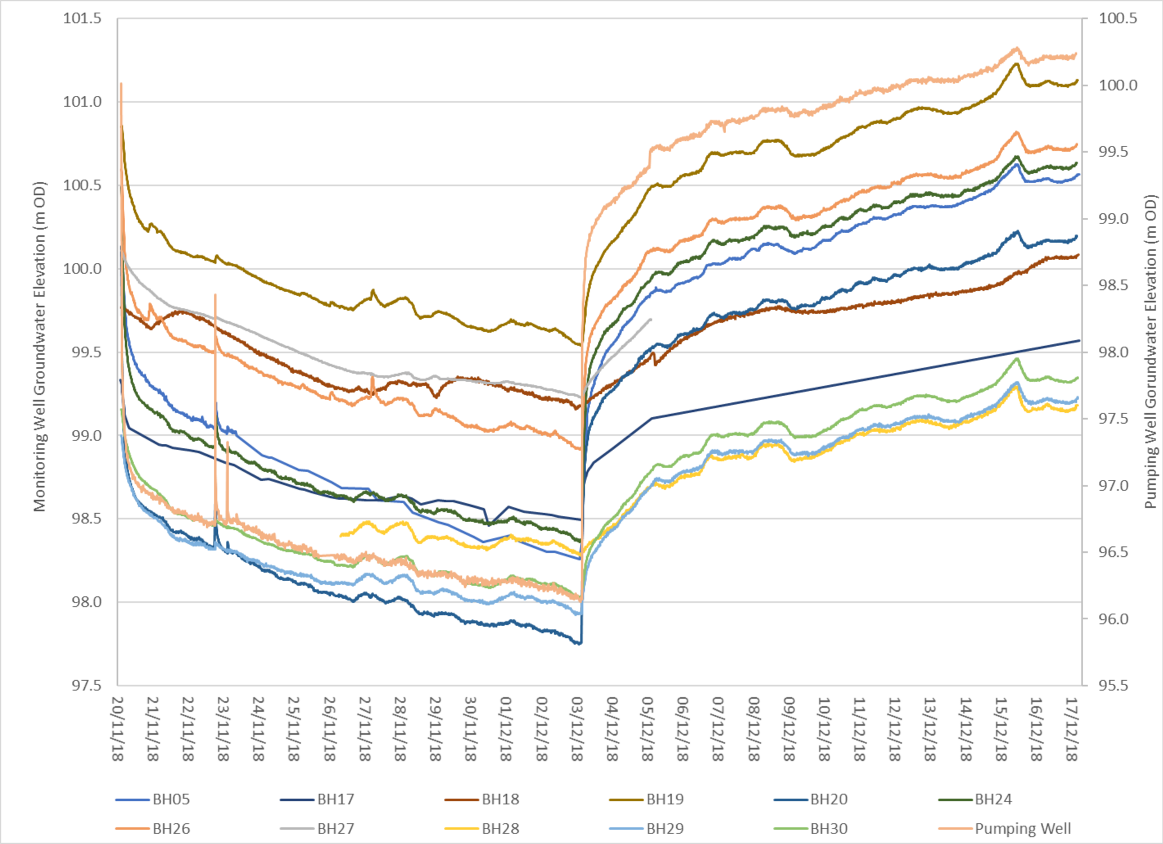

Figure 23: Hydrographs of Wells Responding to Pumping

Figure 24: Examples of Hydrographs of Onsite Wells Responding to Lake Levels

The wells influenced by the lake are mostly screened/open in the LF. Because of the lake's masking of the hydraulic response to pumping, the data associated with wells could not be used for aquifer test analysis.

The influence of the lake in the southern part of the site is demonstrated in Figure 25 which shows a plan map of the drawdown values after 1 day, at the mid-point, and at the end of the pumping phase of the aquifer test. LF wells near the lake did not responded to the pumping. Well BH28 is not plotted as monitoring started after pumping began. BH14 was also not plotted as it did not respond to pumping.

Figure 25: Onsite Drawdown Response During the Aquifer Test

The wells in Response 3 are located either offsite or onsite but at considerably higher elevation than the current ground level of the site. The offsite wells are BH31-OS, TW7, TW10, and the BOTR well monitoring wells. The onsite wells are those located along the western margin of the site. These are hydraulically upgradient of the site (groundwater flow under non-pumping conditions is from the west to the east across the site). Similarly, the data from these wells could not be used for aquifer test analysis.

With regards to BH31-OS, its hydrograph is presented in Figure 26 along with the hydrograph of well BH32, both on a vertical scale of 5 m. The former responds independently of the pumping well. The hydrographs nonetheless show features of relevance which are summarised as follows:

- The hydrograph is influenced by short-duration pumping/recovery cycles which are linked to private farm wells. Over the broader monitoring period, the hydrograph shows a rising trend, which can be attributed to the rainfall over the monitoring period which resulted in groundwater recharge.
- The rising water levels over the monitoring period are mirrored in offsite wells TW-10 and OW-2D, (Figure 27) for the available period of record to 5 December 2018 which covers the pumping phase of the onsite aquifer test. Both wells monitor the LF and OW-2D is located at the centre of the BOTR wellfield. OW-2D does not show pumping or recovery responses that are characteristic of wellfield operational changes. For this reason, it is concluded that the general groundwater level rise is caused by the same groundwater recharge event.

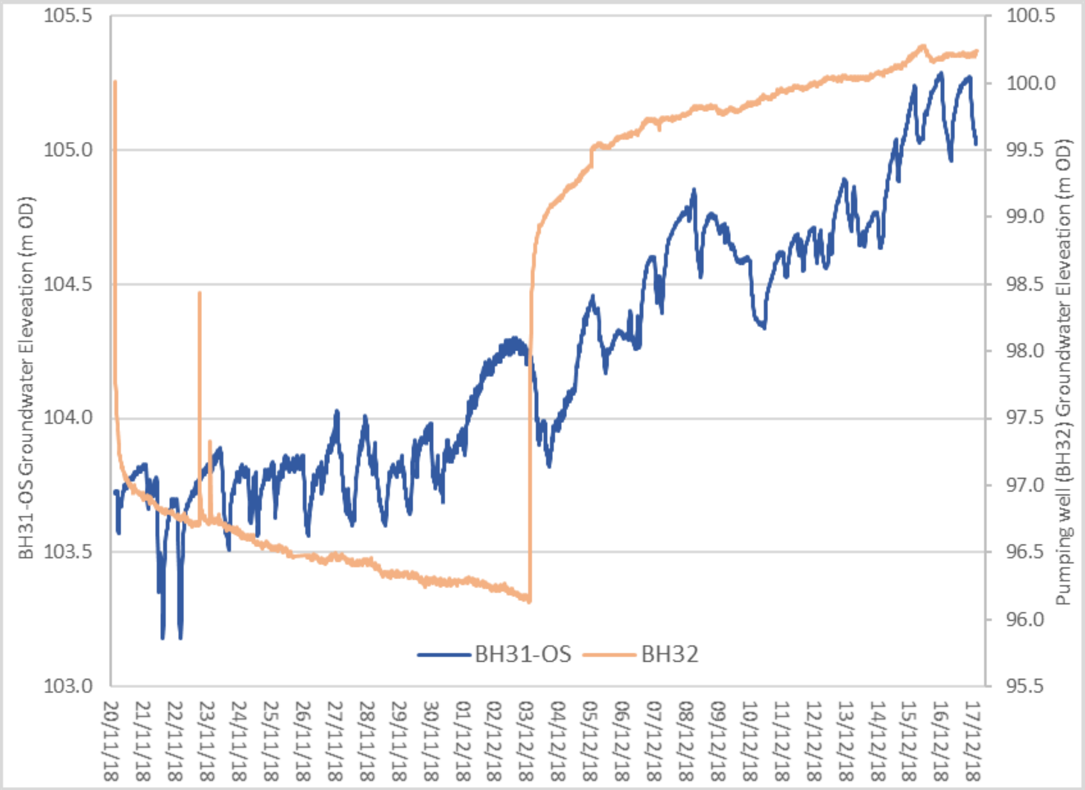

Figure 26: Hydrographs of BH31-OS and BH32 to 12 December 2018

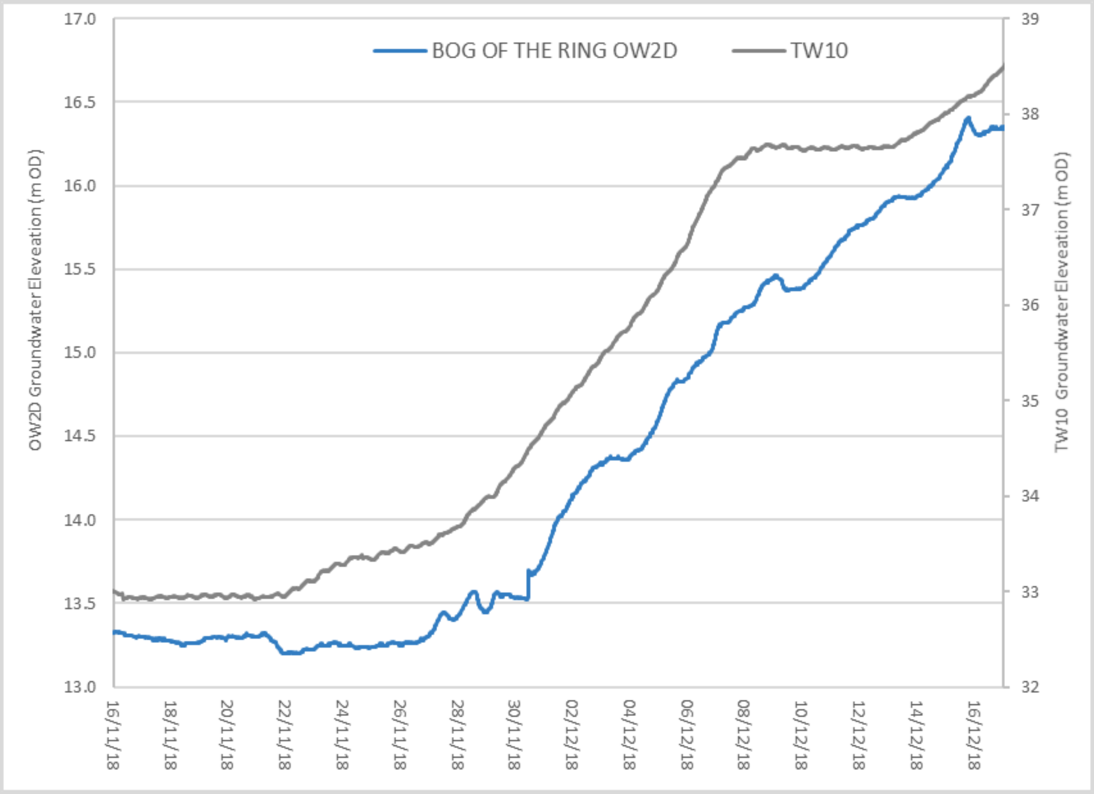

Figure 27: Hydrographs of Offsite Wells TW10 and OW-2D to 17 December 2018

Section 7 Aquifer Test Analysis

The test pumping analysis was conducted on data from wells that responded to pumping. The analysis focused on drawdown data as recovery data, particularly after 5 December 2018, were influenced by the rainfall and recharge that occurred during and following the test pumping period. Minor cm-scale effects are also observed on some of the drawdown data but are not sufficient to require adjustment for analytical purposes.

7.1 Analytical Solutions

The groundwater flow system at the site is heterogeneous and hydraulic responses to pumping reflect both regional and local-scale hydrogeological conditions as well as individual well designs. Accordingly, the approach taken was to review aquifer test data on a case by case basis, recognising that different wells respond differently to pumping, in the knowledge that hydrographs may also be influenced by geological barriers.

Therefore, the shapes of resulting drawdown curves were carefully examined and the overriding principle behind the test pumping analysis was to achieve a good fit between the measured and simulated drawdowns (analytical solutions). Furthermore, simple solutions involving fewer input variables were favoured over more complex solutions requiring more input parameters, many of which must be assumed.

Conceptually, the fractured nature of the bedrock formations beneath the site and absence of significantly thick confining layers imply that the groundwater flow system is generally unconfined. However, the hydraulic responses in some wells may show locally confined conditions, especially wells that are overlain by the shale and clay units of the Walshestown Formation (i.e. upper part of the Namurian sequence at the site). This is supported by hydrographs of some wells which show cm-scale diurnal fluctuations of earth tides and responses to barometric pressure changes. All test data were corrected for barometric pressure effects.

In unconfined aquifers, water levels near pumping wells tend to decline at slower rates than described by the Theis equation. When plotted on semi-logarithmic scale, time-drawdown data for wells in unconfined aquifers is typically S-shaped with three drawdown segments as described by Neuman (1974):

1. A relatively steep early-time segment which tends to conform to the Theis solution.
2. A flatter intermediate segment which does not conform to the Theis solution and reflects pumping of water from aquifer storage*, i.e* drainage.
3. A later-time drawdown segment which again conforms to the Theis solution.

The drawdown data for nearly all the monitored wells do not exhibit the S-shaped characteristic. As implemented, local-scale hydraulic responses to pumping indicate that the Theis solution is applicable.

Marechal et al. (2004) compared confined and unconfined analytical solutions in fractured rocks and showed that when the drawdown does not exceed 25% of the aquifer thickness, “the application of analytical solutions for confined aquifer to the unconfined aquifer of the study area is possible without introducing any inaccuracy." Thus, and in practice, the application of the Theis solution for confined aquifers, even for unconfined aquifers, can be tolerated where drawdown values are small. This is the case for the test described in the current report whereby measured drawdowns did not exceed 3 m over the 13-day pumping period.

Except for wells BH26 and BH32, application of the Neuman solution for unconfined aquifers did not generally yield better curve fitting results and did not materially affect or improve the overall estimation of T. This is exemplified in Figure 28 for well BH30 which shows the simulated Theis (left panel) and Neuman (right panel) solutions (blue lines) compared with the water level data (red dots) for the same value of T (225.3 m^2/d). The characteristic S-shaped drawdown response of Neuman is not observed in the measured data which means an acceptable curve-fit was not achievable with the Neuman method.

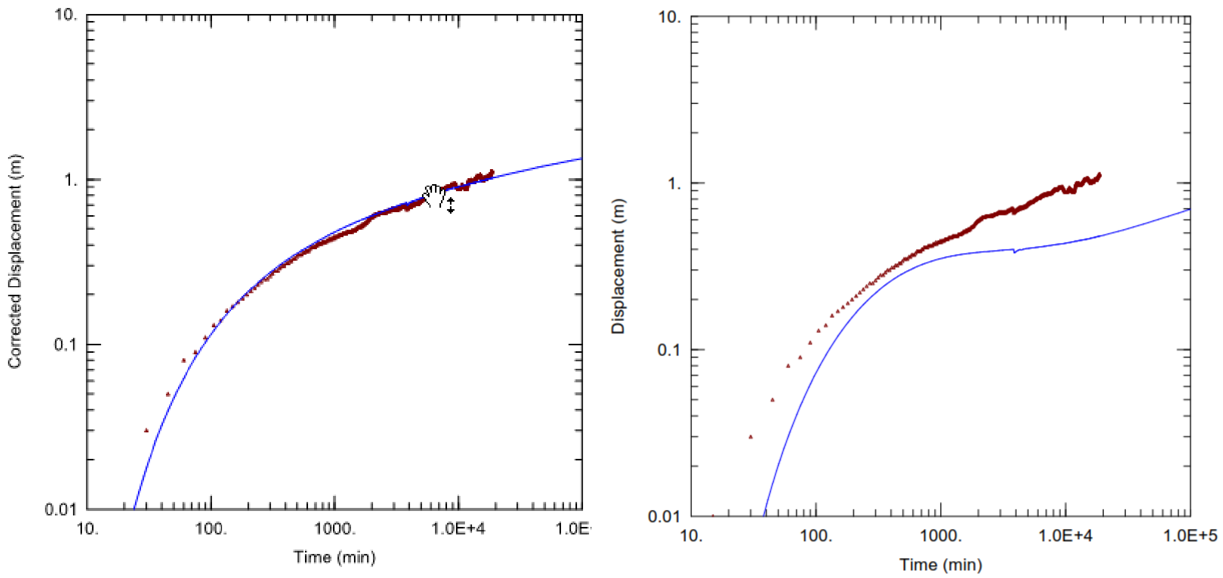

Figure 28: Measured Drawdown (Red Dots) and Neuman-Solution Drawdown (Blue Curve) for Well BH30

In some wells, the measured response shows indications of dewatering of the fracture system which is represented by an increasing drawdown with time which deviates from the Theis solution.

7.2 Derived Hydraulic Properties

Based on the above observations, transmissivity (T) and storativity (S) were mainly estimated using the Cooper-Jacob (C-J) and Theis analytical solutions as implemented in the AQTESOLV software package (Duffield, 2007). With regards to unconfined conditions, the AQTESOLV program applies a correction factor to drawdown values based on the measured data and the assigned depth of the aquifer. The latter was guided by drilling logs and information on screened/open sections of boreholes.

In the analysis, emphasis was placed on curve fitting. Examples of the curve fitting are shown in Figure 29 for well BH29. The derived hydraulic property values are summarised in Table 6 and the AQTESOLV outputs from the analyses of individual well data are presented in **Appendix 4**.

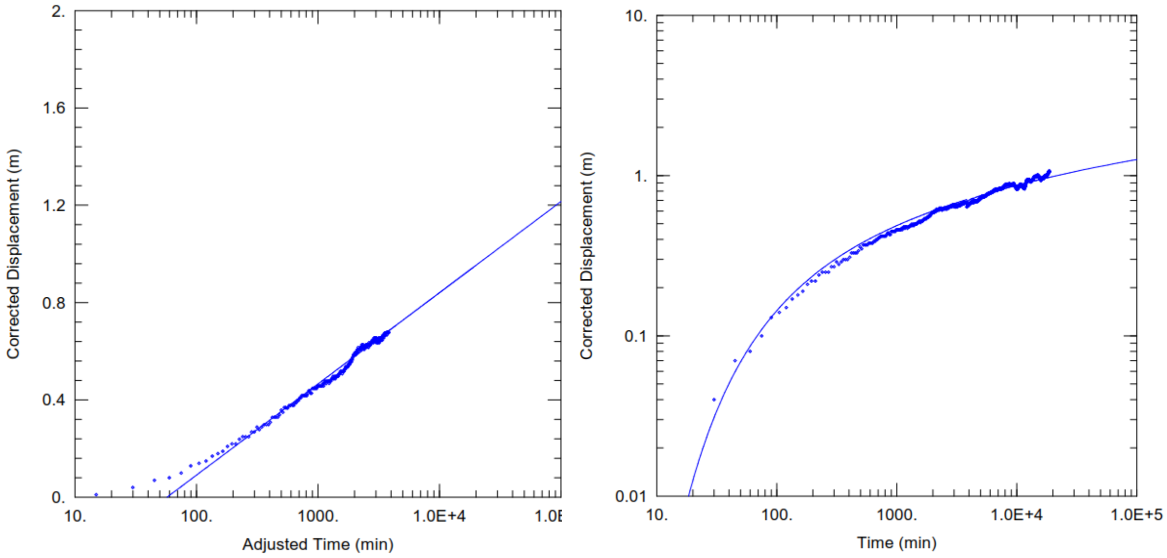

Figure 29: Example of a Good Curve-fit for Well BH29 - Cooper-Jacob (left panel); Theis (right panel)

Table 6: Derived Hydraulic Properties from Wells That Responded to Aquifer Test

Well	Formation	Test	T (m^2/d)	Storativity	Comment
BH32	LF	Step Drawdown	219.4	Not applicable – cannot be derived for a pumping well	Neuman solution yielded good curve fit for T of 173.2 m^2/d
BH32		Constant Rate	181.7 (C-J) 539.0 (Theis)		
BH30			260.4 (C-J) 225.3 (Theis)	3.34x10^{-3} (C-J) 3.98x10^{-3} (Theis)	
BH5	Namurian		193.7 (C-J) 164.8 (Theis)	2.78x10^{-5} (C-J) 5.72x10^{-5} (Theis)	
BH19			241.1 (C-J) 189.4 (Theis)	5.60x10^{-3} (C-J) 7.90x10^{-3} (Theis)	
BH20			207.5 (C-J) 165.3 (Theis)	1.68x10^{-4} (C-J) 1.00x10^{-3} (Theis)	
BH24			205.8 (C-J) 164.2 (Theis)	4.58x10^{-5} (C-J) 1.43x10^{-5} (Theis)	
BH26			308.0 (C-J) 183.6 (Theis)	1.10x10^{-3} (C-J) 8.49x10^{-3} (Theis)	Neuman solution yielded good curve fit for T of 51.1 m^2/d
BH27			321.1 (C-J) 160.7 (Theis)	3.08x10^{-3} (C-J) 7.01x10^{-3} (Theis)	
BH29			258.4 (C-J) 250.8 (Theis)	2.30x10^{-3} (C-J) 2.18x10^{-3} (Theis)	
BH17	Namurian and LF		408.5 (Theis)	5.34x10^{-4} (Theis)	Sensitive to aquifer thickness

As shown in Figure 30, the Neuman solution provided good curve fits with the measured data for wells BH26 (left panel) and BH32 (right panel)). Estimated T values were 51.1 and 173.1 m^2/d respectively, which is lower than both the C-J and Theis solutions as indicated in Table 6.

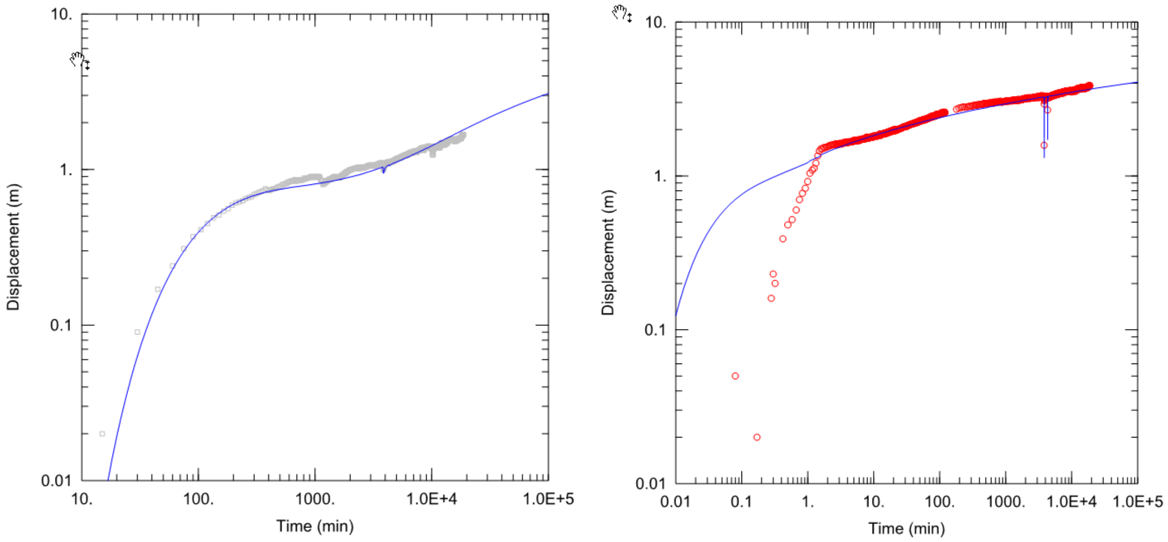

Figure 30: Neuman solutions for BH26 (left) and BH32 (right)

Based on the Theis solution, the estimated T values range from 160 to 539 m^2/d, with an average of 245 m^2/d. By substituting in the derived values using the Neuman solution for BH26 and BH32, the estimated T values range from 51 to 409 m^2/d, with an average of 195 m^2/d.

For the LF wells only, and relying on the Neuman solution for well BH32, the average derived T value from the constant rate test data is 210 m^2/d. For the Namurian wells, and relying on the Neuman solution for well BH26, the average derived T value is approximately the same as for the LF..

The derived T value of BH17, which is screened across both Namurian rocks and the LF, is 408.5 m^2/d, likely reflecting the greater aquifer thickness that was applied to the analysis.

BH18 did respond to pumping due to its proximity to the lake and recharge from rainfall, thus an analytical solution could not be matched to the data.

Estimated storativity values are low, which is expected from fractured bedrock media, and values range over three orders of magnitude, from 8.49x10^{-3} to 1.34x10^{-5}. This reflects the heterogenous nature of the groundwater flow system that is present at the site. The geometric mean of all values is 7.53x10^{-4}.

7.3 Sensitivity Analysis

The use of single parameter values to characterise and model a variable groundwater flow system has inherent uncertainty. For aquifer tests, sensitivity analysis is sometimes performed to determine how sensitive analytical solutions are to input parameter values. Variations in location-specific geology can influence hydraulic responses to pumping at the local scale and, therefore, how analytical solutions are applied.

Parameters which could influence the aquifer test analyses are:

- Aquifer thickness (which determines if the well is partially of fully penetrating the aquifer system); and
- Vertical-to-horizontal anisotropy of the flow system (indicated by the hydraulic conductivity (K) in the x and y directions, and referred to as the Kz/Kr ratio)

Both the Cooper-Jacob and Theis solutions were tested by varying both the aquifer thickness and Kz/Kr ratio in AQTESOLV. Three wells with good information (*i.e.* control points) on well construction and lithological logs were used for the sensitivity analysis:

- BH05 – Namurian;
- BH27 – Namurian; and
- BH30 – Loughshinny.

7.3.1 Aquifer Thickness

The total thickness of the LF at the site is not known. The hydraulically active part of the LF is likely different from the formation thickness as, conceptually, groundwater flow and related fracture systems decrease with depth. At well BH32, water-bearing fractures were encountered at multiple depths during drilling and active groundwater flow was documented to the total drilled depth of 66 m. Accordingly, the total aquifer thickness is considered to be the height of the water column in the completed well under non-pumping conditions, *i.e.* 66 m. This formed the base case for aquifer test analyses.

At monitoring wells, similar considerations, using lithological data and hydrogeological notes presented in driller's logs in past site-related studies were used to judge aquifer unit thicknesses in the different wells as inputs to the AQTESOLV software.

The influence of aquifer thickness was checked as part of the sensitivity analyses and results are summarised in Table 7. The base case considered an aquifer thickness of 66 m which is the total depth of well BH32. In reality, the LF is thicker, but there are no onsite wells that fully penetrated the LF. For this reason, a reference value of 150 m, as presented by the GSI (GSI, 2005), was used to check sensitivity of the analytical solutions to aquifer thickness.

Table 7: Estimated T Values for Different Aquifer Thickness Values

Location	Unit	Estimated T - Cooper Jacob		Estimated T - Theis	
		b=66m (Base case)	b=150m	b=66m (Base case)	b=150m
BH05	m^2/day	193.7	192	164.8	162.3
BH27	m^2/day	321.1	321.1	160.7	157.3
BH30	m^2/day	260.4	259.6	225.3	223.2

Variation of aquifer thickness had a negligible effect on the estimated T values.

7.3.2 Kz/Kr Anisotropy Ratio

The base case scenario applies a Kz/Kr ratio of 1 (*i.e.* no anisotropy). The groundwater flow system at the site is characterised by fractures in both the Namurian rocks and the LF. Most wells responded to pumping, including wells at the margins of the site and open to both the Namurian and LF. This suggests that fracturing is widespread even if faulting may impart some degree of linearity to fracture orientations (not evident in the aquifer test data).

The Kz/Kr ratio was lowered to 1:10 (0.1) and 1:100 (0.01) to test the effect on the estimated T values in wells BH05, BH27 and BH30. Results are presented in Table 8.

Table 8: Estimated T Values for Different Kz/Kr Ratios

Location	Unit	Estimated T - Cooper Jacob			Estimated T - Theis		
		Kz/Kr = 1 (Base case)	Kz/Kr=0.1	Kz/Kr=0.01	Kz/Kr=1 (Base case)	Kz/Kr=0.1	Kz/Kr=0.01
BH05	m^2/day	223.8	223.8	223.8	164.8	164.8	145
BH27	m^2/day	321.1	321.1	321.1	160.7	165.7	86.21
BH30	m^2/day	260.4	260.4	260.4	225.3	225.3	199.5

By invoking anisotropy, *i.e.* lowering the Kz/Kr ratio, estimated T values decreased with the curve-matching Theis solution. This is because higher anisotropy restricts vertical flow, which reduces the effective thickness of the aquifer system resulting in a lower T. The noted changes are not material to the overall range of values presented in Table 6 or the outcome of the aquifer test analysis.

Section 8 Conclusions

The objectives described in Section 1 of this report have been addressed and the broad conclusions from the assessment carried out are summarised below.

8.1 Hydraulic Influence of BOTR Pumping

BOTR wellfield operations did not influence groundwater levels at the site during the extended monitoring period in 2018. The monitoring period included the prolonged drought conditions that were experienced across Ireland in the summer of 2018. This is significant because the BOTR sustained production pumping of approximately 2,700-2,800 m^3/d over the drought period and thus provided possibly the best opportunity to identify a potential hydraulic influence of BOTR pumping at the site.

Groundwater levels in the new offsite well BH31-OS are higher than at the site. This demonstrates that a groundwater divide exists in the offsite area between the BOTR wellfield and the site. In addition, this well does not show a hydraulic influence of BOTR pumping. Well BH31-OS is considered to be hydraulically side-gradient of the site.

8.2 Aquifer Test Results

The aquifer test of the LF using BH32 as the pumping well provides new and reliable information about the hydrogeological characteristics of the bedrock formations beneath the site. The Namurian rocks and LF are hydraulically connected through a dense fracture network which cuts across formations at the locations and within the depths that have been investigated. Therefore, the shallow Namurian rocks at the site cannot be regarded as an aquitard.

Although past geological studies of the site indicate prevalent faulting which is expected to impart enhanced fracture permeability along fault traces/zones, the measured drawdown responses from the aquifer test of BH32 do not highlight any particular linearity to the drawdown response. Hydraulic responses to the pumping of BH32 are seen across the site, even in well BH5, a shallow Namurian well in the northwestern corner of the site. Wells that did not respond to pumping were influenced by their proximity to the 10 m deep lake in the southern part of the site (which extends into the LF) or did not response because the wells are situated at higher elevations and are hydraulically upgradient of the prevailing groundwater flow gradients.

8.3 Other Hydrogeological and Hydrological Data

Groundwater level data from the site demonstrate that groundwater flow is to the east and southeast in the Namurian and LF, respectively. Because there is no identifiable hydraulic influence of BOTR pumping at the site, the observed flow directions imply that any potential groundwater contamination from the site would not migrate towards the wellfield under currently defined pumping regimes and hydrogeological conditions.

The stream along the northern property boundary receives groundwater baseflow from the Namurian in the northern portion of the site. This implies that the stream would be susceptible to potential contamination from groundwater discharges in the north-eastern portion of the site.

Section 9 References

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Appendix 1 Groundwater Levels – Manual Readings

Manual Groundwater Level Measurements

BH05		BH08		BH08A		BH09		BH10A		BH11A		BH13		BH14	
Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC
19-02-18	16.62	24-08-18 12:00	3.43	16-11-18 15:11	33.04	24-08-18	24.25	22-02-18	37.67	24-08-18	0.59	24-08-18	31.87	24-08-18	26.97
20-02-18	16.62	27-08-18 12:00	3.47	20-11-18 09:37	33.05	27-08-18	24.26	23-02-18	37.69	27-08-18	0.62	27-08-18	31.91	27-08-18	27.02
21-02-18	16.63	05-09-18 12:00	3.50	20-11-18 10:13	33.05	05-09-18	24.50	26-02-18	37.70	05-09-18	1.48	05-09-18	32.88	05-09-18	27.10
22-02-18	16.59	13-09-18 12:00	3.80	20-11-18 10:39	33.05	13-09-18	24.55	05-03-18	37.59	13-09-18	1.45	13-09-18	32.75	13-09-18	26.96
23-02-18	16.58	20-09-18 15:26	3.53	20-11-18 11:22	33.05	20-09-18 15:35	24.60	06-03-18	37.58	20-09-18 15:41	1.50	20-09-18 15:53	32.66	20-09-18 16:07	27.01
26-02-18	16.58	27-09-18 15:32	3.62	20-11-18 11:52	33.06	27-09-18 15:27	24.56	08-03-18	37.58	27-09-18 15:09	1.54	27-09-18 14:57	32.94	27-09-18 14:47	27.03
05-03-18	16.44	03-10-18 14:17	3.55	20-11-18 13:02	33.04	03-10-18 14:22	24.64	13-03-18	37.57	03-10-18 14:30	1.52	10-10-18 14:59	32.92	03-10-18 14:45	26.98
06-03-18	16.46	10-10-18 14:26	3.57	20-11-18 13:05	33.05	10-10-18 14:39	24.66	27-03-18	37.60	10-10-18 14:46	1.55	31-10-18 11:00	33.10	10-10-18 15:07	27.02
08-03-18	16.41	18-10-18 14:34	3.19	20-11-18 14:27	33.04	18-10-18 14:40	24.85	06-04-18	37.62	18-10-18 15:08	1.48	08-11-18 14:00	33.03	18-10-18 15:48	27.14
13-03-18	16.39	31-10-18 12:15	3.27	20-11-18 14:59	33.05	31-10-18 10:25	25.04	13-04-18	37.65	31-10-18 10:30	1.42	22-01-19 09:01	34.13	31-10-18 10:18	27.14
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25-05-18	17.03	20-11-18 10:15	3.30	24-11-18 09:05	33.07	20-11-18 13:26	25.30	15-06-18	37.39	20-11-18 12:48	1.59			30-11-18 14:58	27.34
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08-06-18	17.20	20-11-18 14:58	3.30	24-11-18 16:04	33.07	20-11-18 15:02	25.30	29-06-18	37.89	20-11-18 14:57	1.59			01-12-18 15:08	27.26
15-06-18	17.22	20-11-18 13:53	3.30	25-11-18 10:20	33.08	21-11-18 09:32	25.31	06-07-18	37.83	20-11-18 15:35	1.59			02-12-18 10:12	27.26
22-06-18	17.25	21-11-18 12:27	3.02	25-11-18 16:26	33.08	21-11-18 12:30	25.30	13-07-18	37.75	21-11-18 08:37	1.46			02-12-18 15:44	27.24
29-06-18	17.15	21-11-18 09:31	3.01	26-11-18 08:48	33.10	21-11-18 16:03	25.31	20-07-18	37.82	21-11-18 12:05	1.49			03-12-18 08:33	27.29
06-07-18	17.04	21-11-18 15:58	3.01	26-11-18 15:16	33.10	22-11-18 10:23	25.31	27-07-18	37.81	21-11-18 15:40	1.50			03-12-18 11:54	27.29
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27-07-18	17.16	23-11-18 16:20	3.01	28-11-18 09:46	33.04	23-11-18 16:21	25.30	17-08-18	37.80	23-11-18 09:15	1.61			03-12-18 14:43	27.30
01-08-18	17.24	23-11-18 08:50	3.00	28-11-18 15:52	33.05	24-11-18 09:09	25.32	24-08-18	37.83	23-11-18 16:35	1.61			04-12-18 08:31	27.33
09-08-18	17.21	24-11-18 14:16	3.06	29-11-18 09:37	33.03	24-11-18 14:19	25.32	27-08-18	37.87	24-11-18 09:41	1.63			05-12-18 11:00	27.17
17-08-18	17.28	24-11-18 16:03	3.06	29-11-18 15:41	33.03	24-11-18 16:06	25.32	05-09-18	38.20	24-11-18 14:34	1.61			17-12-18 10:12	27.07
24-08-18	17.36	24-11-18 09:07	3.05	30-11-18 09:16	33.04	25-11-18 10:23	25.33	13-09-18	38.26	24-11-18 16:25	1.61			23-01-19 11:19	26.96
27-08-18	17.45	25-11-18 10:19	3.09	30-11-18 15:27	33.04	25-11-18 16:29	25.33	20-09-18 15:30	38.32	25-11-18 11:13	1.61			15-02-19 08:31	26.93
05-09-18	17.71	25-11-18 16:25	3.09	01-12-18 09:22	33.00	26-11-18 08:53	25.34	27-09-18 17:00	38.33	25-11-18 16:51	1.61			08-03-19 08:45	27.10
13-09-18	17.64	26-11-18 08:50	3.10	01-12-18 15:37	32.99	26-11-18 15:18	25.35	03-10-18 17:04	38.36	26-11-18 09:23	1.60			11-04-19 13:01	27.30
20-09-18 15:19	17.78	26-11-18 15:15	3.09	02-12-18 10:45	32.97	27-11-18 09:44	25.31	10-10-18 17:00	38.39	26-11-18 15:49	1.61				
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18-10-18 14:47	17.98	28-11-18 15:51	2.77	03-12-18 11:01	32.93	29-11-18 09:40	25.27	20-11-18 08:01	38.56	28-11-18 16:25	1.60				
31-10-18 10:14	18.06	29-11-18 09:38	2.85	03-12-18 11:46	32.92	29-11-18 15:42	25.27	20-11-18 11:06	38.56	29-11-18 10:10	1.50				
08-11-18 10:05	18.78	29-11-18 15:39	2.80	03-12-18 12:10	32.93	30-11-18 09:18	25.27	20-11-18 11:50	38.57	29-11-18 16:14	1.58				
15-11-18 15:05	18.38	30-11-18 09:15	2.81	03-12-18 13:37	32.93	30-11-18 15:29	25.27	20-11-18 13:11	38.56	30-11-18 10:17	1.61				
20-11-18 09:44	18.33	30-11-18 15:25	2.85	03-12-18 14:03	32.93	01-12-18 09:32	25.24	20-11-18 13:45	38.56	30-11-18 16:00	1.61				
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20-11-18 13:30	19.17	03-12-18 09:05	2.98	05-12-18 12:23	32.87	03-12-18 10:42	25.19	21-11-18 12:05	38.53	03-12-18 09:53	1.60				
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22-11-18 14:46	19.73	03-12-18 15:01	2.98			04-12-18 00:00	25.29	24-11-18 10:21	38.59	04-12-18 07:51	1.60				
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23-11-18 16:25	19.82	04-12-18 07:18	3.00			05-12-18 12:29	24.99	25-11-18 09:46	38.59	17-12-18 11:35	1.55				
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24-11-18 14:22	19.96	17-12-18 12:05	3.10			23-01-19 09:19	23.61	26-11-18 08:20	38.57	15-02-19 09:05	1.52				
24-11-18 16:09	19.96	23-01-19 09:19	3.58			15-02-19 09:40	23.77	26-11-18 14:45	38.60	08-03-19 14:42	1.54				
25-11-18 10:27	20.03	15-02-19 15:02	3.20			08-03-19 12:25	23.93	27-11-18 09:05	38.56	11-04-19 12:33	1.60				
25-11-18 16:33	20.03	08-03-19 12:15	2.95			11-04-19 11:36	23.18	27-11-18 15:05	38.55						
26-11-18 08:37	20.10	11-04-19 11:29	3.26					28-11-18 09:05	38.51						
26-11-18 15:21	20.14							28-11-18 15:16	38.54						
27-11-18 09:47	20.14							29-11-18 08:55	38.50						
27-11-18 15:50	20.21							29-11-18 14:56	38.53						
28-11-18 09:51	20.22							30-11-18 08:33	38.54						
28-11-18 15:58	20.28							30-11-18 14:52	38.56						
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30-11-18 15:32	20.46							02-12-18 15:39	38.52						
01-12-18 09:35	20.42							03-12-18 08:28	38.54						
01-12-18 15:43	20.46							03-12-18 11:38	38.54						
02-12-18 10:50	20.52							03-12-18 12:28	38.54						
02-12-18 16:13	20.52							03-12-18 13:45	38.50						
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03-12-18 11:10	20.26							05-12-18 13:27	38.44						
03-12-18 11:17	20.01							17-12-18 09:30	38.39						
03-12-18 11:53	20.08							23-01-19 08:44	38.25						
03-12-18 13:48	19.82							15-02-19 08:05	38.24						
03-12-18 14:10	19.80							08-03-19 15:35	38.27						
03-12-18 14:37	19.77							11-04-19 12:55	39.09						
03-12-18 15:12	19.73														
04-12-18 07:27	19.38														
05-12-18 12:18	19.02														
17-12-18 12:18	18.31														
15-02-19 14:38	17.31														
08-03-19 15:35	17.24														
11-04-19 12:43	17.46														
🟩	Background or Long-Term Monitoring														
🟦	Constant Rate Test														

Manual Groundwater Level Measurements

BH15A		BH17		BH18		BH19		BH20		BH24		BH25	
Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC
19-02-18	6.45	19-02-18	4.90	16-11-18 12:30	10.61	24-08-18 12:00	4.30	18-10-18 16:20	4.64	23-02-18	3.82	15-11-18 14:12	6.07
20-02-18	6.56	20-02-18	4.91	20-11-18 09:09	10.65	27-08-18 12:00	4.35	31-10-18 11:18	5.06	26-02-18	3.82	20-11-18 09:24	6.09
21-02-18	6.56	21-02-18	4.92	20-11-18 10:06	10.65	05-09-18 12:00	4.48	08-11-18 11:45	8.52	05-03-18	3.74	20-11-18 10:08	6.09
22-02-18	6.53	22-02-18	4.92	20-11-18 10:31	10.66	13-09-18 12:00	4.59	15-11-18 11:15	4.94	06-03-18	3.74	20-11-18 10:34	6.09
23-02-18	6.54	23-02-18	4.91	20-11-18 10:56	10.66	20-09-18 16:38	4.59	19-11-18 09:12	4.98	08-03-18	3.74	20-11-18 11:16	6.09
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06-03-18	6.48	06-03-18	4.73	20-11-18 12:33	10.67	10-10-18 15:35	4.56	20-11-18 10:25	5.55	06-04-18	3.67	20-11-18 13:45	6.09
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13-03-18	6.50	13-03-18	4.70	20-11-18 13:39	10.68	31-10-18 11:20	4.98	20-11-18 10:46	5.84	20-04-18	3.81	20-11-18 14:52	6.09
27-03-18	6.51	27-03-18	4.82	20-11-18 14:16	10.68	08-11-18 11:35	5.54	20-11-18 11:05	5.95	27-04-18	3.53	20-11-18 15:24	6.10
06-04-18	6.45	06-04-18	4.75	20-11-18 14:44	10.69	15-11-18 11:59	4.79	20-11-18 11:20	6.03	04-05-18	3.54	21-11-18 09:41	6.05
13-04-18	6.65	13-04-18	4.65	20-11-18 15:55	10.70	19-11-18 09:22	4.79	20-11-18 11:36	6.08	18-05-18	3.77	21-11-18 12:17	6.05
20-04-18	6.50	20-04-18	4.72	21-11-18 08:44	10.76	20-11-18 09:07	4.84	20-11-18 11:49	6.13	25-05-18	3.72	21-11-18 15:51	6.04
27-04-18	6.24	27-04-18	4.67	21-11-18 11:25	10.76	20-11-18 10:11	4.84	20-11-18 12:36	6.24	01-06-18	3.76	22-11-18 10:15	6.05
04-05-18	6.37	04-05-18	4.71	21-11-18 15:28	10.73	20-11-18 10:29	4.86	20-11-18 13:37	6.33	08-06-18	3.92	22-11-18 14:33	6.04
18-05-18	6.52	18-05-18	4.56	22-11-18 10:32	10.71	20-11-18 10:39	4.88	20-11-18 14:42	6.38	15-06-18	3.97	23-11-18 08:41	6.05
25-05-18	6.67	25-05-18	4.70	22-11-18 15:04	10.74	20-11-18 10:46	4.89	20-11-18 15:34	6.42	22-06-18	4.05	23-11-18 15:37	6.05
01-06-18	6.87	01-06-18	4.43	23-11-18 08:46	10.83	20-11-18 11:04	4.92	20-11-18 16:33	6.45	29-06-18	3.87	24-11-18 09:28	6.07
08-06-18	6.93	08-06-18	4.40	23-11-18 15:29	10.87	20-11-18 11:23	4.96	20-11-18 19:11	6.51	06-07-18	4.02	24-11-18 14:09	6.06
15-06-18	6.97	15-06-18	4.60	24-11-18 09:32	10.96	20-11-18 11:38	4.99	21-11-18 07:34	6.61	13-07-18	4.13	24-11-18 16:16	6.06
22-06-18	7.00	22-06-18	4.72	24-11-18 14:13	10.98	20-11-18 11:52	5.01	21-11-18 11:15	6.65	20-07-18	4.36	25-11-18 10:41	6.08
29-06-18	7.05	29-06-18	4.78	24-11-18 16:12	10.99	20-11-18 12:38	5.08	21-11-18 14:08	6.66	27-07-18	4.40	25-11-18 16:39	6.07
06-07-18	7.00	06-07-18	4.64	25-11-18 10:44	11.08	20-11-18 13:39	5.15	21-11-18 16:26	6.68	01-08-18	4.43	26-11-18 09:10	6.07
13-07-18	6.93	13-07-18	4.60	25-11-18 16:42	11.09	20-11-18 14:48	5.21	21-11-18 20:38	6.73	09-08-18	4.41	26-11-18 15:33	6.08
20-07-18	6.78	20-07-18	4.52	26-11-18 09:14	11.15	20-11-18 15:37	5.24	22-11-18 08:21	6.77	17-08-18	4.45	27-11-18 09:59	6.07
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01-08-18	6.81	01-08-18	4.52	27-11-18 10:06	11.20	20-11-18 19:14	5.35	22-11-18 18:12	6.80	27-08-18	4.55	28-11-18 10:12	6.04
09-08-18	6.79	09-08-18	4.54	27-11-18 16:10	11.20	20-11-18 21:54	5.40	23-11-18 08:10	6.84	13-09-18	4.96	28-11-18 16:10	6.05
17-08-18	6.81	17-08-18	4.54	28-11-18 10:15	11.15	21-11-18 07:37	5.42	23-11-18 14:13	6.86	20-09-18 16:47	5.01	29-11-18 09:54	6.03
24-08-18	7.03	24-08-18	4.58	28-11-18 16:14	11.16	21-11-18 11:18	5.47	23-11-18 18:09	6.87	27-09-18 14:05	5.05	29-11-18 15:58	6.03
27-08-18	7.15	27-08-18	4.64	29-11-18 10:01	11.18	21-11-18 14:12	5.49	24-11-18 08:40	6.95	03-10-18 15:21	5.03	30-11-18 09:49	6.03
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20-09-18 16:16	7.41	20-09-18 16:23	5.76	30-11-18 15:49	11.16	22-11-18 08:25	5.62	25-11-18 10:49	7.05	31-10-18 11:35	5.38	01-12-18 15:53	6.03
27-09-18 14:36	7.37	27-09-18 14:25	5.71	01-12-18 09:01	11.20	22-11-18 14:17	5.63	25-11-18 14:05	7.05	08-11-18 12:00	7.72	02-12-18 11:04	6.03
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20-11-18 14:17	7.79	20-11-18 12:07	6.27	03-12-18 15:37	11.28	27-11-18 08:49	5.89	30-11-18 08:20	7.29	20-11-18 14:42	6.84	22-01-19 09:55	5.76
20-11-18 14:49	7.78	20-11-18 13:36	6.32	03-12-18 16:26	11.28	27-11-18 14:10	5.87	30-11-18 16:12	7.33	20-11-18 15:58	6.89	15-02-19 13:47	5.72
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21-11-18 09:22	7.80	20-11-18 14:43	6.35	05-12-18 11:26	10.97	28-11-18 08:39	5.88	01-12-18 08:40	7.29	20-11-18 21:37	7.04	11-04-19 11:52	6.77
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22-11-18 14:28	7.82	21-11-18 16:30	6.46	08-03-19 12:35	9.91	29-11-18 14:23	5.98	02-12-18 18:26	7.38	21-11-18 16:24	7.17		
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23-11-18 15:34	7.83	22-11-18 08:27	6.49			30-11-18 08:22	6.08	03-12-18 10:50	6.81	22-11-18 09:30	7.28		
24-11-18 09:26	7.85	22-11-18 14:23	6.50			30-11-18 16:09	6.10	03-12-18 11:00	6.69	22-11-18 14:12	7.28		
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24-11-18 16:15	7.85	23-11-18 08:21	6.56			01-12-18 08:42	6.04	03-12-18 11:22	6.54	23-11-18 08:05	7.34		
25-11-18 16:38	7.87	23-11-18 14:19	6.58			01-12-18 19:19	6.07	03-12-18 11:35	6.56	23-11-18 14:08	7.36		
25-11-18 22:38	7.87	23-11-18 18:14	6.60			02-12-18 09:45	6.09	03-12-18 11:50	6.49	23-11-18 18:04	7.38		
26-11-18 09:08	7.81	24-11-18 08:44	6.67			02-12-18 14:14	6.10	03-12-18 12:11	6.42	24-11-18 08:37	7.45		
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28-11-18 10:10	7.74	25-11-18 14:08	6.73			03-12-18 11:04	6.18	03-12-18 13:48	6.24	25-11-18 14:01	7.55		
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29-11-18 09:52	7.76	26-11-18 07:51	6.77			03-12-18 11:25	6.14	03-12-18 15:26	6.15	26-11-18 07:43	7.61		
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30-11-18 09:46	7.80	26-11-18 18:14	6.78			03-12-18 11:53	6.08	03-12-18 18:38	6.08	26-11-18 18:05	7.63		
30-11-18 15:44	7.80	27-11-18 08:50	6.79			03-12-18 12:14	6.05	04-12-18 06:55	5.90	27-11-18 08:43	7.61		
01-12-18 08:56	7.75	27-11-18 14:12	6.79			03-12-18 12:26	6.03	05-12-18 08:46	5.04	27-11-18 14:05	7.63		
01-12-18 15:51	7.75	27-11-18 18:28	6.79			03-12-18 12:52	6.00	17-12-18 10:53	4.98	27-11-18 18:10	7.66		
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02-12-18 16:21	7.75	28-11-18 15:08	6.78			03-12-18 13:50	5.93	15-02-19 12:47	4.20	28-11-18 14:58	7.66		
03-12-18 09:36	7.79	28-11-18 21:02	6.82			03-12-18 14:34	5.89	08-03-19 13:37	4.20	28-11-18 20:53	7.73		
03-12-18 10:52	7.78	29-11-18 08:48	6.79			03-12-18 15:28	5.85	11-04-19 12:11	4.48	29-11-18 08:19	7.67		
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03-12-18 12:00	7.78	29-11-18 19:18	6.80			03-12-18 18:41	5.76			29-11-18 19:07	7.73		
03-12-18 12:23	7.78	30-11-18 08:25	6.83			04-12-18 06:57	5.58			30-11-18 08:17	7.79		
03-12-18 13:54	7.77	30-11-18 16:08	6.84			05-12-18 09:14	5.21			30-11-18 16:15	7.82		
03-12-18 14:18	7.78	30-11-18 19:10	6.94			17-12-18 11:00	4.60			30-11-18 19:05	7.81		
03-12-18 14:43	7.78	01-12-18 08:45	6.83			23-01-19 10:22	3.84			01-12-18 08:38	7.78		
03-12-18 19:20	7.78	01-12-18 19:20	6.86			15-02-19 12:58	3.87			01-12-18 19:13	7.82		
04-12-18 07:35	7.78	02-12-18 09:47	6.87			08-03-19 13:38	3.83			02-12-18 09:40	7.84		
05-12-18 11:15	7.64	02-12-18 14:16	6.88			11-04-19 12:08	3.96			02-12-18 14:10	7.84		
17-12-18 11:46	7.45	02-12-18 18:30	6.89							02-12-18 18:22	7.86		
23-01-19 09:46	7.41	03-12-18 10:35	6.91							03-12-18 10:32	7.91		
15-02-19 14:00	7.31	03-12-18 11:16	6.77							03-12-18 10:46	7.83		
08-03-19 12:54	7.33	03-12-18 11:54	6.71							03-12-18 10:57	7.71		
11-04-19 11:48	7.93	03-12-18 12:09	6.69							03-12-18 11:07	7.61		
		03-12-18 12:58	6.65							03-12-18 11:19	7.52		
		03-12-18 13:22	6.64							03-12-18 11:33	7.43		
		03-12-18 14:06	6.62							03-12-18 11:43	7.37		
		03-12-18 14:27	6.62							03-12-18 12:08	7.26		
		03-12-18 15:40	6.60							03-12-18 12:19	7.22		
		03-12-18 16:29	6.59							03-12-18 12:38	7.16		
		03-12-18 18:43	6.56							03-12-18 13:22	7.06		
		04-12-18 07:05	6.48							03-12-18 13:45	7.02		
		05-12-18 09:45	6.30							03-12-18 14:26	6.96		
		17-12-18 12:29	5.83							03-12-18 15:23	6.91		
		22-01-19 11:00	5.61							03-12-18 16:32	6.87		
		15-02-19 13:04	5.54							03-12-18 18:34	6.81		
		08-03-19 13:42	5.49							04-12-18 06:49	6.63		
		11-04-19 12:14	6.16							05-12-18 09:26	6.35		
										17-12-18 10:39	5.68		
										22-01-19 10:30	4.95		
										15-02-19 12:39	4.66		
										08-03-19 13:37	4.20		
										11-04-19 12:04	5.08		

🟩 **or Long-Term Monitoring**
🟦 **nstant Rate Test**

Manual Groundwater Level Measurements

BH26		BH27		BH28		BH29		BH30		TW07		TW10		BH31-OS	
Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC
18-10-18 16:00	4.89	15-11-18 12:13	6.64	24-08-18	27.53	24-08-18	24.37	23-02-18	23.83	06-09-18	7.65	06-09-18	15.45	20-11-18 16:30	25.11
31-10-18 10:55	4.74	20-11-18 09:13	6.71	27-08-18	27.58	27-08-18	24.40	26-02-18	23.84	13-09-18	7.69	13-09-18	15.47	20-11-18 08:40	25.07
08-11-18 11:40	5.95	20-11-18 10:16	6.70	05-09-18	27.26	05-09-18	24.48	05-03-18	23.78	20-09-18	7.62	20-09-18	15.48	20-11-18 11:39	25.07
15-11-18 11:43	4.58	20-11-18 10:43	6.72	13-09-18	26.70	13-09-18	24.56	06-03-18	23.78	27-09-18 16:20	7.60	27-09-18 15:55	15.41	20-11-18 12:18	25.14
20-11-18 09:06	4.64	20-11-18 10:51	6.72	20-09-18 16:51	26.77	20-09-18 17:00	24.35	08-03-18	23.77	02-10-18 16:30	7.58	02-10-18 16:50	15.40	20-11-18 13:30	25.14
20-11-18 10:09	4.62	20-11-18 10:53	6.71	27-09-18 13:50	26.75	27-09-18 13:37	24.49	13-03-18	23.76	10-10-18 15:40	7.62	10-10-18 15:20	15.21	20-11-18 13:55	25.14
20-11-18 10:26	4.69	20-11-18 11:38	6.75	03-10-18 15:29	26.78	03-10-18 13:37	24.54	27-03-18	23.94	18-10-18 11:37	7.68	18-10-18 11:47	15.17	20-11-18 14:15	25.14
20-11-18 10:38	4.77	20-11-18 12:08	6.75	10-10-18 15:58	26.84	10-10-18 13:56	24.58	06-04-18	23.82	31-10-18 16:25	7.60	31-10-18 16:00	- *	20-11-18 15:00	25.14
20-11-18 10:47	4.82	20-11-18 13:37	6.78	18-10-18 15:25	26.65	18-10-18 15:38	24.52	13-04-18	23.90	08-11-18 15:00	7.58	08-11-18 15:30	- *	20-11-18 15:23	25.14
20-11-18 11:02	4.89	20-11-18 14:12	6.80	31-10-18 12:00	26.70	31-10-18 12:05	24.60	20-04-18	23.90	16-11-18 08:30	7.67	20-11-18 08:35	- *	21-11-18 08:33	24.98
20-11-18 11:21	4.97	20-11-18 14:44	6.80	08-11-18 12:23	26.80	08-11-18 12:37	24.86	27-04-18	23.75	20-11-18 08:15	7.61	20-11-18 11:27	- *	21-11-18 10:40	24.98
20-11-18 11:37	5.02	20-11-18 15:17	6.82	26-11-18 15:40	27.46	16-11-18 12:48	24.70	04-05-18	23.82	20-11-18 11:19	7.61	20-11-18 12:08	- *	21-11-18 12:42	24.99
20-11-18 11:50	5.06	21-11-18 11:22	6.99	27-11-18 10:08	27.40	20-11-18 09:06	24.70	18-05-18	23.72	20-11-18 11:56	7.61	20-11-18 13:21	- *	21-11-18 15:24	25.07
20-11-18 12:37	5.16	21-11-18 14:15	7.01	27-11-18 16:13	27.47	20-11-18 10:13	24.71	25-05-18	23.86	20-11-18 13:17	7.61	20-11-18 13:55	- *	22-11-18 08:50	25.15
20-11-18 13:38	5.25	21-11-18 16:32	7.02	28-11-18 10:18	27.42	20-11-18 10:26	24.73	01-06-18	23.76	20-11-18 13:51	7.61	20-11-18 14:41	- *	22-11-18 11:57	25.59
20-11-18 14:46	5.31	21-11-18 20:45	7.04	28-11-18 16:16	27.50	20-11-18 10:51	24.77	08-06-18	23.42	20-11-18 14:31	7.61	20-11-18 15:18	- *	22-11-18 15:52	25.16
20-11-18 15:35	5.35	22-11-18 08:29	7.07	29-11-18 10:05	27.49	20-11-18 11:10	24.80	15-06-18	23.49	20-11-18 15:10	7.61	21-11-18 08:45	- *	23-11-18 08:56	25.00
20-11-18 16:34	5.37	22-11-18 14:25	7.08	29-11-18 16:05	27.53	20-11-18 11:22	24.81	22-06-18	23.76	21-11-18 08:12	7.57	21-11-18 10:30	- *	23-11-18 14:28	24.94
20-11-18 19:12	5.45	22-11-18 18:22	7.09	30-11-18 10:09	27.60	20-11-18 11:33	24.82	29-06-18	23.80	21-11-18 10:15	7.57	21-11-18 12:37	19.78	23-11-18 16:12	24.94
21-11-18 07:34	5.47	23-11-18 08:23	7.13	30-11-18 15:51	27.60	20-11-18 11:46	24.84	06-07-18	24.04	21-11-18 12:21	7.57	21-11-18 15:52	19.62	24-11-18 10:44	25.01
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21-11-18 16:28	5.58	24-11-18 08:45	7.22	02-12-18 11:10	27.59	20-11-18 13:45	24.93	27-07-18	24.31	22-11-18 11:36	7.62	22-11-18 15:43	19.42	25-11-18 16:18	25.01
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22-11-18 08:23	5.68	24-11-18 19:36	7.26	03-12-18 09:43	27.65	20-11-18 14:52	24.97	09-08-18	24.39	23-11-18 08:42	7.62	23-11-18 14:16	19.24	26-11-18 15:08	25.08
22-11-18 14:16	5.69	25-11-18 10:45	7.31	03-12-18 10:43	27.65	20-11-18 15:27	24.99	17-08-18	24.25	23-11-18 14:08	7.60	23-11-18 16:05	19.23	27-11-18 09:28	24.83
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23-11-18 14:16	5.77	26-11-18 07:52	7.39	03-12-18 11:50	27.64	21-11-18 11:55	25.21	05-09-18	24.76	24-11-18 15:37	7.61	25-11-18 10:00	19.05	28-11-18 15:40	25.09
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26-11-18 18:10	6.03	29-11-18 14:28	7.47	17-01-19 11:07	26.76	25-11-18 16:47	25.56	20-11-18 09:05	25.13	29-11-18 15:10	7.55	30-11-18 08:52	18.04	03-12-18 12:20	24.65
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28-11-18 15:03	6.04	01-12-18 08:46	7.49			28-11-18 10:24	25.59	20-11-18 11:08	25.20	02-12-18 10:21	7.57	02-12-18 15:54	17.14	05-12-18 14:54	24.45
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29-11-18 08:30	6.04	02-12-18 09:48	7.53			29-11-18 10:08	25.66	20-11-18 11:31	25.23	03-12-18 08:39	7.59	03-12-18 12:10	16.90	22-01-19 14:28	21.57
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03-12-18 13:26	5.81	08-03-19 13:43	5.95			03-12-18 16:21	25.52	25-11-18 11:06	25.99						
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03-12-18 14:33	5.74					05-12-18 10:41	25.05	26-11-18 09:17	26.03						
03-12-18 15:27	5.70					17-12-18 11:18	24.55	26-11-18 15:44	26.06						
03-12-18 16:32	5.66					23-01-19 11:07	24.13	27-11-18 10:12	26.01						
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04-12-18 06:56	5.45					08-03-19 14:20	24.14	28-11-18 10:22	26.02						
05-12-18 08:58	5.14					11-04-19 12:29	24.55	28-11-18 16:19	26.08						
17-12-18 10:50	4.50							29-11-18 10:07	26.10						
23-01-19 10:46	3.82							29-11-18 16:07	26.13						
15-02-19 12:50	3.87							30-11-18 10:11	26.21						
08-03-19 13:36	3.73							30-11-18 15:55	26.22						
11-04-19 12:10	3.87							01-12-18 09:08	26.16						
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								03-12-18 14:40	26.03						
								03-12-18 15:27	26.01						
								03-12-18 16:20	26.00						
								04-12-18 07:45	25.81						
								04-12-18 07:45	25.81						
								05-12-18 10:34	25.50						
								17-12-18 11:15	24.97						
								22-01-19 10:59	24.52						
								15-02-19 14:19	24.51						
								08-03-19 14:30	24.54						
								11-04-19 12:27	24.91						
🟩	**Background or Long-Term Monitoring**														
🟦	**Constant Rate Test**														

Manual Groundwater Level Measurements

Pumping Well											
Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC	Date/Time	m bTOC
19-11-18 10:00	5.82	19-11-18 12:50	7.03	19-11-18 15:40	8.52	20-11-18 10:35	7.97	27-11-18 02:00	9.45	03-12-18 12:15	7.37
19-11-18 10:00	6.20	19-11-18 12:55	7.04	19-11-18 15:45	8.53	20-11-18 10:40	8.02	27-11-18 06:00	9.41	03-12-18 12:30	7.33
19-11-18 10:01	6.35	19-11-18 13:00	7.04	19-11-18 15:50	8.54	20-11-18 10:45	8.06	27-11-18 10:03	9.41	03-12-18 13:00	7.26
19-11-18 10:01	6.23	19-11-18 13:00	7.24	19-11-18 15:55	8.55	20-11-18 10:50	8.09	27-11-18 14:00	9.42	03-12-18 13:30	7.20
19-11-18 10:02	6.21	19-11-18 13:01	7.28	19-11-18 16:00	8.56	20-11-18 10:55	8.15	27-11-18 18:00	9.45	03-12-18 14:00	7.16
19-11-18 10:02	6.21	19-11-18 13:01	7.28	19-11-18 16:00	7.10	20-11-18 11:00	8.17	27-11-18 22:00	9.49	03-12-18 14:30	7.13
19-11-18 10:03	6.22	19-11-18 13:02	7.28	19-11-18 16:01	7.03	20-11-18 11:15	8.25	28-11-18 02:00	9.48	03-12-18 15:30	7.08
19-11-18 10:03	6.23	19-11-18 13:02	7.30	19-11-18 16:01	7.00	20-11-18 11:30	8.32	28-11-18 06:00	9.45	03-12-18 16:30	7.04
19-11-18 10:04	6.23	19-11-18 13:03	7.31	19-11-18 16:02	6.97	20-11-18 11:45	8.37	28-11-18 10:00	9.45	03-12-18 17:30	7.04
19-11-18 10:04	6.23	19-11-18 13:03	7.31	19-11-18 16:02	6.95	20-11-18 12:00	8.42	28-11-18 14:00	9.47	03-12-18 18:30	7.00
19-11-18 10:05	6.24	19-11-18 13:04	7.31	19-11-18 16:03	6.92	20-11-18 12:30	8.50	28-11-18 18:00	9.53	03-12-18 19:30	6.97
19-11-18 10:06	6.25	19-11-18 13:04	7.32	19-11-18 16:03	6.92	20-11-18 13:00	8.56	28-11-18 22:00	9.57	03-12-18 21:30	6.94
19-11-18 10:07	6.24	19-11-18 13:05	7.32	19-11-18 16:04	6.90	20-11-18 13:30	8.61	29-11-18 02:00	9.56	03-12-18 23:30	6.90
19-11-18 10:08	6.27	19-11-18 13:06	7.32	19-11-18 16:04	6.89	20-11-18 14:00	8.63	29-11-18 06:00	9.51	04-12-18 03:30	6.84
19-11-18 10:09	6.27	19-11-18 13:07	7.32	19-11-18 16:05	6.89	20-11-18 15:00	8.69	29-11-18 10:00	9.52	04-12-18 06:30	6.80
19-11-18 10:10	6.28	19-11-18 13:08	7.33	19-11-18 16:06	6.86	20-11-18 16:00	8.73	29-11-18 14:00	9.56	04-12-18 09:30	6.79
19-11-18 10:12	6.29	19-11-18 13:09	7.33	19-11-18 16:07	6.84	20-11-18 17:00	8.76	29-11-18 18:00	9.56	05-12-18 08:44	6.54
19-11-18 10:14	6.30	19-11-18 13:10	7.34	19-11-18 16:08	6.82	20-11-18 18:00	8.80	29-11-18 22:00	9.58	17-12-18 10:29	5.57
19-11-18 10:16	6.31	19-11-18 13:12	7.35	19-11-18 16:09	6.80	20-11-18 19:00	8.81	30-11-18 02:00	9.61	23-01-19 10:32	4.77
19-11-18 10:18	6.32	19-11-18 13:14	7.35	19-11-18 16:10	6.78	20-11-18 20:00	8.83	30-11-18 06:00	9.60	15-02-19 15:15	4.69
19-11-18 10:20	6.33	19-11-18 13:16	7.36	19-11-18 16:14	6.72	20-11-18 22:00	8.85	30-11-18 10:00	9.62	08-03-19 13:22	4.67
19-11-18 10:22	6.34	19-11-18 13:18	7.37	19-11-18 16:16	6.69	21-11-18 12:00	8.87	30-11-18 14:00	9.63	11-04-19 12:02	4.83
19-11-18 10:24	6.35	19-11-18 13:20	7.37	19-11-18 16:18	6.66	21-11-18 02:00	8.88	30-11-18 18:00	9.65		
19-11-18 10:26	6.36	19-11-18 13:22	7.38	19-11-18 16:20	6.64	21-11-18 04:00	8.89	30-11-18 22:00	9.64		
19-11-18 10:28	6.36	19-11-18 13:24	7.39	19-11-18 16:22	6.62	21-11-18 06:00	-	01-12-18 02:00	9.65		
19-11-18 10:30	6.37	19-11-18 13:26	7.39	19-11-18 16:24	6.60	21-11-18 08:00	8.92	01-12-18 06:00	9.64		
19-11-18 10:35	6.39	19-11-18 13:28	7.40	19-11-18 16:26	6.57	21-11-18 10:00	8.94	01-12-18 10:00	9.63		
19-11-18 10:40	6.40	19-11-18 13:30	7.40	19-11-18 16:28	6.56	21-11-18 12:00	8.95	01-12-18 14:00	9.62		
19-11-18 10:45	6.42	19-11-18 13:35	7.42	19-11-18 16:30	6.53	21-11-18 14:00	8.96	01-12-18 19:09	9.65		
19-11-18 10:50	6.43	19-11-18 13:40	7.43	19-11-18 16:35	6.50	21-11-18 16:00	8.98	01-12-18 22:00	9.66		
19-11-18 10:55	6.44	19-11-18 13:45	7.44	19-11-18 16:40	6.46	21-11-18 18:00	9.02	02-12-18 02:00	9.66		
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19-11-18 11:05	6.46	19-11-18 13:55	7.46	19-11-18 16:50	6.39	21-11-18 22:00	9.05	02-12-18 10:00	9.69		
19-11-18 11:10	6.47	19-11-18 14:00	7.47	19-11-18 16:55	6.36	22-11-18 02:00	9.05	02-12-18 14:00	9.70		
19-11-18 11:15	6.48	19-11-18 14:05	7.48	19-11-18 17:00	6.34	22-11-18 06:00	9.07	02-12-18 18:00	9.70		
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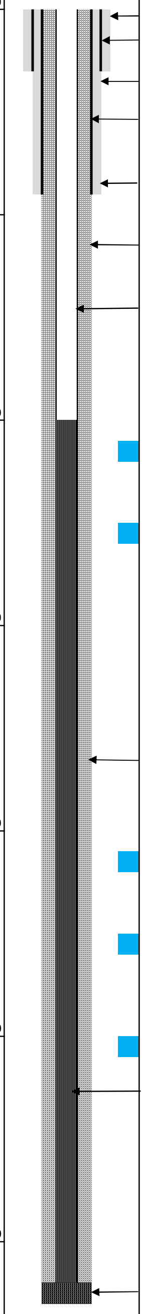
19-11-18 11:31	6.76	19-11-18 14:30	7.51	19-11-18 18:30	6.07	23-11-18 02:20	8.93	03-12-18 10:30	8.28		
19-11-18 11:31	6.78	19-11-18 14:30	8.09	19-11-18 19:00	6.03	23-11-18 02:35	8.98	03-12-18 10:31	8.31		
19-11-18 11:32	6.79	19-11-18 14:31	8.16	19-11-18 19:30	5.99	23-11-18 02:45	9.00	03-12-18 10:31	8.29		
19-11-18 11:32	6.79	19-11-18 14:31	8.18	19-11-18 20:00	5.97	23-11-18 03:00	9.02	03-12-18 10:32	8.27		
19-11-18 11:33	6.80	19-11-18 14:32	8.19	19-11-18 22:00	5.93	23-11-18 04:00	9.07	03-12-18 10:32	8.25		
19-11-18 11:33	6.80	19-11-18 14:32	8.20	20-11-18 02:00	5.85	23-11-18 05:00	9.09	03-12-18 10:33	8.23		
19-11-18 11:34	6.81	19-11-18 14:33	8.21	20-11-18 07:30	5.84	23-11-18 07:00	9.12	03-12-18 10:33	8.21		
19-11-18 11:34	6.81	19-11-18 14:33	8.21	20-11-18 10:00	5.83	23-11-18 08:00	9.15	03-12-18 10:34	8.20		
19-11-18 11:35	6.82	19-11-18 14:34	8.22	20-11-18 10:00	6.24	23-11-18 09:00	9.14	03-12-18 10:34	8.18		
19-11-18 11:36	6.82	19-11-18 14:34	8.22	20-11-18 10:01	6.70	23-11-18 10:00	9.15	03-12-18 10:35	8.17		
19-11-18 11:37	6.83	19-11-18 14:35	8.23	20-11-18 10:01	7.30	23-11-18 10:05	8.99	03-12-18 10:36	8.15		
19-11-18 11:38	6.83	19-11-18 14:36	8.24	20-11-18 10:02	7.37	23-11-18 14:00	9.13	03-12-18 10:37	8.12		
19-11-18 11:39	6.84	19-11-18 14:37	8.25	20-11-18 10:02	7.42	23-11-18 18:00	9.14	03-12-18 10:38	8.10		
19-11-18 11:40	6.84	19-11-18 14:38	8.26	20-11-18 10:03	7.44	23-11-18 22:00	9.17	03-12-18 10:39	8.08		
19-11-18 11:42	6.85	19-11-18 14:39	8.26	20-11-18 10:03	7.45	24-11-18 02:00	9.17	03-12-18 10:40	8.06		
19-11-18 11:44	6.86	19-11-18 14:40	8.27	20-11-18 10:04	7.48	24-11-18 06:00	9.18	03-12-18 10:42	8.03		
19-11-18 11:46	6.87	19-11-18 14:42	8.28	20-11-18 10:04	7.50	24-11-18 10:00	9.24	03-12-18 10:44	7.98		
19-11-18 11:48	6.88	19-11-18 14:44	8.30	20-11-18 10:05	7.51	24-11-18 14:00	9.24	03-12-18 10:46	7.96		
19-11-18 11:50	6.88	19-11-18 14:46	8.31	20-11-18 10:06	7.54	24-11-18 18:00	9.24	03-12-18 10:48	7.93		
19-11-18 11:52	6.89	19-11-18 14:48	8.32	20-11-18 10:07	7.57	24-11-18 22:00	9.29	03-12-18 10:50	7.90		
19-11-18 11:54	6.90	19-11-18 14:50	8.33	20-11-18 10:08	7.59	25-11-18 02:00	9.30	03-12-18 10:52	7.88		
19-11-18 11:56	6.91	19-11-18 14:52	8.34	20-11-18 10:09	7.62	25-11-18 06:00	9.29	03-12-18 10:54	7.85		
19-11-18 11:58	6.91	19-11-18 14:54	8.35	20-11-18 10:10	7.64	25-11-18 11:00	9.33	03-12-18 10:56	7.83		
19-11-18 12:00	6.92	19-11-18 14:56	8.36	20-11-18 10:12	7.67	25-11-18 14:00	9.33	03-12-18 10:58	7.81		
19-11-18 12:05	6.93	19-11-18 14:58	8.37	20-11-18 10:14	7.71	25-11-18 18:00	9.33	03-12-18 11:00	7.79		
19-11-18 12:10	6.95	19-11-18 15:00	8.38	20-11-18 10:16	7.74	25-11-18 22:00	9.37	03-12-18 11:05	7.75		
19-11-18 12:15	6.96	19-11-18 15:05	8.41	20-11-18 10:18	7.77	26-11-18 02:00	9.39	03-12-18 11:10	7.71		
19-11-18 12:20	6.97	19-11-18 15:10	8.42	20-11-18 10:20	7.80	26-11-18 04:00	9.38	03-12-18 11:15	7.66		
19-11-18 12:25	6.98	19-11-18 15:15	8.44	20-11-18 10:22	7.82	26-11-18 06:00	9.37	03-12-18 11:20	7.63		
19-11-18 12:30	6.99	19-11-18 15:20	8.46	20-11-18 10:24	7.85	26-11-18 10:00	9.41	03-12-18 11:25	7.59		
19-11-18 12:35	7.00	19-11-18 15:25	8.48	20-11-18 10:26	7.87	26-11-18 14:00	9.41	03-12-18 11:30	7.57		
19-11-18 12:40	7.02	19-11-18 15:30	8.49	20-11-18 10:28	7.90	26-11-18 18:00	9.42	03-12-18 11:45	7.49		
19-11-18 12:45	7.02	19-11-18 15:35	8.51	20-11-18 10:30	7.92	26-11-18 22:00	9.44	03-12-18 12:00	7.44		

🟨	**Step Test**	
🟦	**Constant Rate Test**	

Appendix 2 Borehole Logs

PROJECT:	Naul Hydrogeological Assessment	**BH Name:**	BH31-OS	1 of 2
CLIENT:	Integrated Materials Solutions			
LOCATION:	Naul	**EASTING (X)**	316379.4	
DRILLING CONTRACTOR:	Patrick Briody & Sons Ltd.	**NORTHING (Y)**	259315.7	
DRILLING METHOD	Air Percussion	**ELEVATION (Z) - mOD**	128.86	
DRILLING FLUID	None (water/air)	**FINAL DEPTH (m):**	126	
SUPERVISED AND LOGGED BY:	Conor McCabe	**DATE STARTED:**	30-Oct-18	
GROUNDWATER LEVEL (m BTOC):	25.57 m at 15:30 on 15/11/2018	**DATE COMPLETED:**	1-Nov-18	

mbgl	BOREHOLE SCHEMATIC	Water strike	WELL CONSTRUCTION FEATURES	LITHOLOGY	OBSERVATIONS	FORMATION	mbgl



Drill 14¾" open hole from 0 m to 6 m
12" steel casing 0 m to 18 m
Drill 12" open hole from 6 m to 18 m
8" steel casing 0 m to 18 m
Cement grout from 0 m to 18 m.
Drill 8" open hole from 18 m to 126 m
Blank (140 mm OD) PVC casing from 0 m to 40 m
0.5 l/s
1.5 l/s
Open hole
2.0 l/s
0.2 l/s
0.8 l/s
Slotted (140 mm OD) PVC casing from 40 m to 124 m
Fall back 124 - 126 m

Soft to firm low plasticity orange brown pale sandy CLAY with gravels, fine to coarse, angular to sub-rounded. (Boulder clay)

Weak, fractured and thinly laminated dark orange/ brown, MUDSTONE, with thin, fine sandstone bands (Inferred Walshestown). Iron oxide staining on surfaces. .

Colour change to dark grey/black

Distinct black clay band (<0.2m)

Less iron oxide staining of surfaces

Quartz fragments (<5 mm)

Quartz fragments (<5 mm)

Quartz fragments (<5 mm)

Weak, fractured thinly laminated pale grey/black fine grained MUDSTONE, with more prominent siltstone and sandstone bands, with iron oxide staining. Possible transistion into Balrickard Fm.
Fracture zone 101-102 m
Colour change in the discharge, to creamy gray

Overburden / Till

Walshestown

Balrickard?

BOREHOLE CONSTRUCTION & HYDROGEOLOGICAL LOG

Client:	Client Representative:	Drilling Contractor:	**Page 2 of 2**
IMS INTEGRATED MATERIALS SOLUTIONS	CDM Smith	PATRICK BRIODY & SONS LTD	

PROJECT LOCATIONS AND DETAILS

Project Name:	Naul Hydrogeological Assessment	**Drilling Contractor**	Patrick Briody & Sons Ltd	**Completion Date:**	01/11/2018	**Latitude (dec. degrees):**	53.571021
Borehole Name:	BH31-OS	**Contractor Representative:**	Aidan Briody	**Map Reference:**	E 316379.9 N 259315.7	**Longitude (dec. degrees):**	-6.2437728
Spud Date:	30-Oct-18	**Supervised and Logged by:**	Conor McCabe (CDM Smith)	**Geo Coord System:**	Irish Grid	**Elevation (z) - mOD**	128.86

WATER STRIKES

Depth (mbgl)	Est. Strike Yield (l/s)	Temperature (^{0}C)	pH	EC (µS/cm)
42	~0.5	10.3	7,54	493
51	~1.5	9.9	7.47	480
84	~2	10.1	7.86	493
92-93	~0.2	10.0	8.02	505
101-102	~0.8	10.0	8.02	505

CONSTRUCTION DETAILS

Permanent Steel Casing	**12" Casing**	**8" Casing**	**Comment**
From (mbgl):	0	0	
To (mbgl):	6	18	
PVC Casing	**PVC Blank**	**PVC Slotted**	**Comment**
From (mbgl):	0	40	Slotted on site, Casing OD 140 mm, casing wall 6.7 mm thick.
To (mbgl):	40	124	
To (mbgl):			

DRILLED DIAMETER

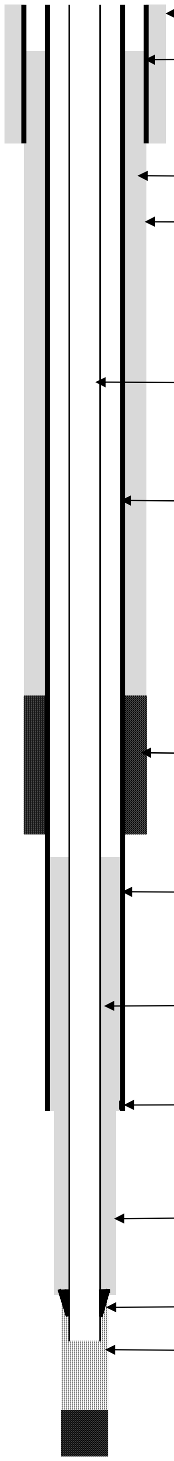
Method: Rotory Hammer		
14 3/4" open hole from 0 m to 6 m	0	6
12" open hole from 6 m to 18 m	6	18
8" open hole from 18 m to 126 m	18	126

SANITARY SEAL DETAILS: Cement Grout		**Comment**
From (mbgl):	0	39 bags of cement
To (mbgl):	18	500 L of water
Volume (litres)	790	

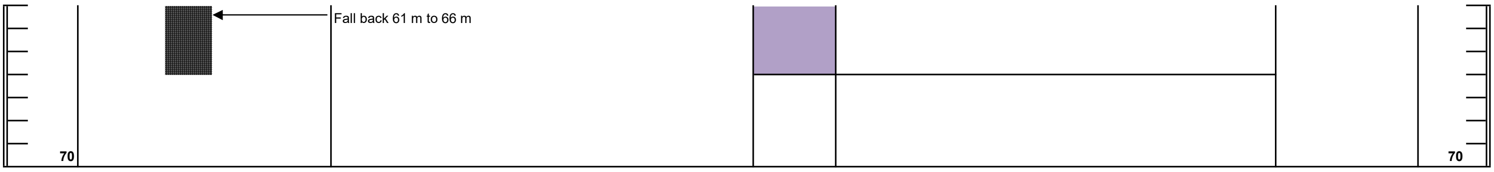
WELL DEVELOPMENT	Air surging for 4 hrs (sediment-free water)

DEPTH (m)		**LITHOLOGY / FORMATION**	**CHIP SIZE (mm)**	**WEATHERING**	**Penetration Rate**	**Blow Yield**	**Temperature**	**Parameters**		**Comments**
					(minutes)	**(l/sec)**	**(^{0}C)**	**pH**	**EC (µS/cm)**	
0	3	Soft to firm low plasticity orange brown pale sandy CLAY with gravels, fine to coarse, angular to sub-rounded. (Boulder clay)	<25	-	-					
3	5.1		<25	-	-					
5.1	6	Weak, fractured and thinly laminated dark orange/ brown, MUDSTONE, with thin, fine sandstone bands (Inferred Walshestown). Iron oxide staining on surfaces.	<25	Highly	-					
6	9		<30	Highly	7					
9	12		<30	Highly	6					
12	15		<30	Highly	8					
15	18		<30	Moderately	6					
18	21		<30	Moderately	7					
21	24		<30	Fresh	7					
24	27	Colour change grey/black	<10	Fresh	10					
27	30		<10	Fresh	7					
30	33	Black clay band (<0.2 m, sudden change in drill dust colour)	<10	Fresh	7					
33	36		<10	Fresh	6					
36	39	Less iron oxide staining on surfaces	<10	Fresh	7					
39	42		<10	Fresh	7					
42	45	Quartz fragments (< 5 mm) and water strike	<30	Fresh	7	0.5	10.3	7,54	493	Increase in water at 42 mbgl
45	48		<30	Fresh	7					
48	51		<30	Fresh	8					
51	54		<30	Fresh	9	2	9.9	7.47	480	Increase in water at 51 mbgl
54	57		<30	Fresh	4					
57	60	Silicious staining	<30	Fresh	7					
60	63		<30	Fresh	8					
63	66	Quartz fragments (< 5 mm)	<30	Fresh	7					
66	69		<30	Fresh	7					
69	72	Fracture zone, noticeable increase in strike yield	<30	Fresh	5	4	10.1	7.86	493	Increase in water at 84 mbgl
72	75		<30	Fresh	12					
75	78		<10	Fresh	10					
78	81		<10	Fresh	7					
81	84		<10	Fresh	8					
84	87		<10	Fresh	10					
87	90		<10	Fresh	10					
90	93	Quartz fragments (< 5 mm)	<30	Fresh	10	4.2	10	7.82	505	Increase in water at 92 -93 mbgl
93	96		<30	Fresh	13					
96	99	Weak, fractured thinly laminated pale grey/black fine grained MUDSTONE, with more prominent siltstone and sandstone bands, with iron oxide staining. Possible transistion into Balrickard Fm. Fracture zone 101-102 m.	<30	Moderately	10					
99	102		<30	Moderately	26	5	10	7.87	492	Increase in water at 101 -102 mbgl
102	105		<30	Moderately	29					
105	108		<30	Moderately	25					
108	111		<30	Moderately	20					
111	114		<30	Moderately	22					
114	117		<30	Moderately	21					
117	120		<30	Moderately	25					
120	123		<30	Moderately	25					
123	126		<30	Moderately	27					
126	129		<30	Moderately	27					

PROJECT:	Naul Hydrogeological Assessment	BH Name		BH32	Part 1 of 2
CLIENT:	Integrated Materials Solutions				
LOCATION:	Naul	EASTING (X):		315893.0	
DRILLING CONTRACTOR:	Patrick Briody & Sons Ltd.	NORTHING (Y):		258108.9	
DRILLING METHODS:	Symmetrix and Air Percussion	ELEVATION (Z) - mOD:		105.81	
DRILLING FLUID:	None (water/air)	TOTAL DRILLED DEPTH (m):		66	
SUPERVISED AND LOGGED BY:	Conor McCabe	DATE STARTED:		5-Nov-18	
GROUNDWATER LEVEL m below TOC:	5.5 on 15/11/2018 at 10:00	DATE COMPLETED:		9-Nov-18	



mbgl	Water strike	WELL CONSTRUCTION FEATURES	LITHOLOGY	OBSERVATIONS	FORMATION	mbgl
0						0
		Drill 15" open hole from 0 m to 6 m	🟨	Soft to firm low plastcity orange brown sandy gravelly CLAY, fine to course, angular to sub-rounded mudstone.	Walshestown	
		12" steel casing 0 m to 6 m				
				Pale orange / brown interbedded thinly laminated fractured siltstone and sandstone with mudstone/shale (Namurian, Interpreted Balrickard Fm)	Balrickard	
		Grouted 4 m to 30 m				
10		Drill nominal 12" open hole from 6 m to 36 m				10
				Colour change to pale gray and black		
	🟦	0.5 l/s				
		Blank 5" (140 mm OD) PVC from 0 m to 56 m				
20						20
		Drill 8" Symmetrix (with casing) from 30 m to 48 m		Highly fractured broken rock		
	🟦	3.5 l/s		Increased blow yield		
30						30
		Fall back 30 m to 36 m				
	🟦	2.0 l/s		Increased blow yield		
		8" steel casing 0 m to 48 m				
40						40
		Cement Grout from 37 m to 56 m				
			🟪	Strong black shaley fractured LIMESTONE	Loughshinny	
		Symmetrix casing shoe at 48 m				
				Less fractured, more competent rock (Limestone)		
50						50
	🟦	6.0 l/s		Increased blow yield		
		Drill 7½" open hole from 48 m to 56 m				
		Plug with oversized casing		Colour change in water from clear to creamy white		
				57 - 58 rods drop, inferred fracture/conduit		
		Drill 6" open hole from 56 m to 66 m				
60						60
	🟦	6.0 to 9.0 l/s		Significant void/fracture		
				Less fractured, more competent rock (Limestone)		


Fall back 61 m to 66 m
70
70

BOREHOLE CONSTRUCTION & HYDROGEOLOGICAL LOG

Client: IMS INTEGRATED MATERIALS SOLUTIONS	Client Representative: CDM Smith	Drilling Contractor: PATRICK BRIODY & SONS LTD	**Page 2 of 2**

PROJECT LOCATIONS AND DETAILS

Project Name:	Naul Hydrogeological Assessment	**Drilling Contractor :**	Patrick Briody & Sons Ltd	**Completion Date:**	09/11/2018	**Latitude (dec. degrees):**	53.560288
Borehole Name:	BH32	**Contractor Representative:**	Aidan Briody	**Map Reference:**	E 315893.0 N 258108.9	**Longitude (dec. degrees):**	-6.2515685
Spud Date:	5-Nov-18	**Supervised and Logged by:**	Conor McCabe (CDM Smith)	**Geo Coord System:**	Irish Grid	**Elevation (z) - mOD**	105.81

WATER STRIKES

Depth (mbgl):	Est. Strike Yield (l/s)	Temperature (^{0}C)	pH	EC (µS/cm)
14 - 15	~0.5	10.2	7.56	845
26 - 27	~3.5	10.5	7.76	836
36 - 37	~2	10.5	6.89	857
50 - 51	~6	10.7	7.67	922
60 - 61	~9	10.5	8.76	821

CONSTRUCTION DETAILS

Permanent Steel Casing	**12" Casing**	**8" Casing**	**Comment**
From (mbgl):	0	0	
To (mbgl):	6	48	
PVC Casing	**PVC Blank**	**PVC Slotted**	**Comment**
From (mbgl):	0	-	
To (mbgl):	56	-	
To (mbgl):			

DRILLED DIAMETER

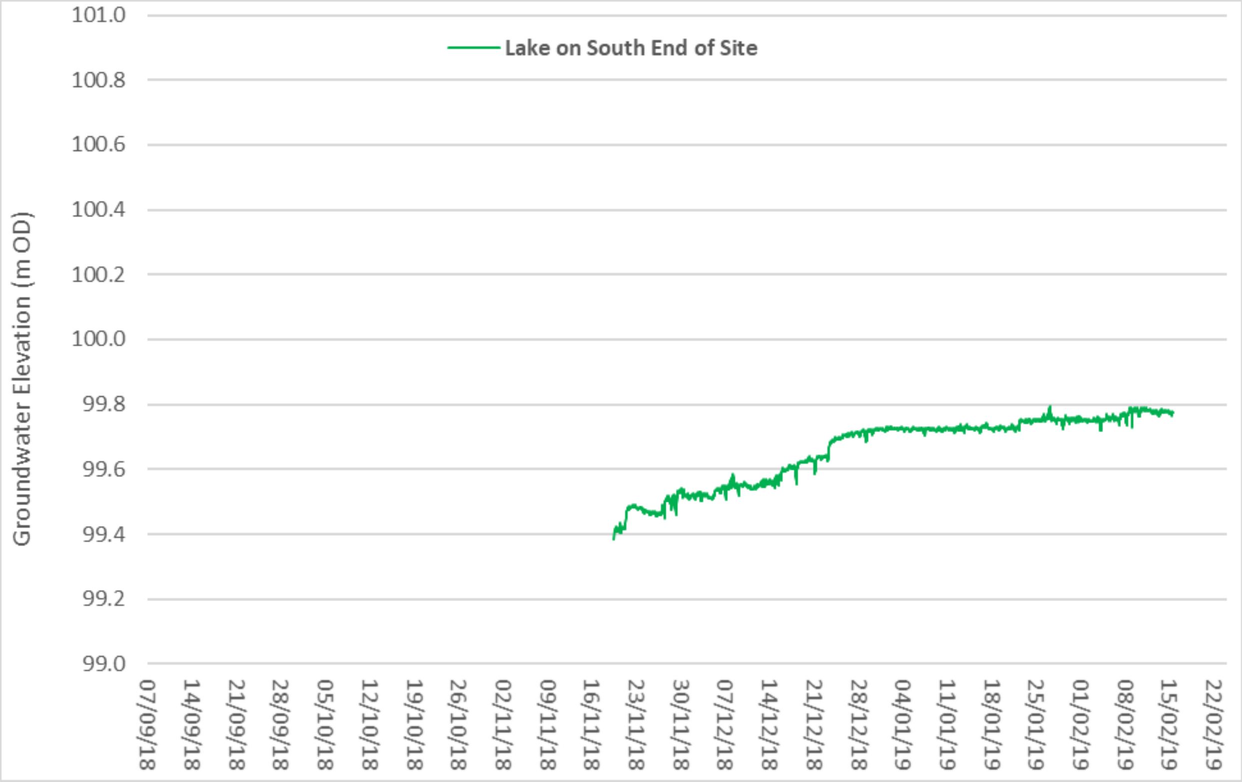
Method: Air Percussion (Rotary Hammer)	From (mbgl)	To (mbgl)
15" Open hole	0	6
12" Open hole	6	36
8" Symmetrix (with casing)	36	48
7½" Open hole	48	56
6" Open hole	56	66

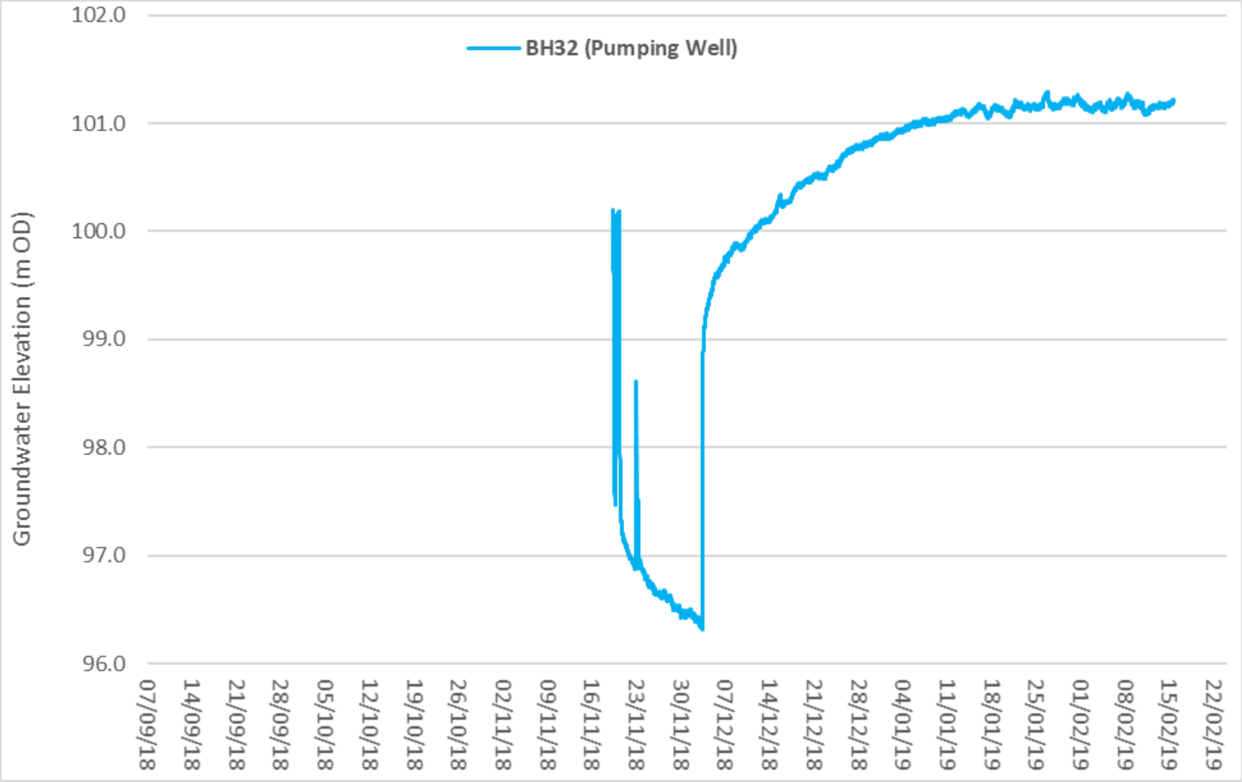
SANITARY SEAL DETAILS: Cement Grout	**Upper**	**Deep**	**Comment**
From (mbgl):	4	37	Shallow seal, 65 bags of cement and 659 L of water, Deep seal 21 bags of cement, 210 L of water
To (mbgl):	30	56	
Volume (litres)	1050	343	
Bags of bentonite			

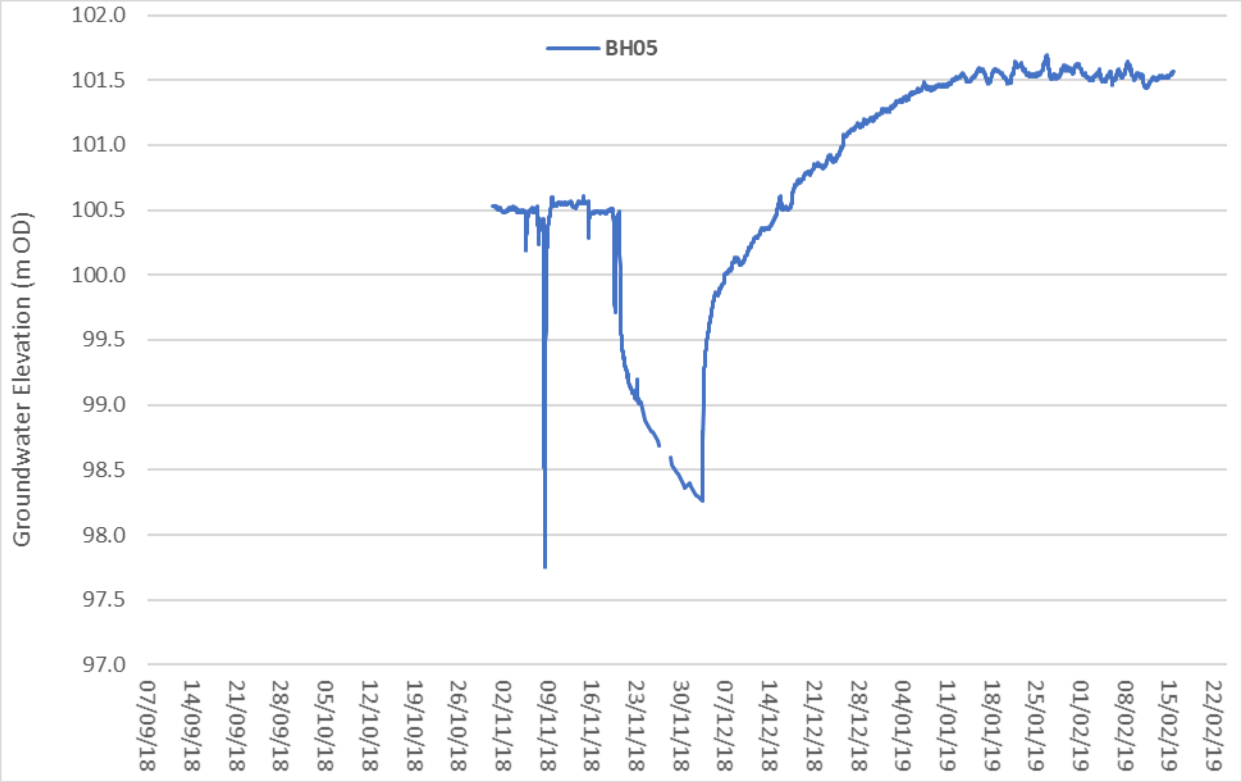
WELL DEVELOPMENT Air surging for 4 hrs (clear water, free of cuttings)

DEPTH (m)		LITHOLOGY / FORMATION	CHIP SIZE (mm)	WEATHERING	Penetration Rate	Est. Blow Yield	Temperature	Parameters		Comments
					(min/m)	(l/sec)	(^{0}C)	pH	EC (µS/cm)	
0	1	Soft to firm low plasticity orange brown sandy gravelly CLAY, fine to coarse, angular to sub-rounded mudstone.	<30	-	-	-				
1	2		<30	-						
2	3		<30	-						
3	4		<30	-						
4	5.4		<30	-						
5.4	6	Pale orange / brown interbedded thinly laminated, fractured siltstone and sandstone with mudstone/shale (Namurian, Interpreted Balrickard Fm)	<30	Moderately to Highly	2					
6	7		<30	Moderately to Highly	3					
7	8		<30	Moderately to Highly	2					
8	9		<30	Moderately to Highly	3					
9	10		<30	Moderately to Highly	2					
10	11		<30	Moderately to Highly	2					
11	12		<30	Moderately to Highly	2					
12	13		<40	Slightly to Moderately	2					
13	14	Colour change to pale gray and black (thin laminations?)	<40	Slightly to Moderately	3					
14	15		<40	Slightly to Moderately	2	0.5	10.2	7.56	845	
15	16		<40	Slightly to Moderately	3					
16	17		<40	Slightly to Moderately	2					
17	18		<40	Slightly to Moderately	3					
18	19		<40	Slightly to Moderately	2					
19	20		<40	Slightly to Moderately	2					
20	21		<60	Fresh	2					
21	22	Highly fractured broken rock	<60	Fresh	2					
22	23		<60	Fresh	2					
23	24		<60	Fresh	3					
24	25		<60	Fresh	3					
25	26		<60	Fresh	3					
26	27		<60	Fresh	3	4	10.5	7.76	836	
27	28		<30	Fresh	4					
28	29		<30	Fresh	2					
29	30		<30	Fresh	2					
30	31		<30	Fresh	3					
31	32		<30	Fresh	2					
32	33		<30	Fresh	2					
33	34		<30	Fresh	2					
34	35		<30	Fresh	2					
35	36		<40	Fresh	3					
36	37		<40	Fresh	2	6	10.5	6.89	857	
37	38		<40	Fresh	3					
38	39		<40	Fresh	2					
39	40		<40	Fresh	3					
40	41		<40	Fresh	2					
41	42		<40	Fresh	2					
42	43		<40	Fresh	2					
43	44		<40	Fresh	2					
44	45		<40	Fresh	2					
45	46	Competent black shaley and fractured LIMESTONE	<50	Fresh	3					Carbonate confirmed with HCl testing
46	47		<50	Fresh	3					as above
47	48		<50	Fresh	3					as above
48	49	Less fractured, more competent LIMESTONE	<10	Fresh	4					as above
49	50		<10	Fresh	5					as above
50	51		<10	Fresh	4	6	10.7	7.67	922	as above
51	52		<10	Fresh	5					as above
52	53		<10	Fresh	5					as above
53	54		<10	Fresh	6					as above
54	55		<10	Fresh	4	6	10.7	7.67	922	as above
55	56	Colour change in water from clear to creamy white	<10	Moderately	5					as above
56	57	57 - 58 rods drop, inferred fracture/conduit	<40	Moderately	3					as above
57	58	Return to clear water, broken LIMESTONE	<40	Fresh	4					as above
58	59		<40	Fresh	4					as above
59	60		<40	Fresh	4					as above
60	61	Significant void/fracture	<50	Fresh	1	12 – 15	10.5	8.76	821	as above
61	62		<50	Fresh	2					as above
62	63	Less fractured, more competent LIMESTONE	<50	Fresh	2					as above
63	64		<50	Fresh	5					as above
64	65		<50	Fresh	4					as above
65	66		<50	Fresh	5					as above

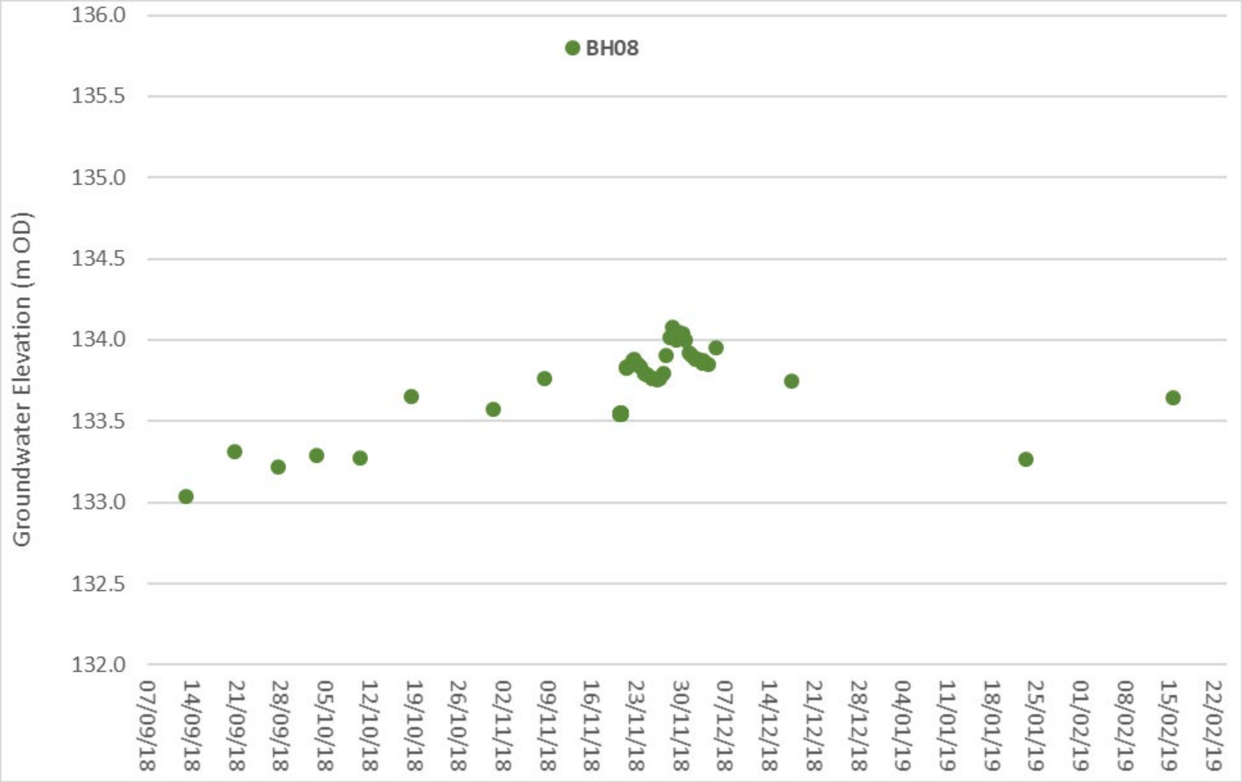
Appendix 3 Hydrographs of Individual Monitoring Wells


Lake on South End of Site
Groundwater Elevation (m OD)
101.0
100.8
100.6
100.4
100.2
100.0
99.8
99.6
99.4
99.2
99.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19


BH32 (Pumping Well)
Groundwater Elevation (m OD)
102.0
101.0
100.0
99.0
98.0
97.0
96.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19



BH05
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19



BH08
Groundwater Elevation (m OD)
136.0
135.5
135.0
134.5
134.0
133.5
133.0
132.5
132.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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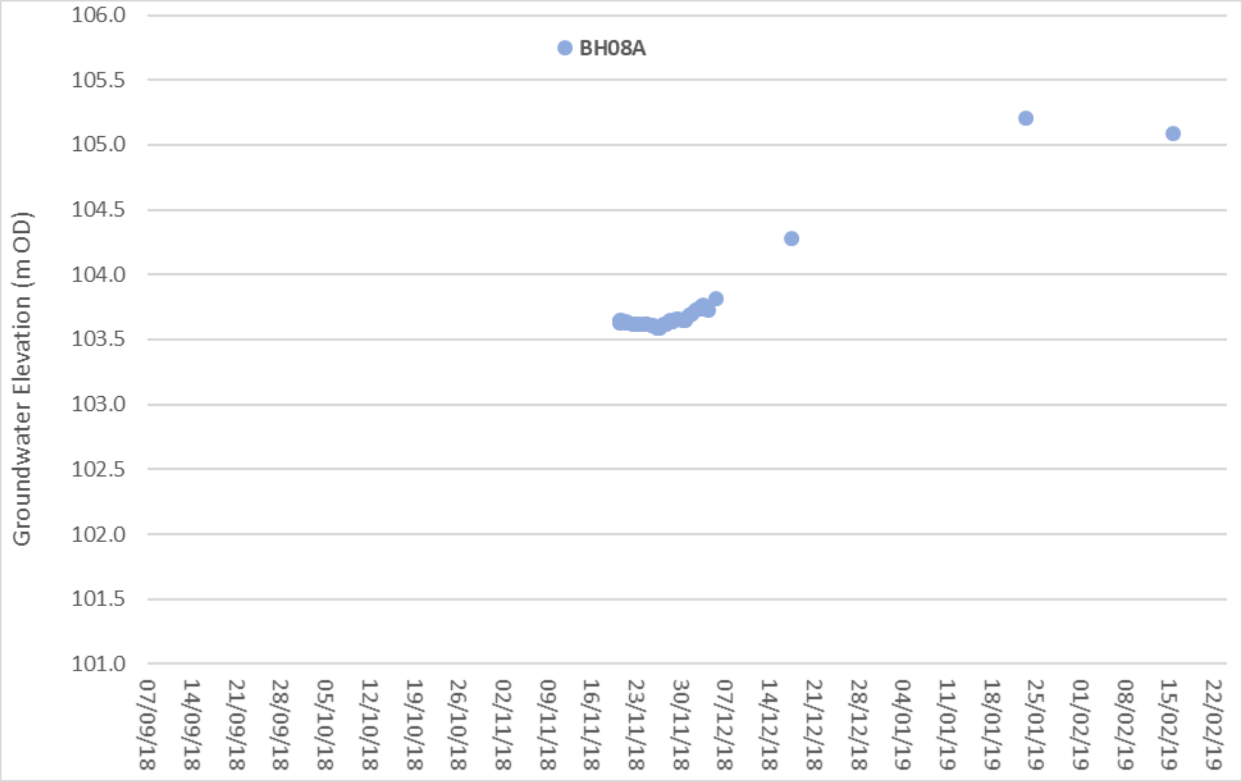
08/02/19
15/02/19
22/02/19


BH08A
Groundwater Elevation (m OD)
106.0
105.5
105.0
104.5
104.0
103.5
103.0
102.5
102.0
101.5
101.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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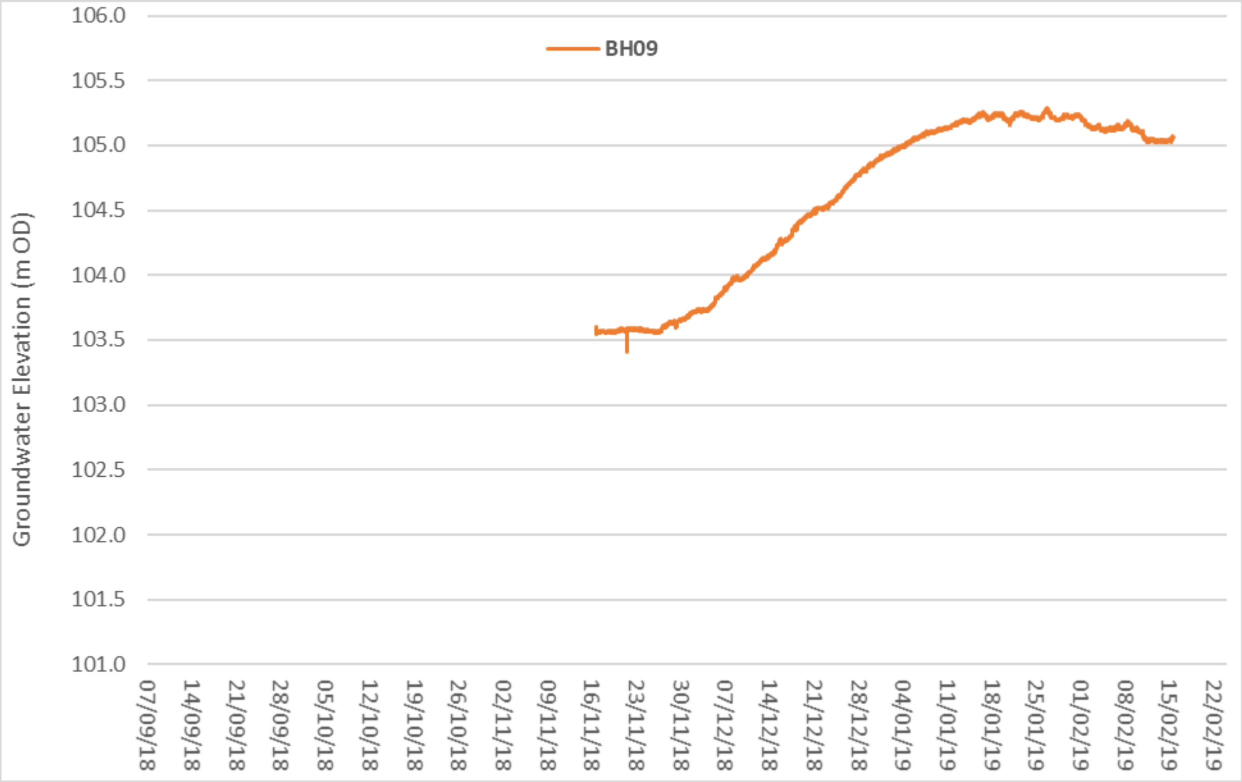
08/02/19
15/02/19
22/02/19


BH09
Groundwater Elevation (m OD)
106.0
105.5
105.0
104.5
104.0
103.5
103.0
102.5
102.0
101.5
101.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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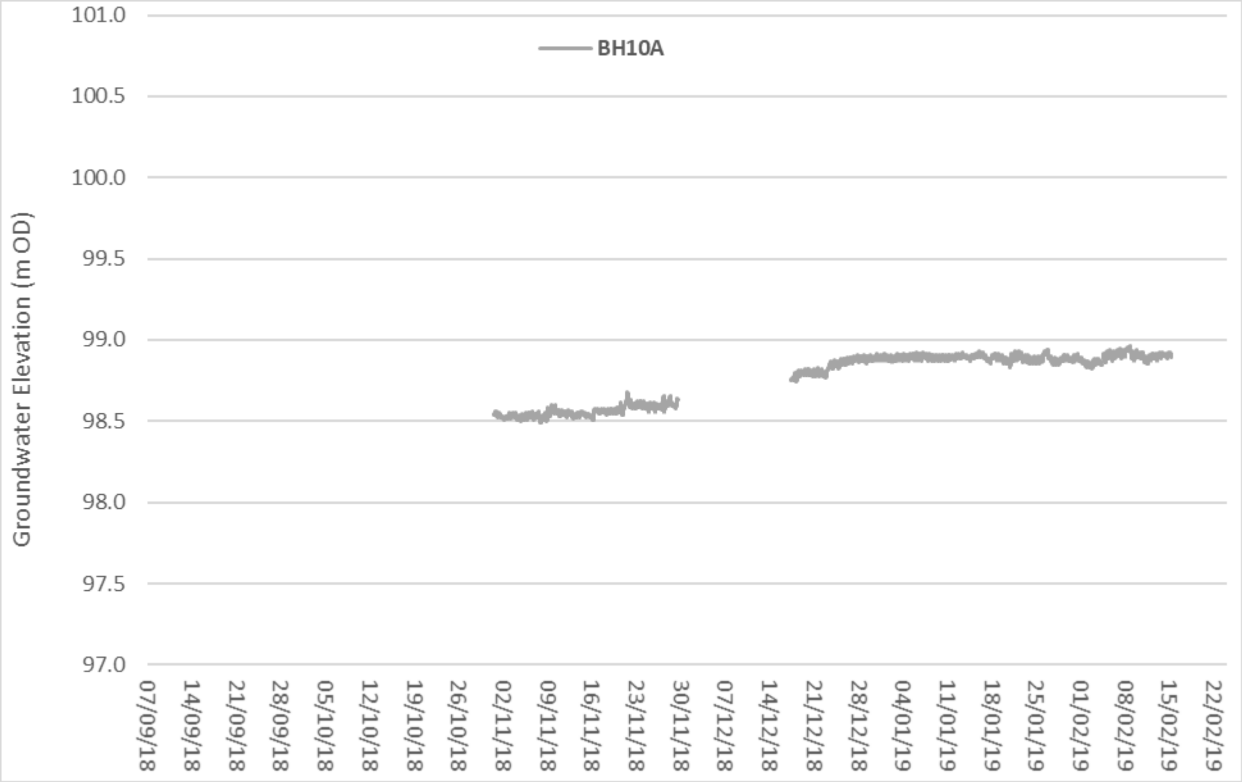
08/02/19
15/02/19
22/02/19


BH10A
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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18/01/19
25/01/19
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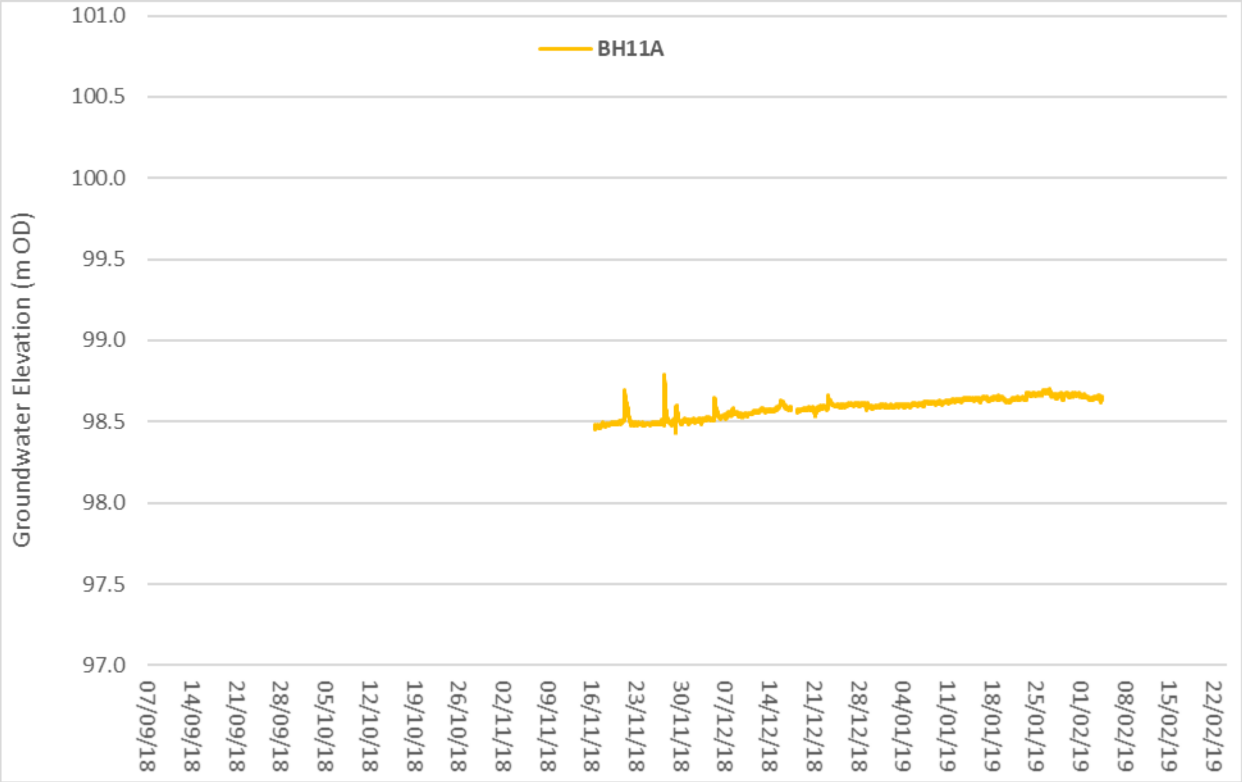
08/02/19
15/02/19
22/02/19


BH11A
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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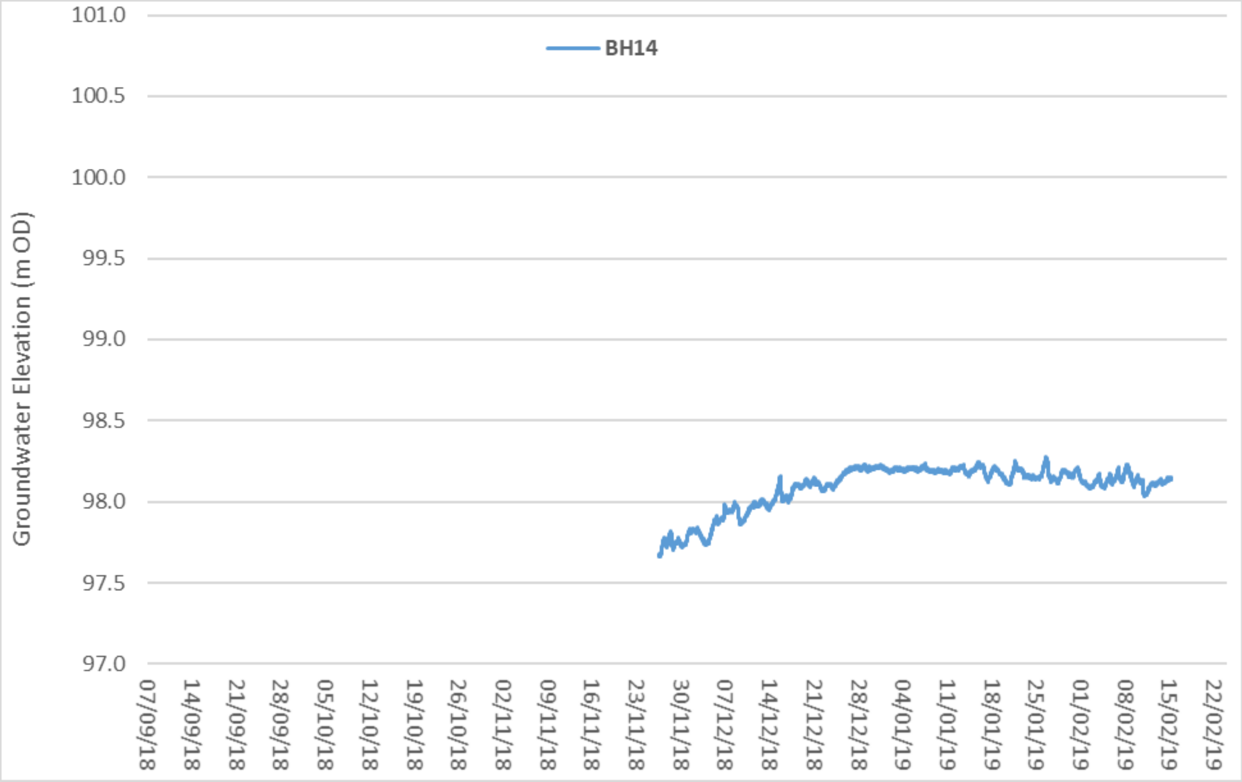
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19



BH14
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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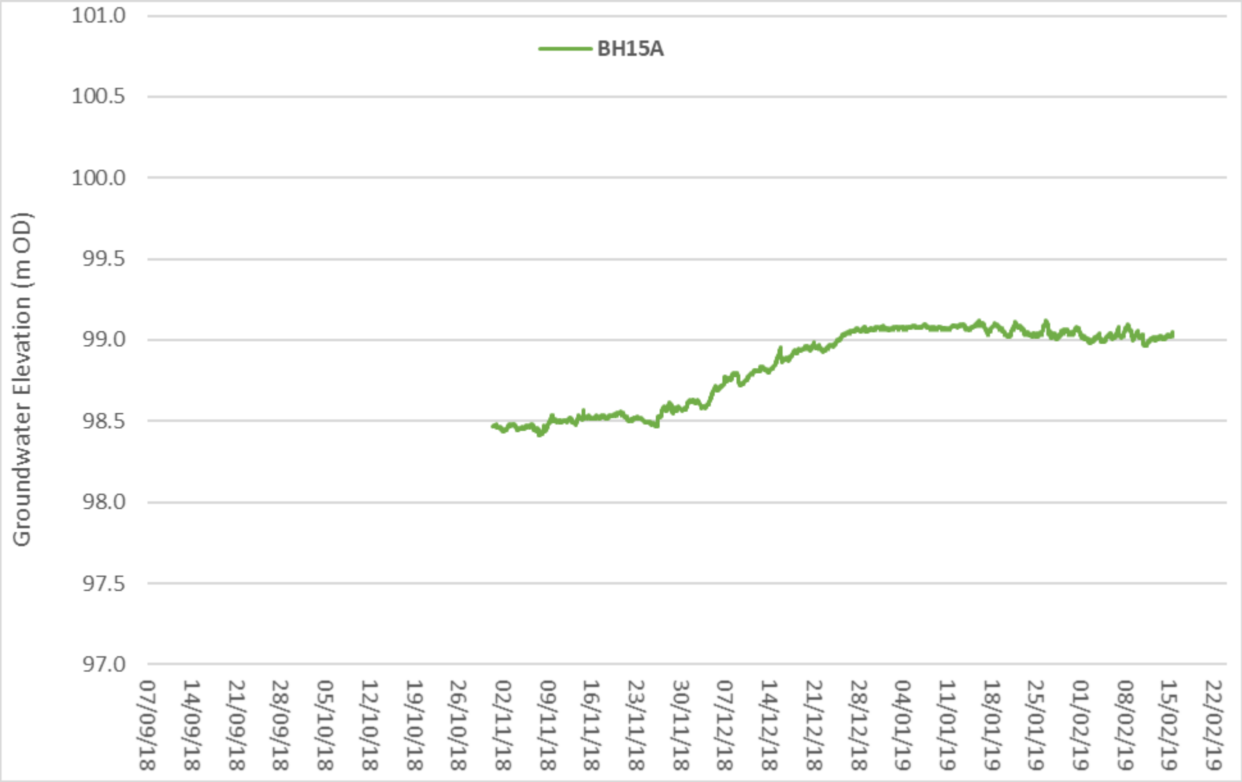
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19



BH15A
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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18/01/19
25/01/19
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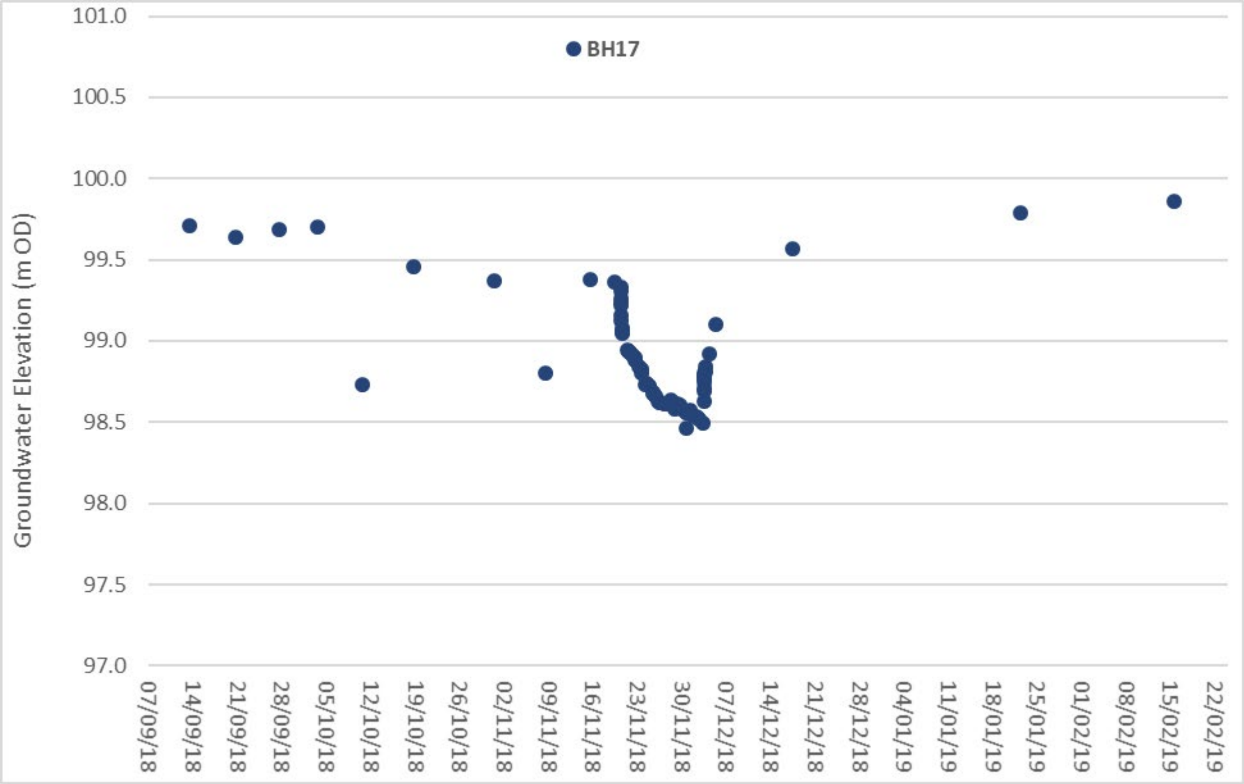
08/02/19
15/02/19
22/02/19


BH17
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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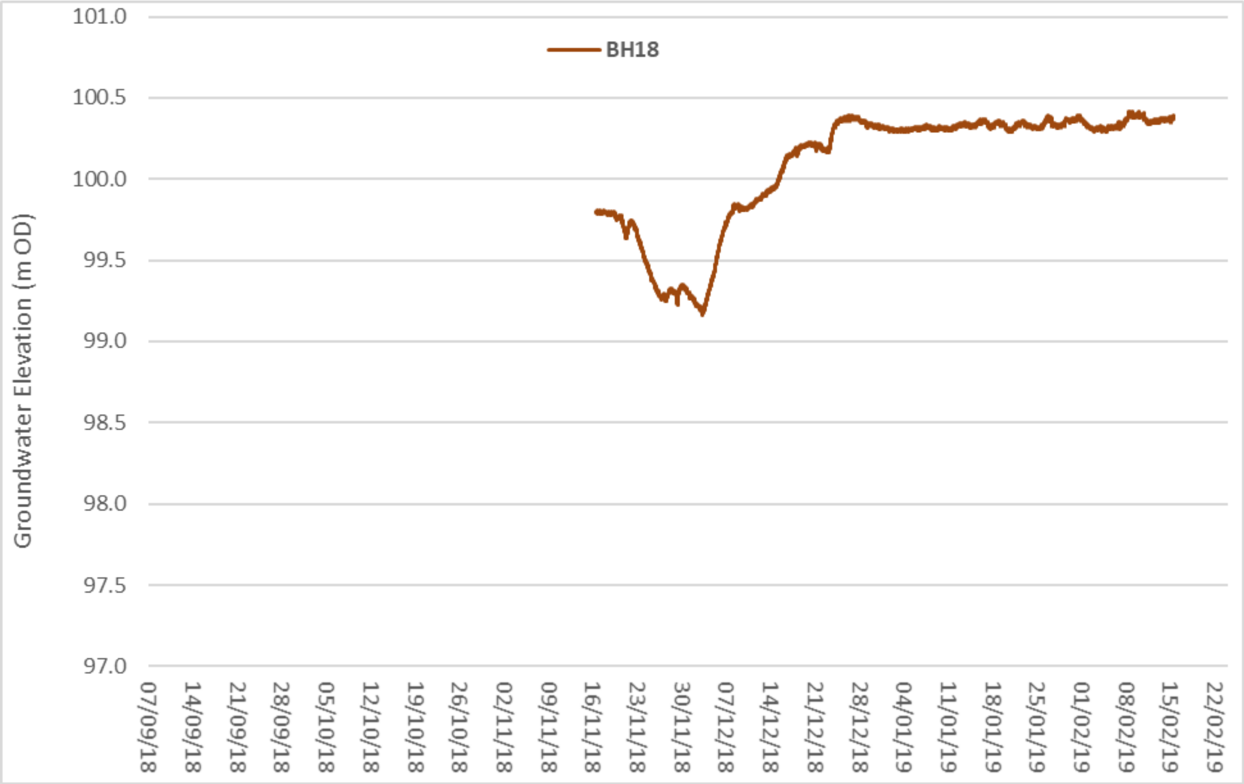
15/02/19
22/02/19


BH18
Groundwater Elevation (m OD)
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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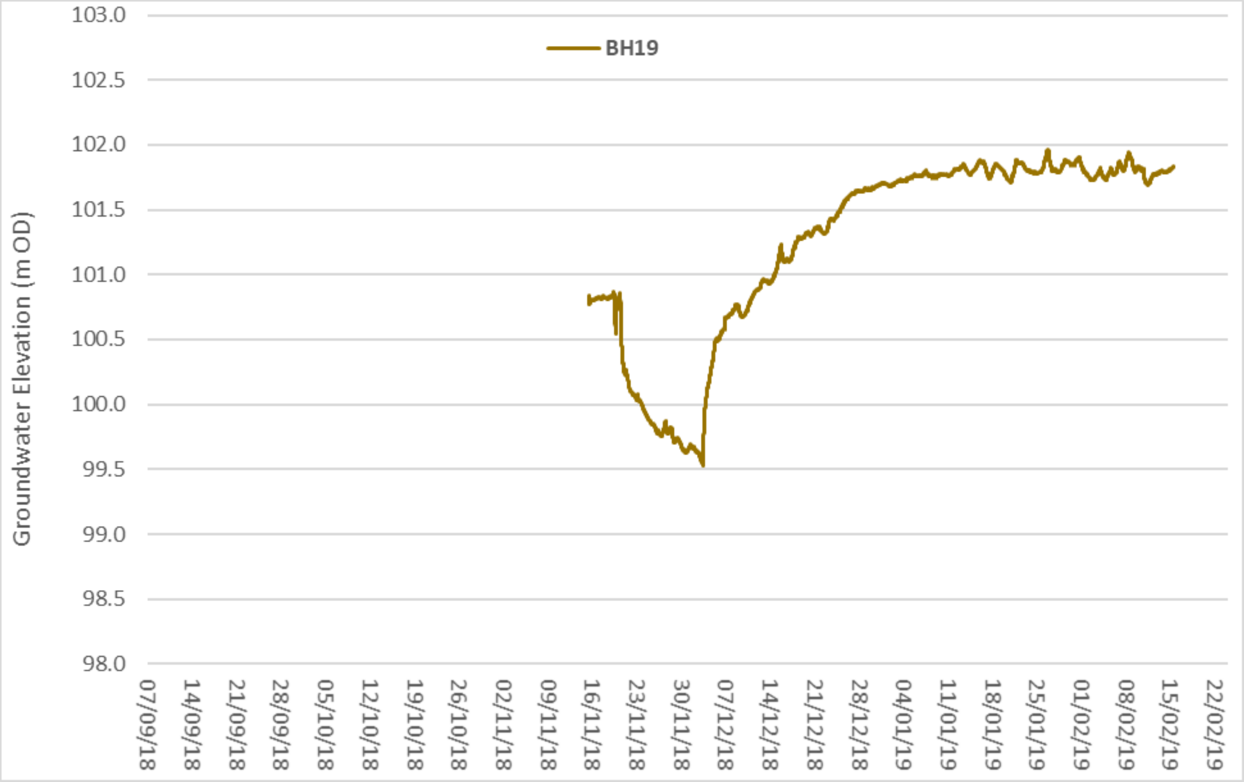
01/02/19
08/02/19
15/02/19
22/02/19


BH19
Groundwater Elevation (m OD)
103.0
102.5
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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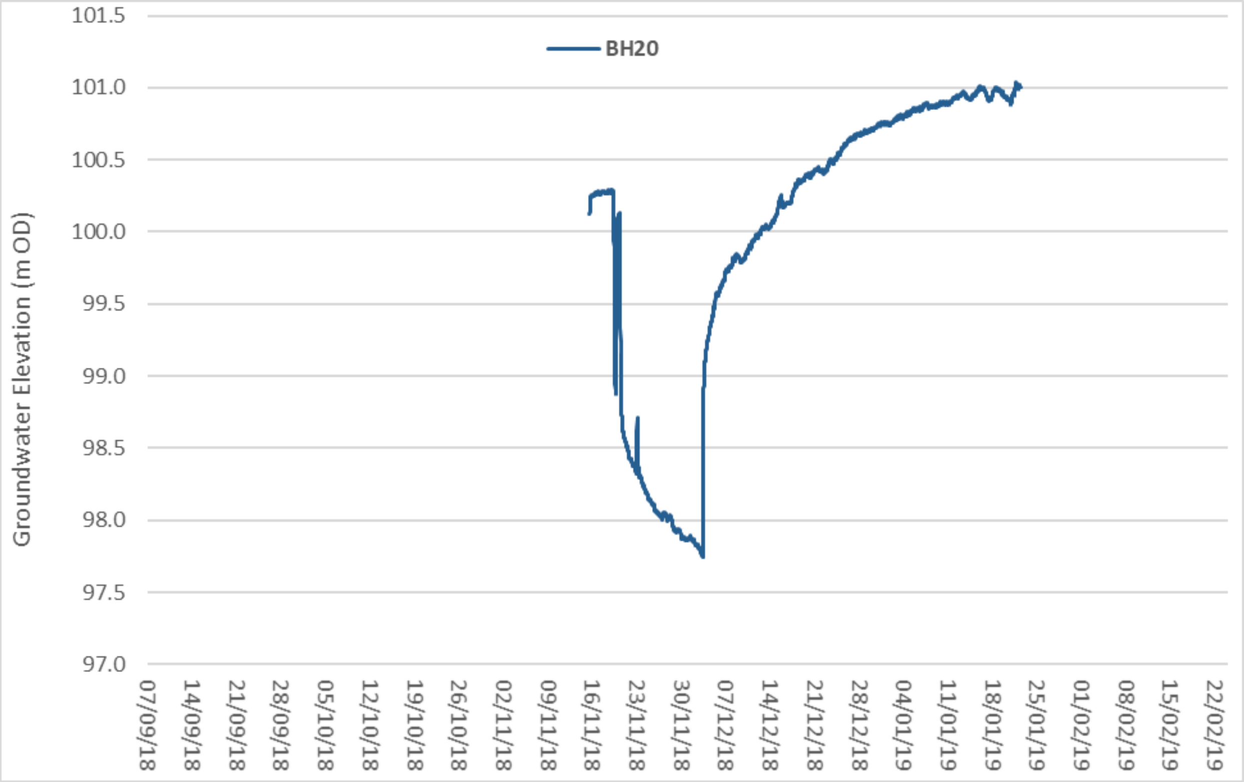
08/02/19
15/02/19
22/02/19


BH20
Groundwater Elevation (m OD)
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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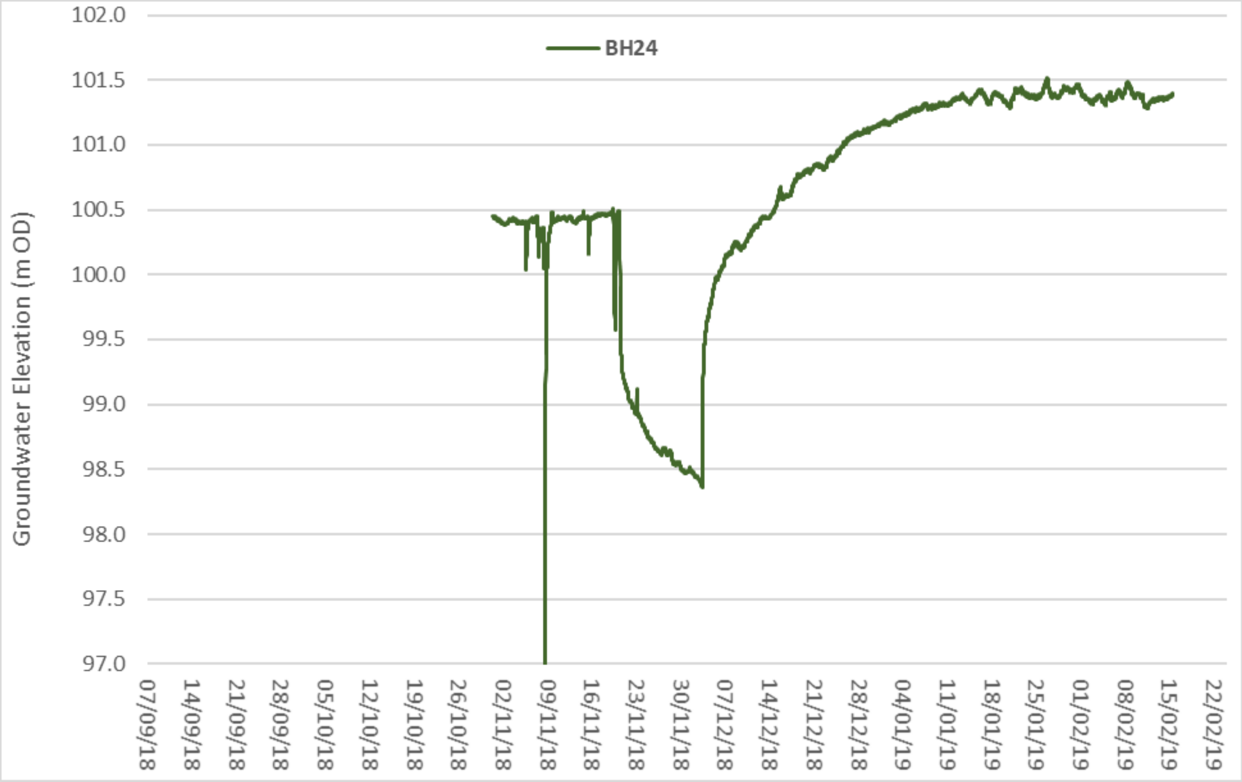
08/02/19
15/02/19
22/02/19



BH24
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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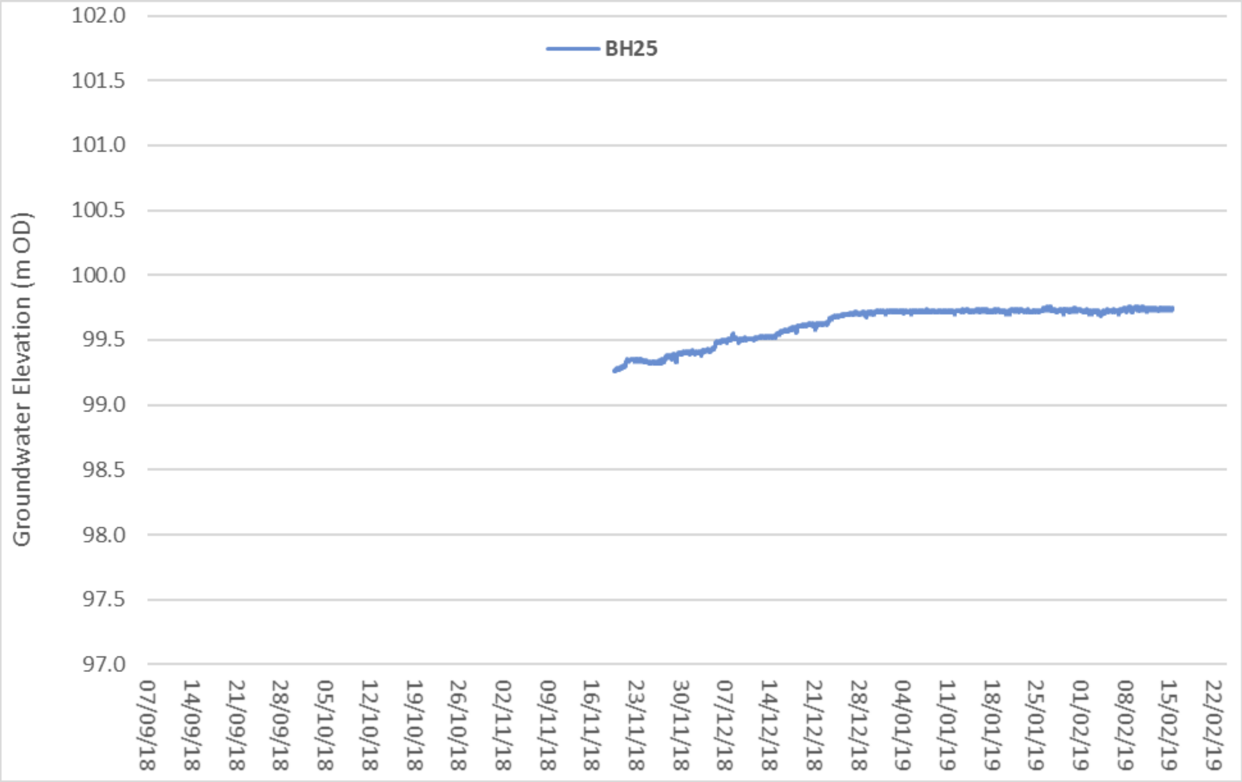
08/02/19
15/02/19
22/02/19



BH25
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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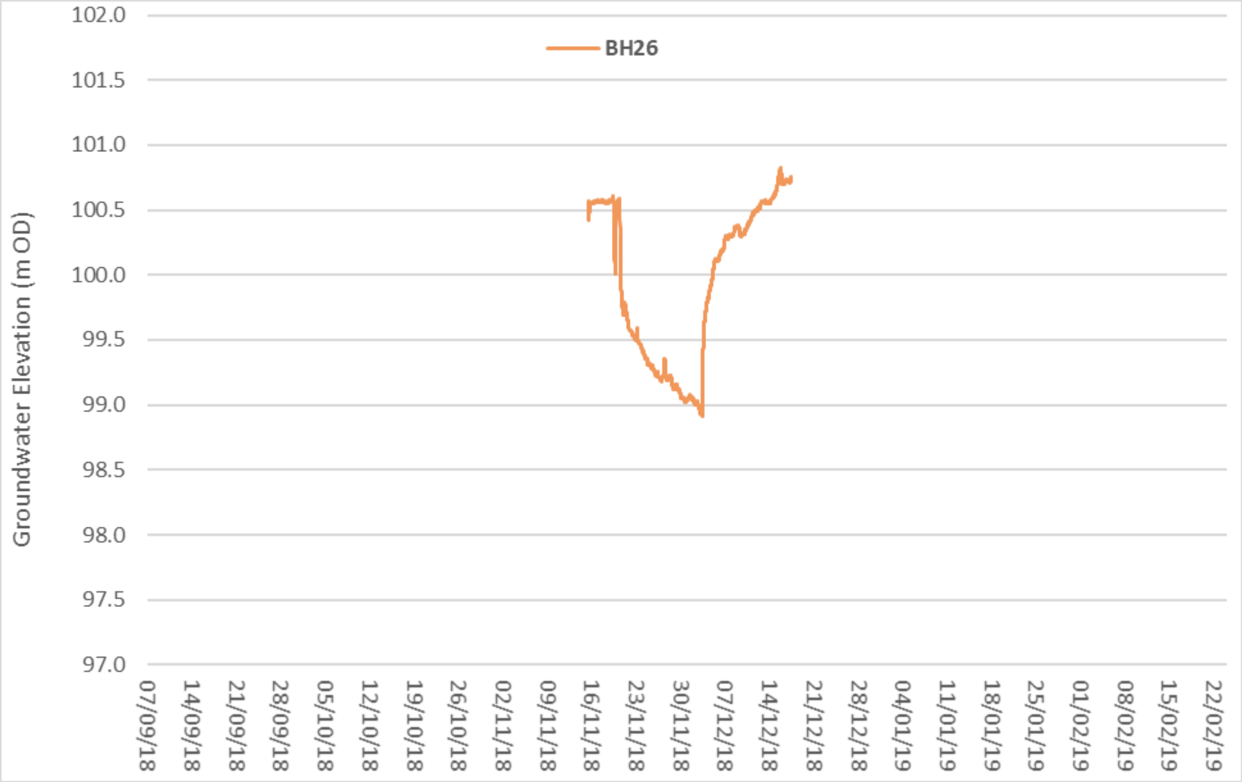
08/02/19
15/02/19
22/02/19


BH26
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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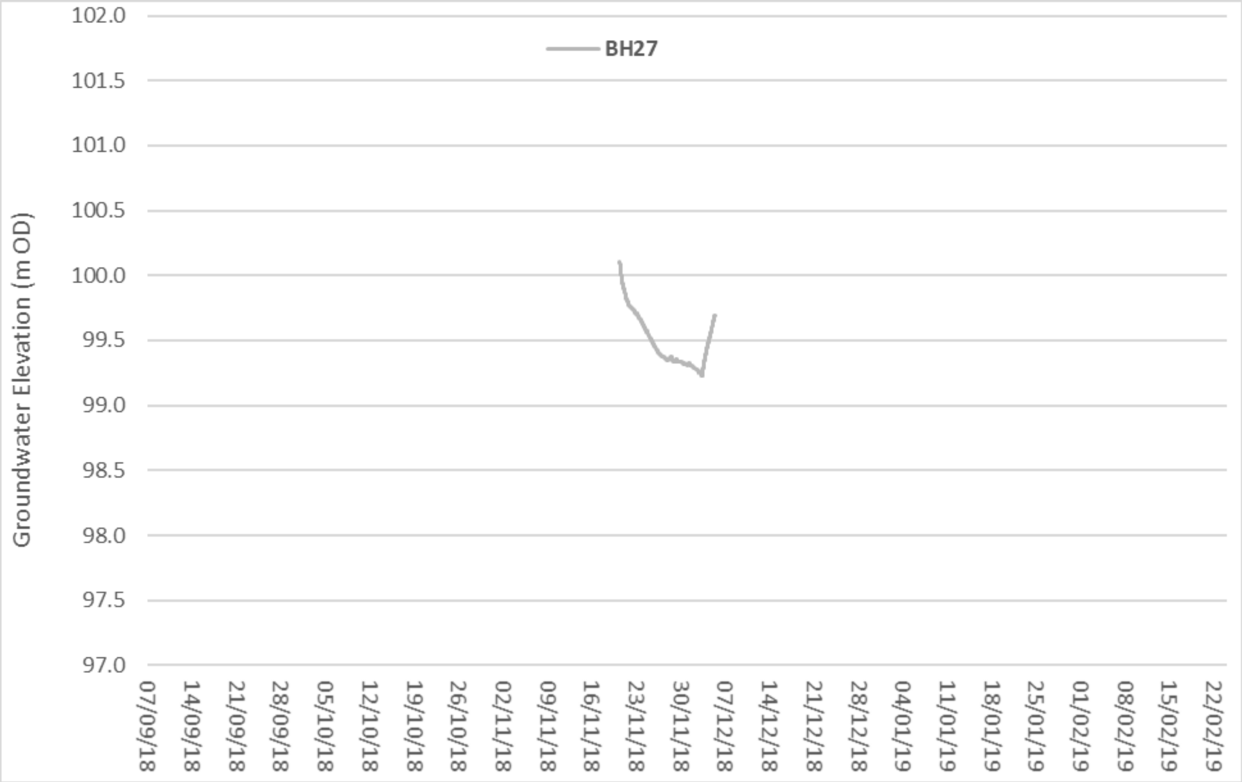
08/02/19
15/02/19
22/02/19


BH27
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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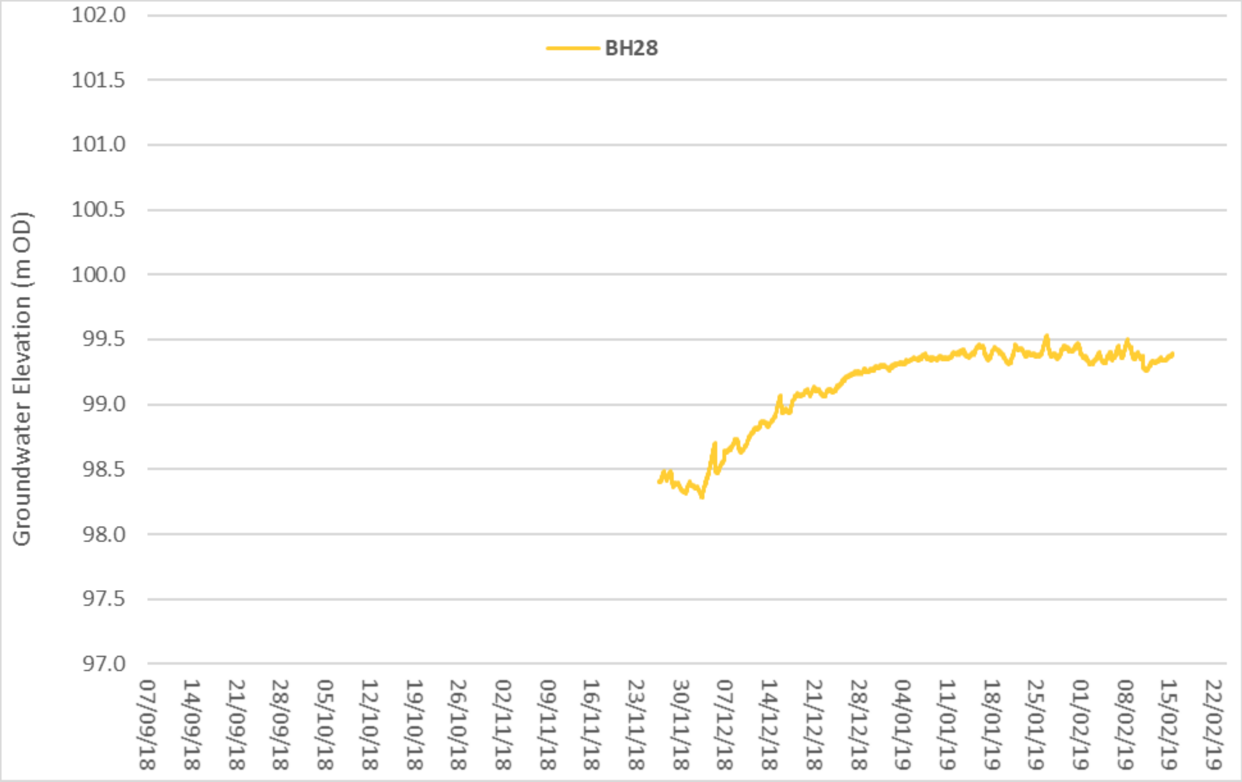
08/02/19
15/02/19
22/02/19


Groundwater Elevation (m OD)
BH28
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
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25/01/19
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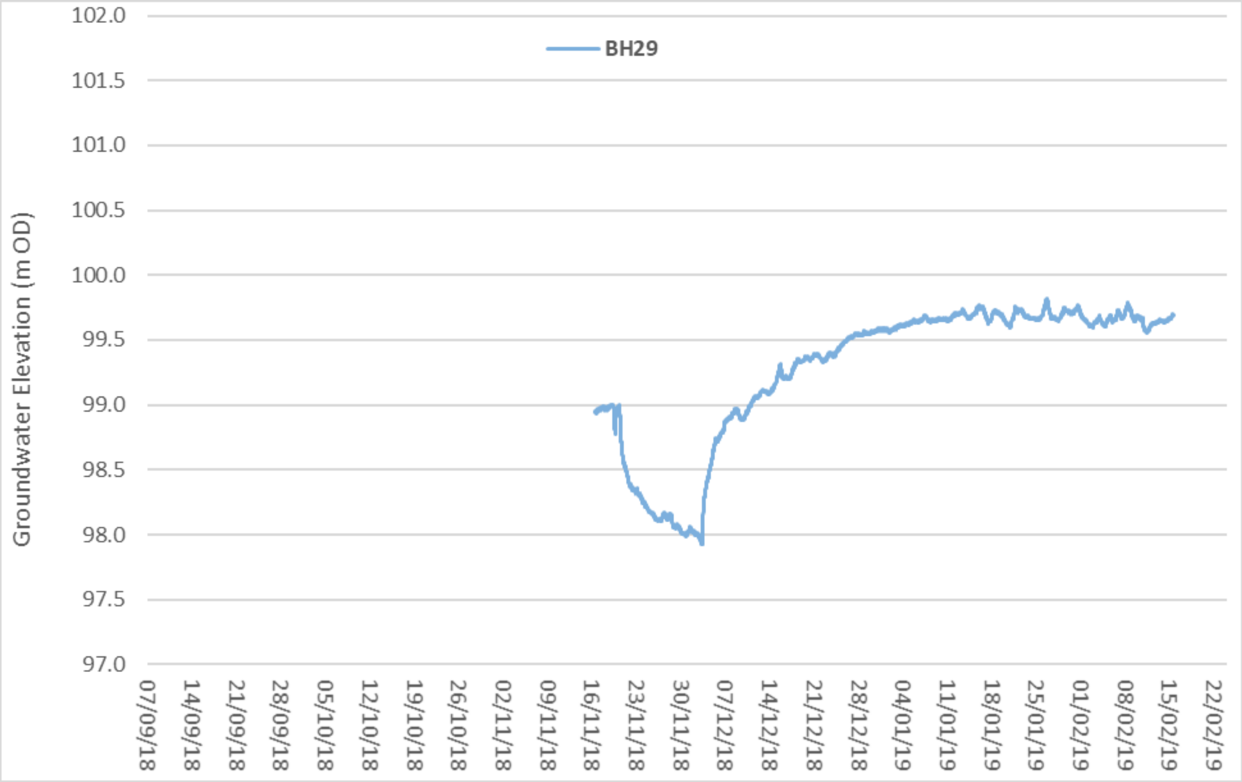
08/02/19
15/02/19
22/02/19


Groundwater Elevation (m OD)
BH29
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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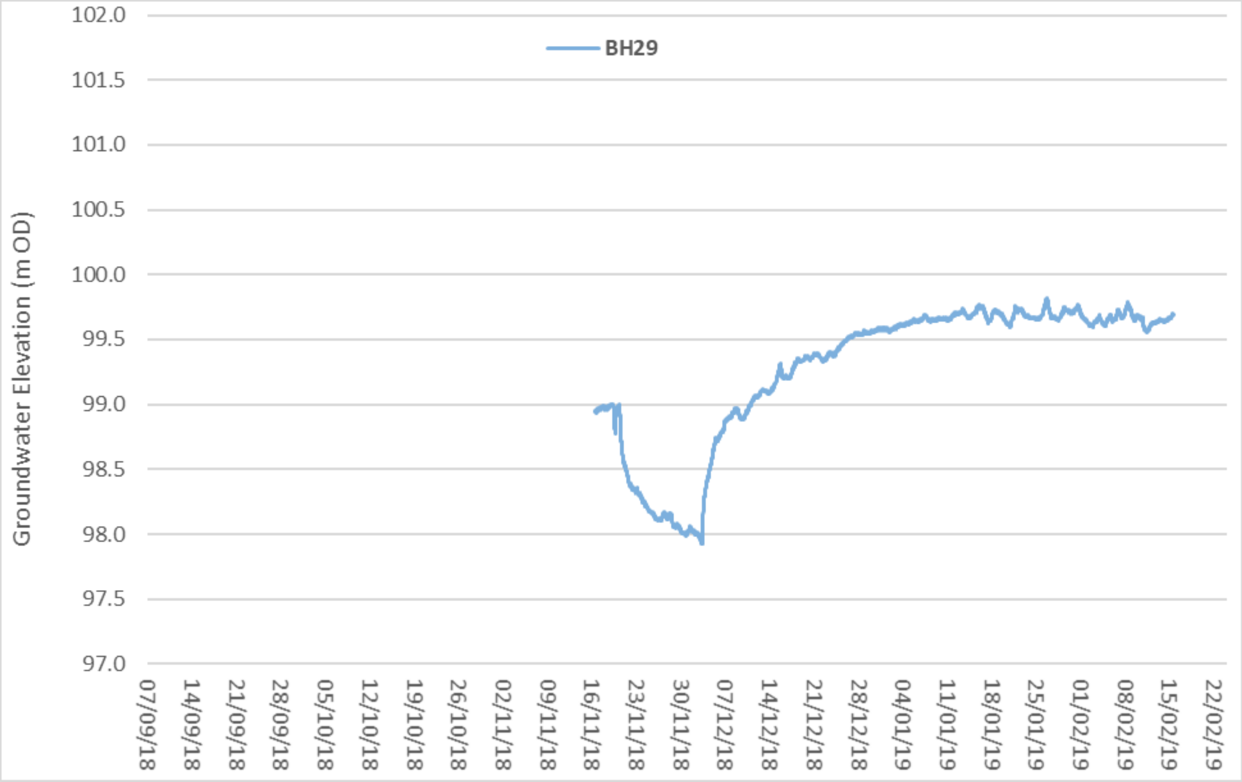
08/02/19
15/02/19
22/02/19


BH29
Groundwater Elevation (m OD)
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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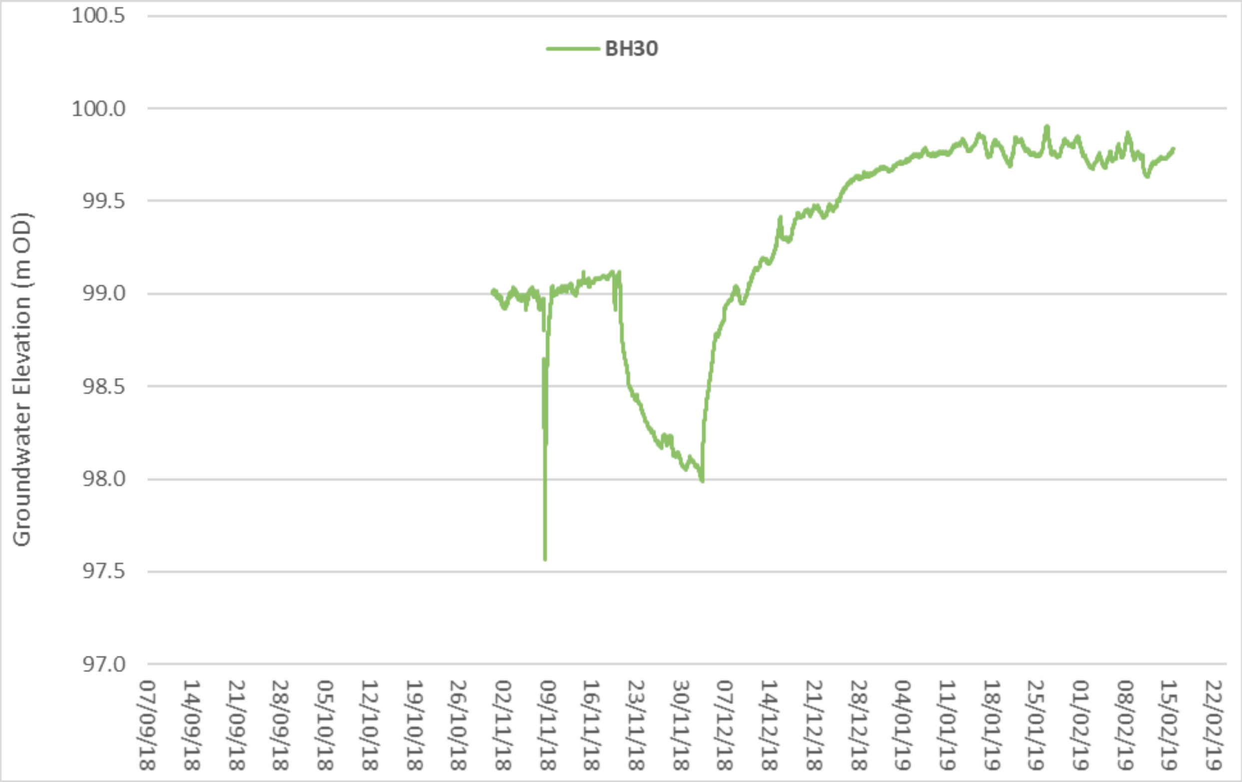
15/02/19
22/02/19


BH30
Groundwater Elevation (m OD)
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
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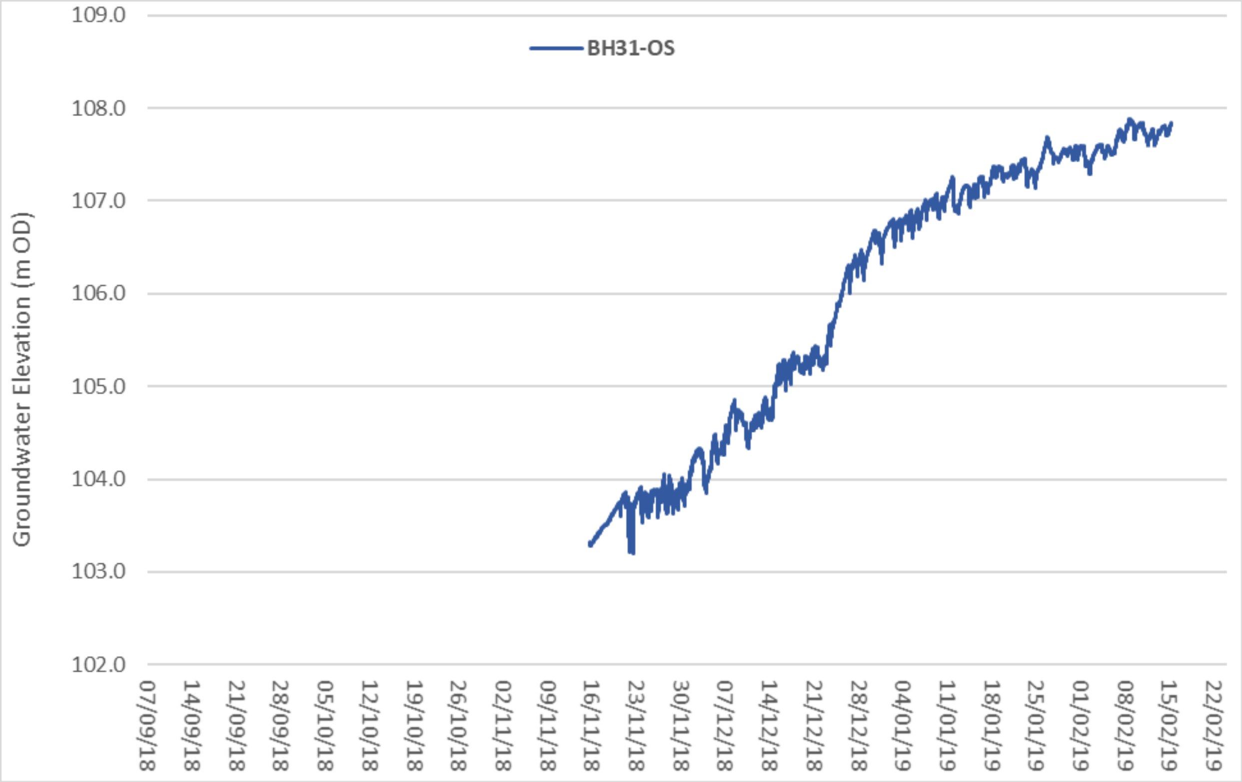
08/02/19
15/02/19
22/02/19


BH31-OS
Groundwater Elevation (m OD)
109.0
108.0
107.0
106.0
105.0
104.0
103.0
102.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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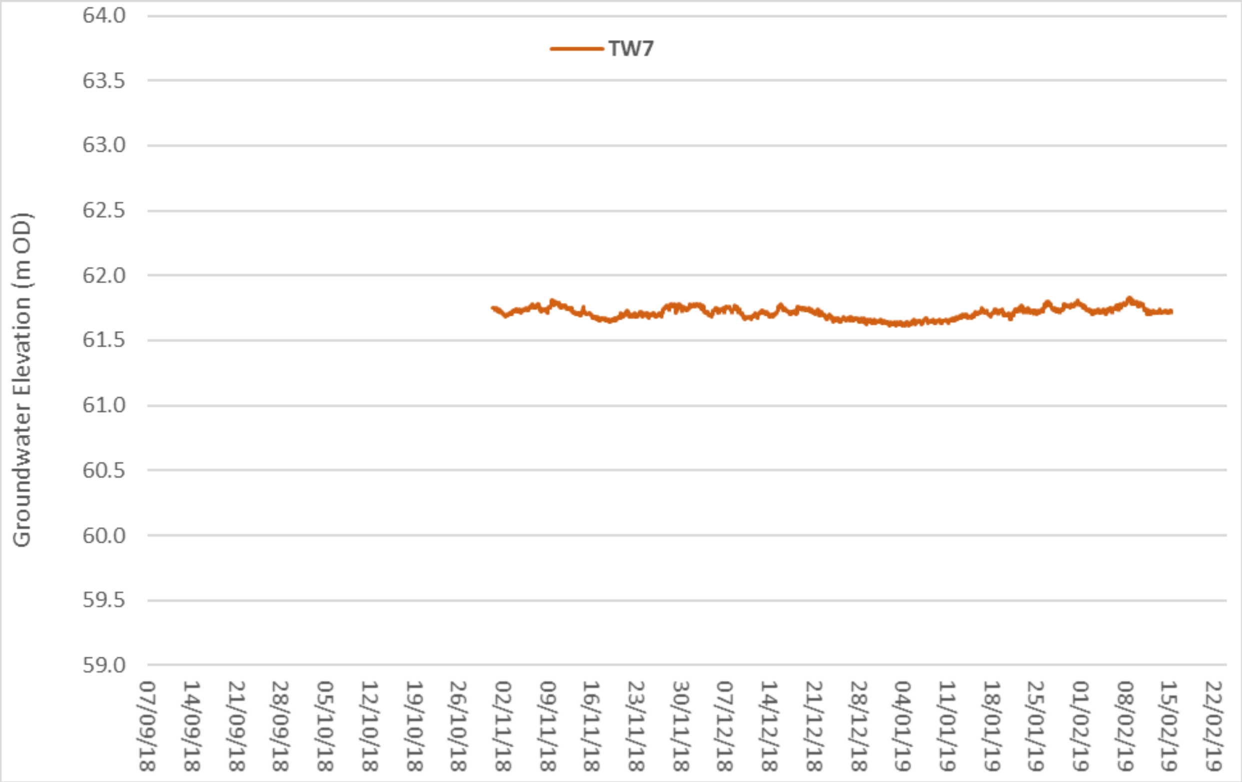
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19


TW7
Groundwater Elevation (m OD)
64.0
63.5
63.0
62.5
62.0
61.5
61.0
60.5
60.0
59.5
59.0
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
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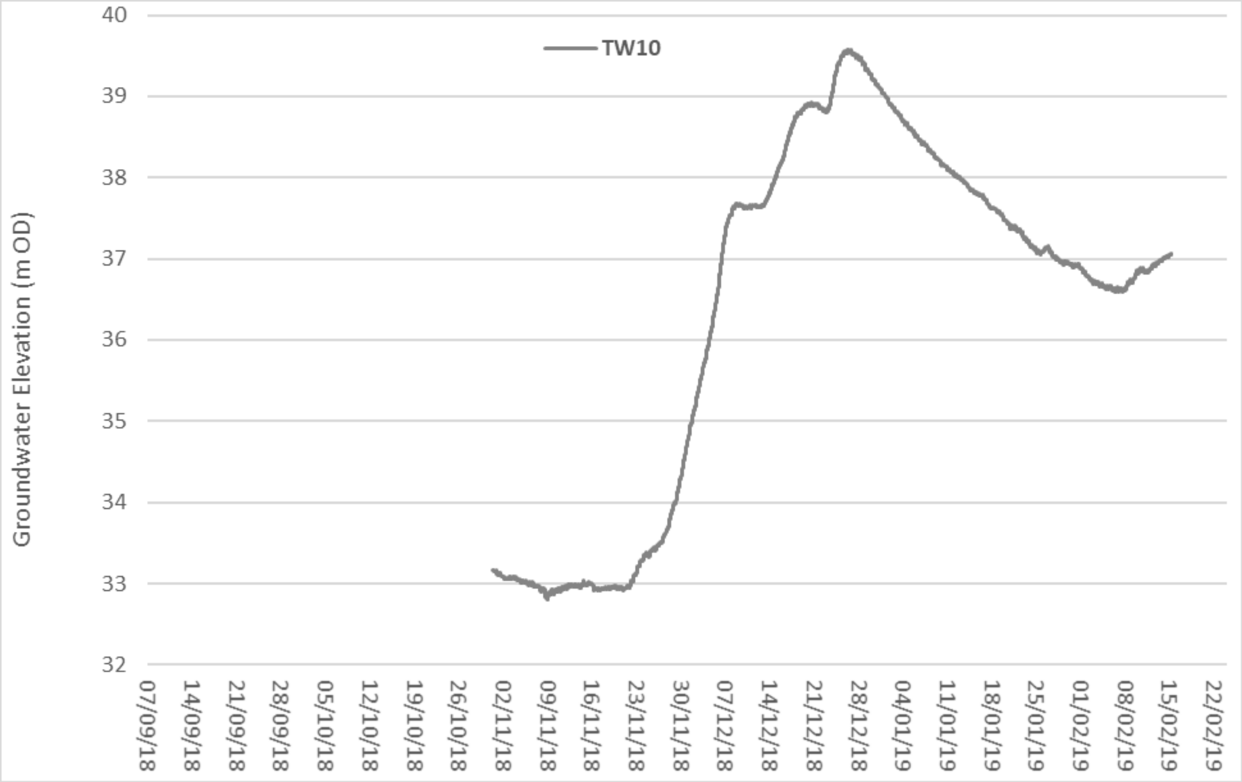
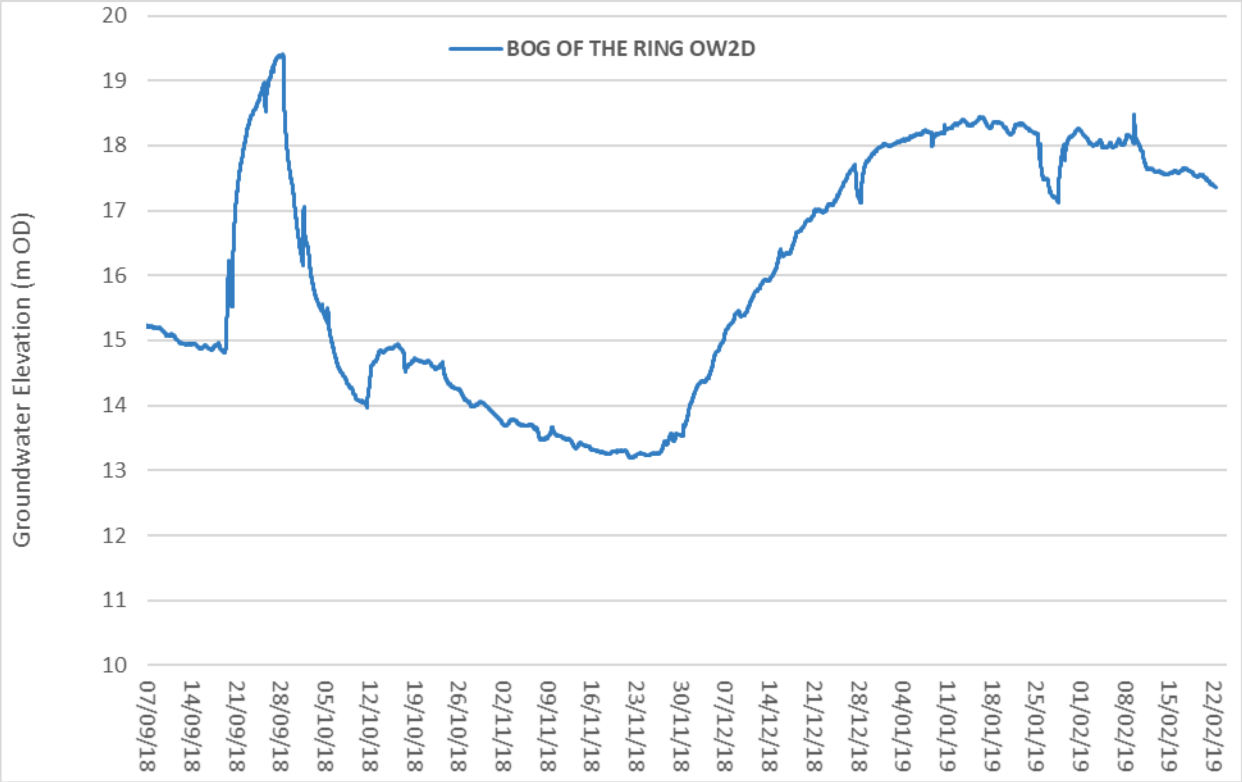
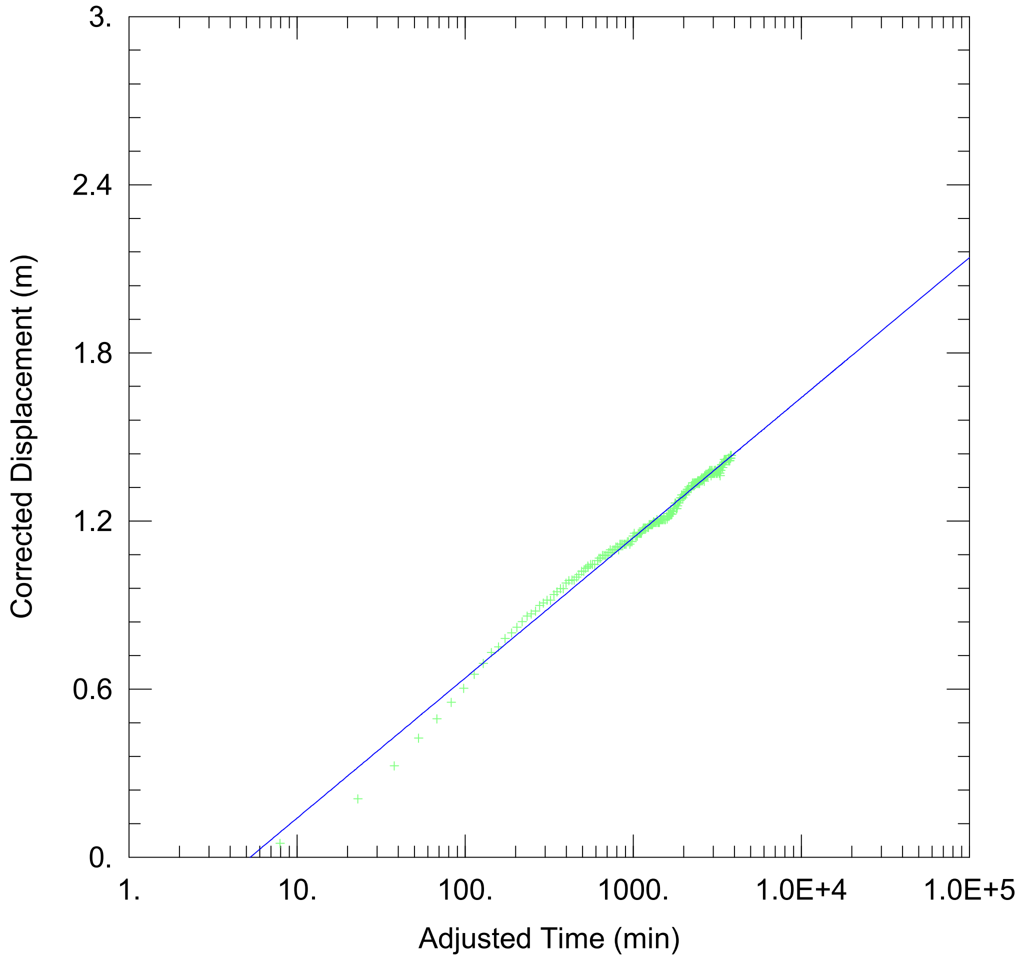
08/02/19
15/02/19
22/02/19


TW10
Groundwater Elevation (m OD)
40
39
38
37
36
35
34
33
32
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19


BOG OF THE RING OW2D
Groundwater Elevation (m OD)
20
19
18
17
16
15
14
13
12
11
10
07/09/18
14/09/18
21/09/18
28/09/18
05/10/18
12/10/18
19/10/18
26/10/18
02/11/18
09/11/18
16/11/18
23/11/18
30/11/18
07/12/18
14/12/18
21/12/18
28/12/18
04/01/19
11/01/19
18/01/19
25/01/19
01/02/19
08/02/19
15/02/19
22/02/19

Appendix 4 Aqtesolv Curve Fitting and Test Report



WELL TEST ANALYSIS

Data Set: \...\BH05 - d150m.aqt

Date: 05/08/19 Time: 10:32:20

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

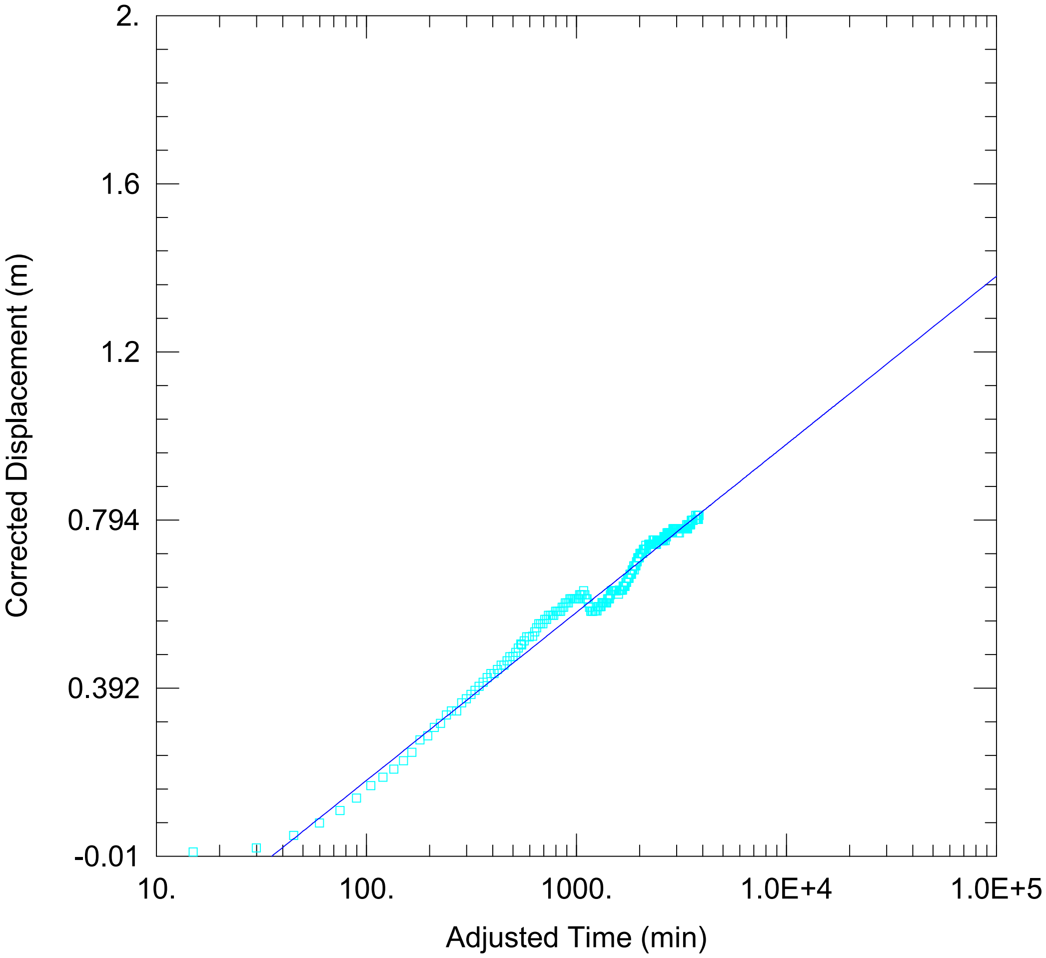
Observation Wells

Well Name	X (m)	Y (m)
+ BH05	315796	258328

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 193.7 m^2/day S = 2.775E-5



WELL TEST ANALYSIS

Data Set: \...\BH19.aqt
Date: 05/07/19 Time: 16:11:59

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

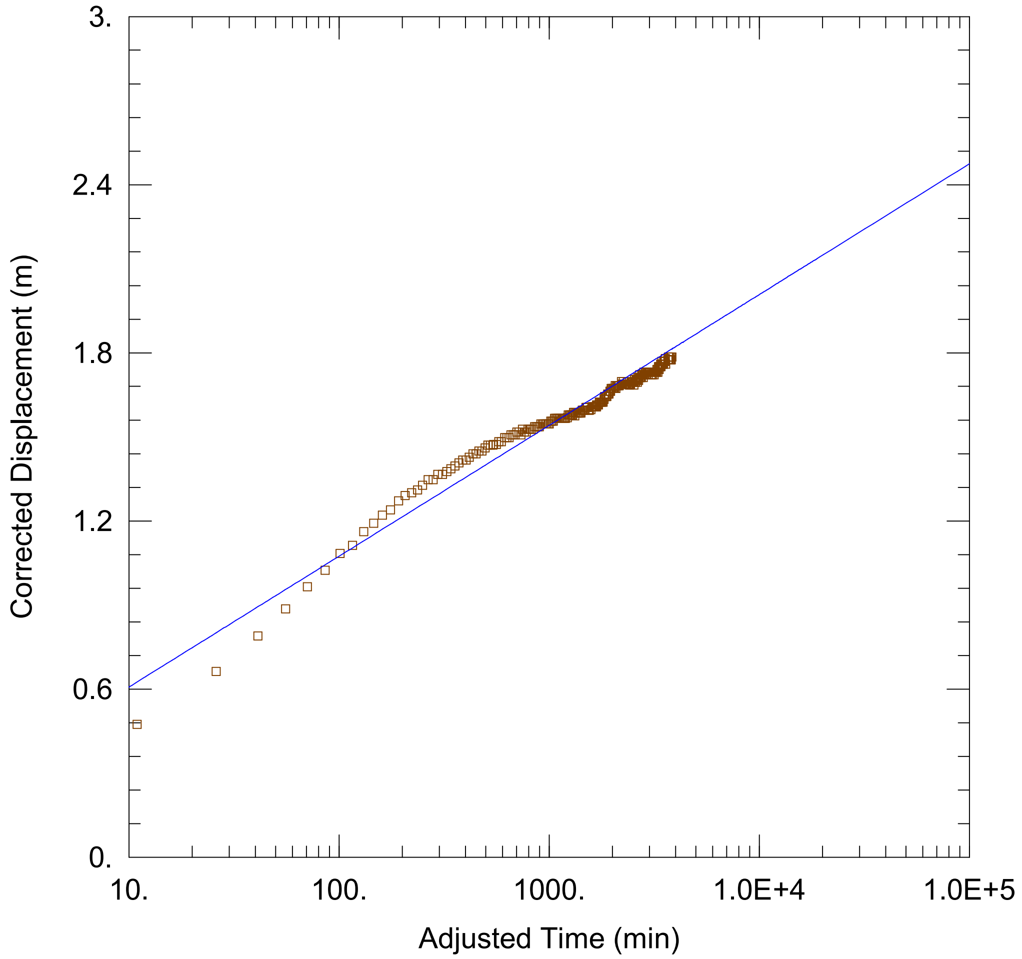
Observation Wells

Well Name	X (m)	Y (m)
▫ BH19	315887	258059

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 241. m^2/day
S = 0.0056



WELL TEST ANALYSIS

Data Set: \...\BH20.aqt
Date: 05/07/19 Time: 16:14:25

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

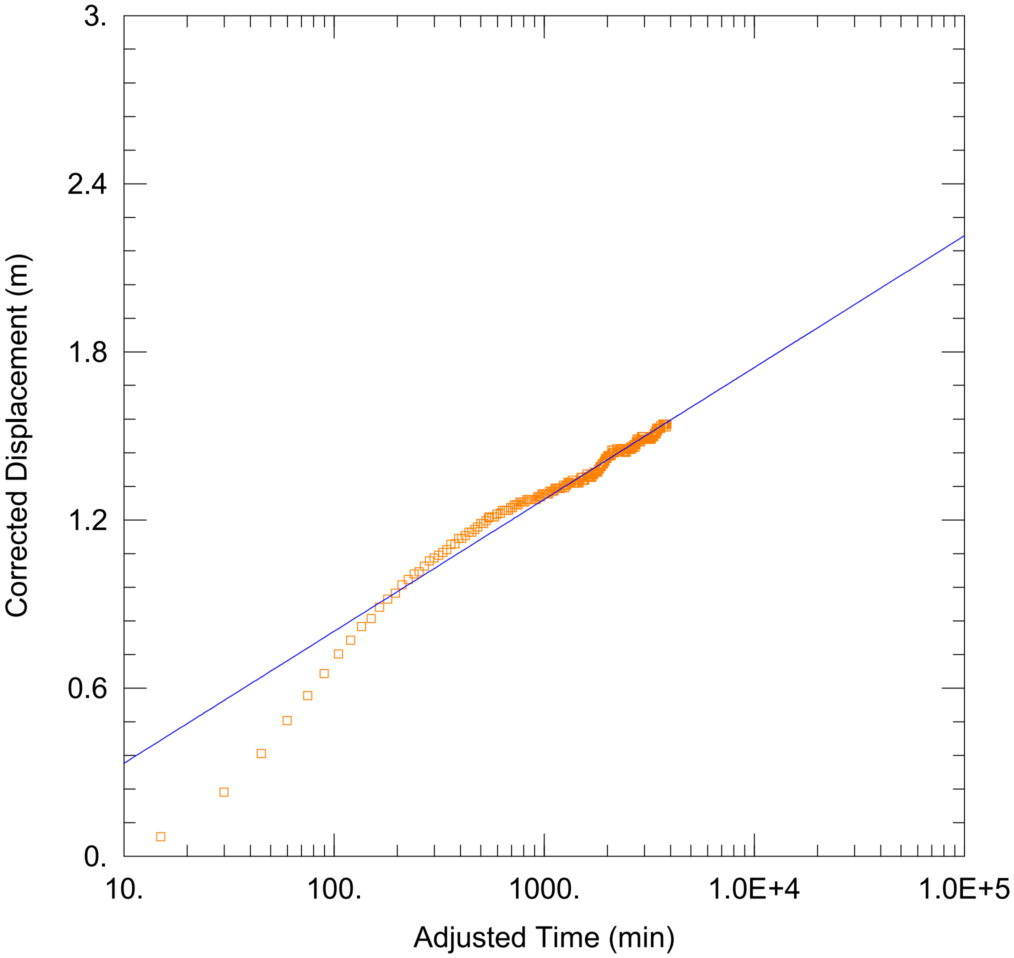
Observation Wells

Well Name	X (m)	Y (m)
□ BH20	315862.6	258102.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 207.5 m^2/day
S = 0.0001679



WELL TEST ANALYSIS

Data Set: \...\BH24.aqt
Date: 05/07/19 Time: 16:15:28

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

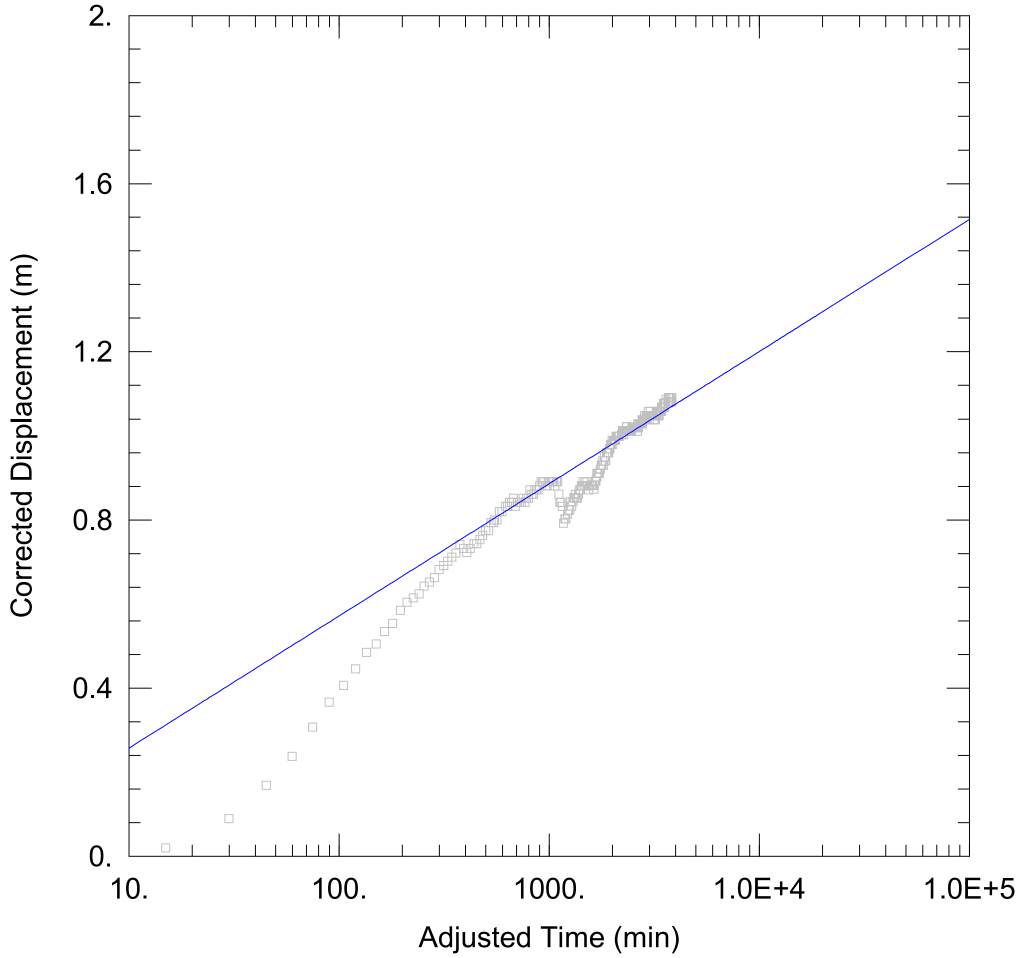
Observation Wells

Well Name	X (m)	Y (m)
□ BH24	315955	258209

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 205.8 m^2/day
S = 4.582E-5



WELL TEST ANALYSIS

Data Set: \...\BH26.aqt
Date: 05/07/19 Time: 16:16:24

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

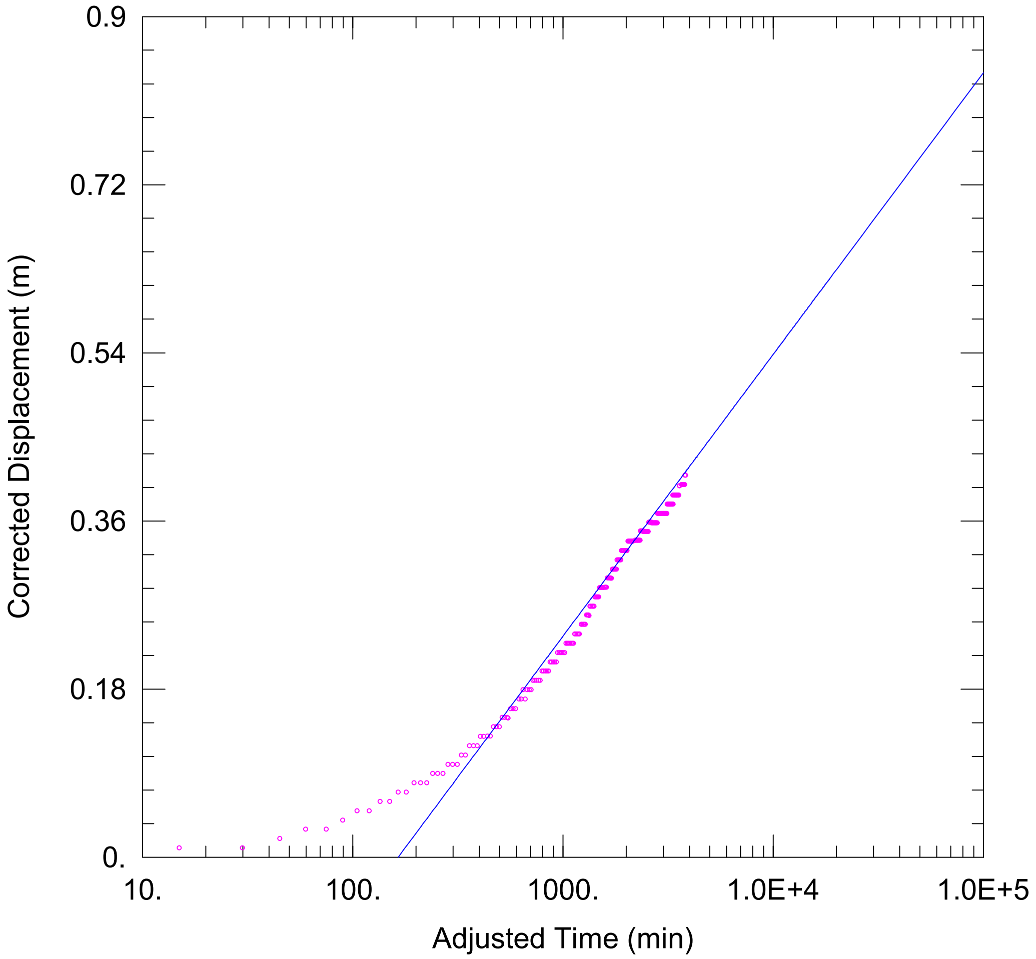
Observation Wells

Well Name	X (m)	Y (m)
□ BH26	315881	258086

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 308. m^2/day
S = 0.001098



WELL TEST ANALYSIS

Data Set: \...\BH27.aqt
Date: 05/07/19 Time: 16:18:03

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

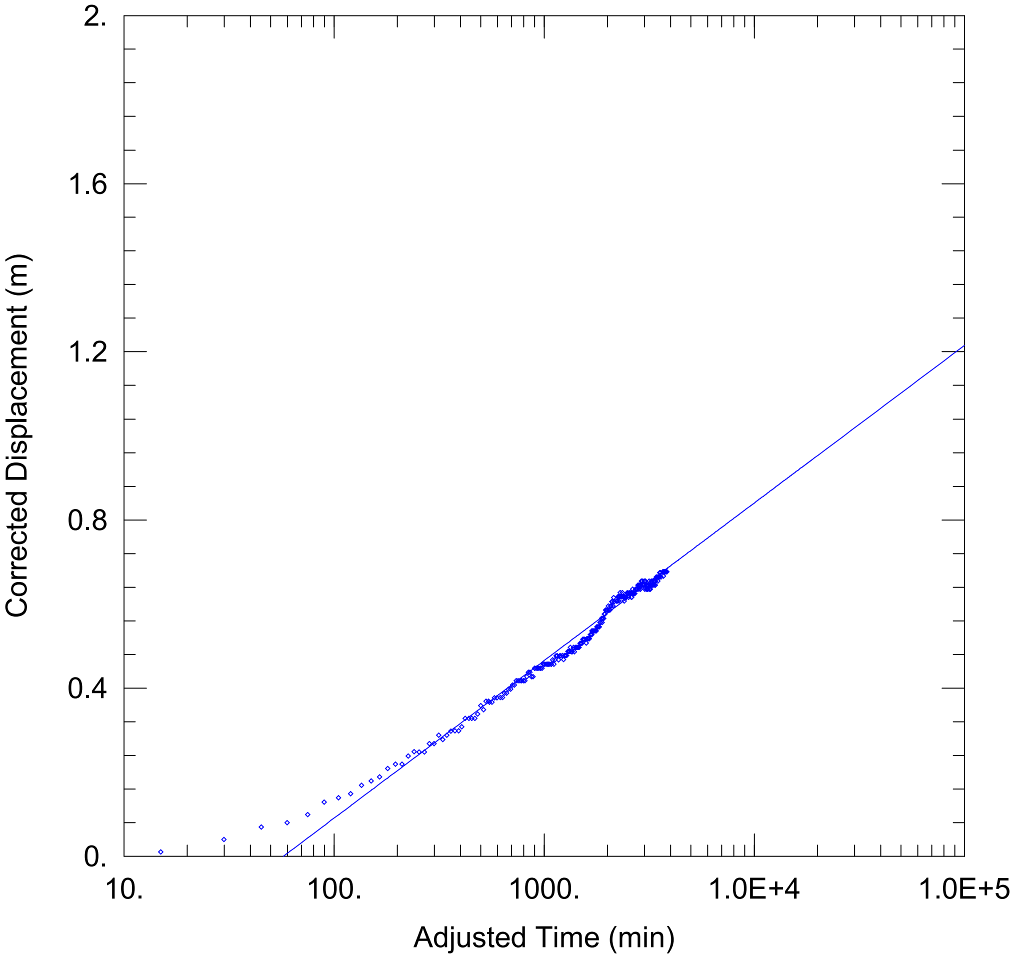
Observation Wells

Well Name	X (m)	Y (m)
∘ BH27	315757	258018

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 321.1 m^2/day S = 0.003082



WELL TEST ANALYSIS

Data Set: \...\BH29.aqt
Date: 05/07/19 Time: 16:20:08

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

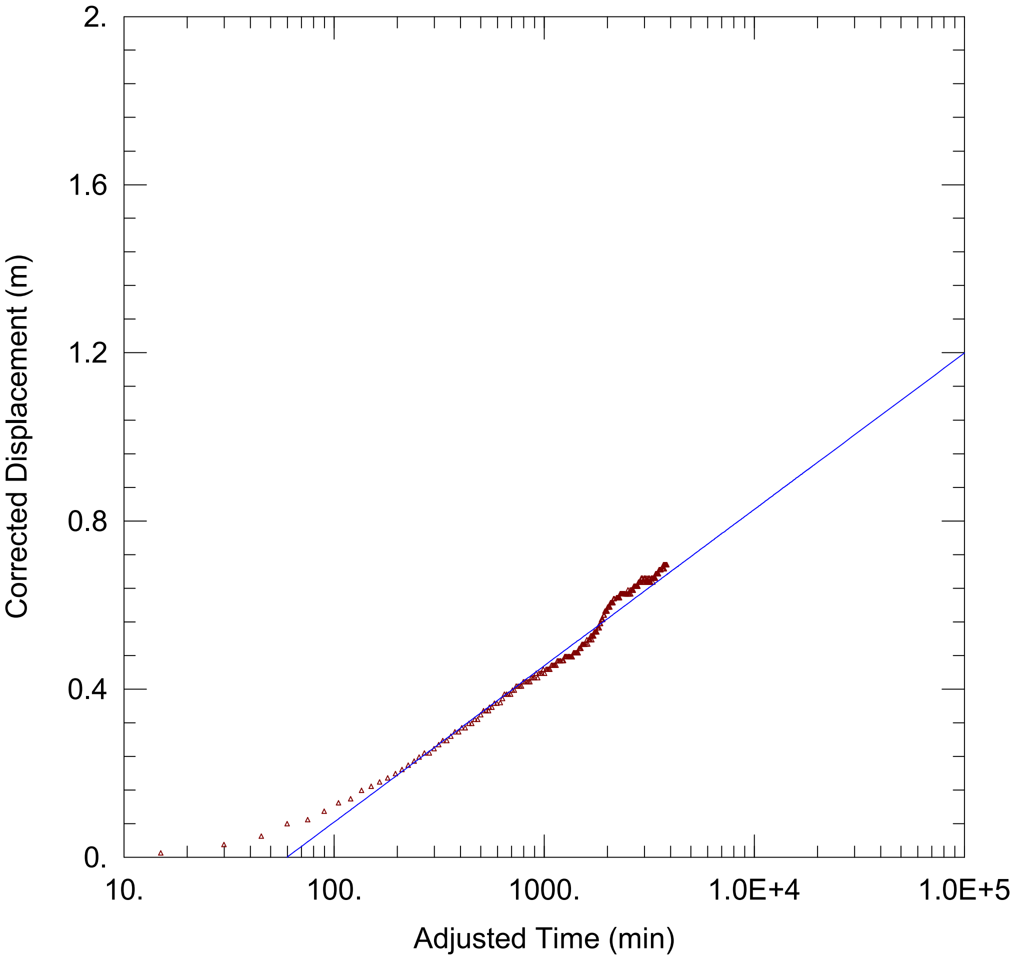
Observation Wells

Well Name	X (m)	Y (m)
◇ BH29	315986	258071

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 258.4 m^2/day S = 0.002296



WELL TEST ANALYSIS

Data Set: \...\BH30.aqt
Date: 05/07/19 Time: 16:21:04

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m
Anisotropy Ratio (Kz/Kr): 0.7586

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

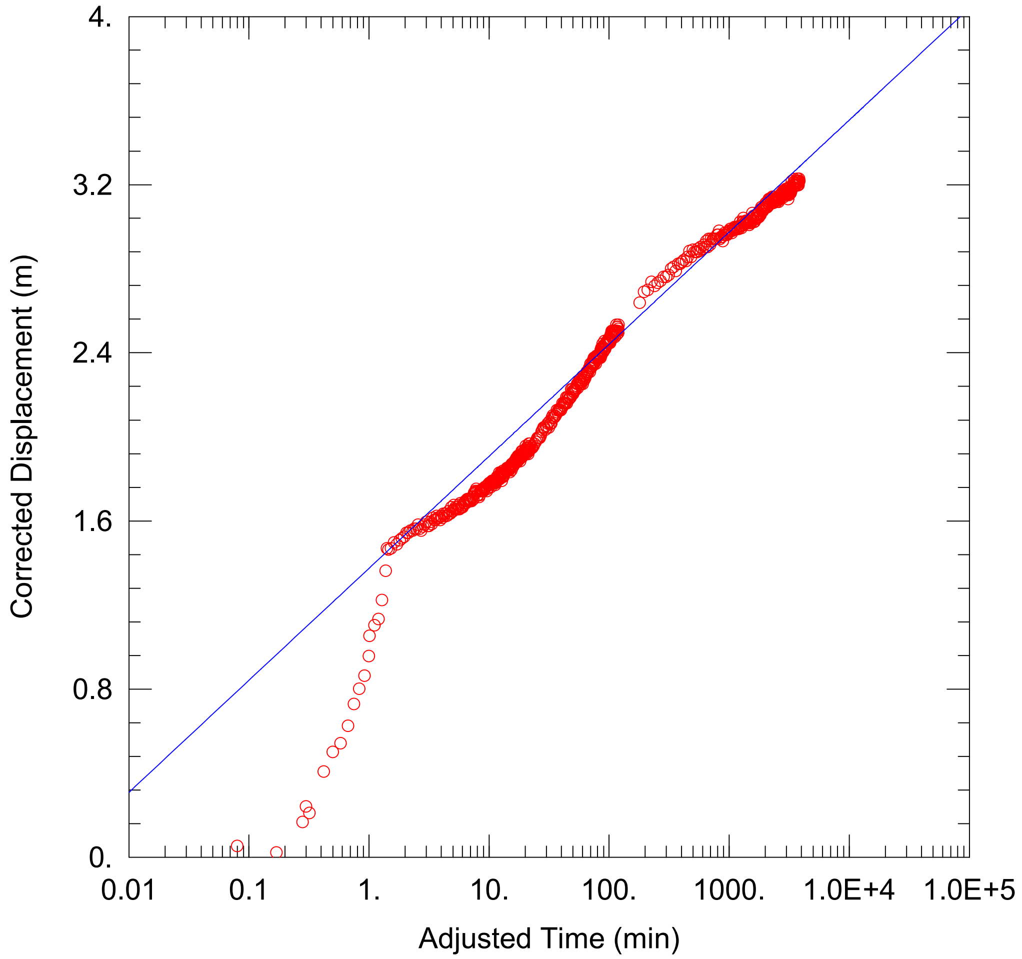
Observation Wells

Well Name	X (m)	Y (m)
▵ BH30	315970	258073

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 260.4 m^2/day
S = 0.003364



WELL TEST ANALYSIS

Data Set: \...\1. pumping well.aqt
Date: 05/07/19 Time: 16:09:15

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

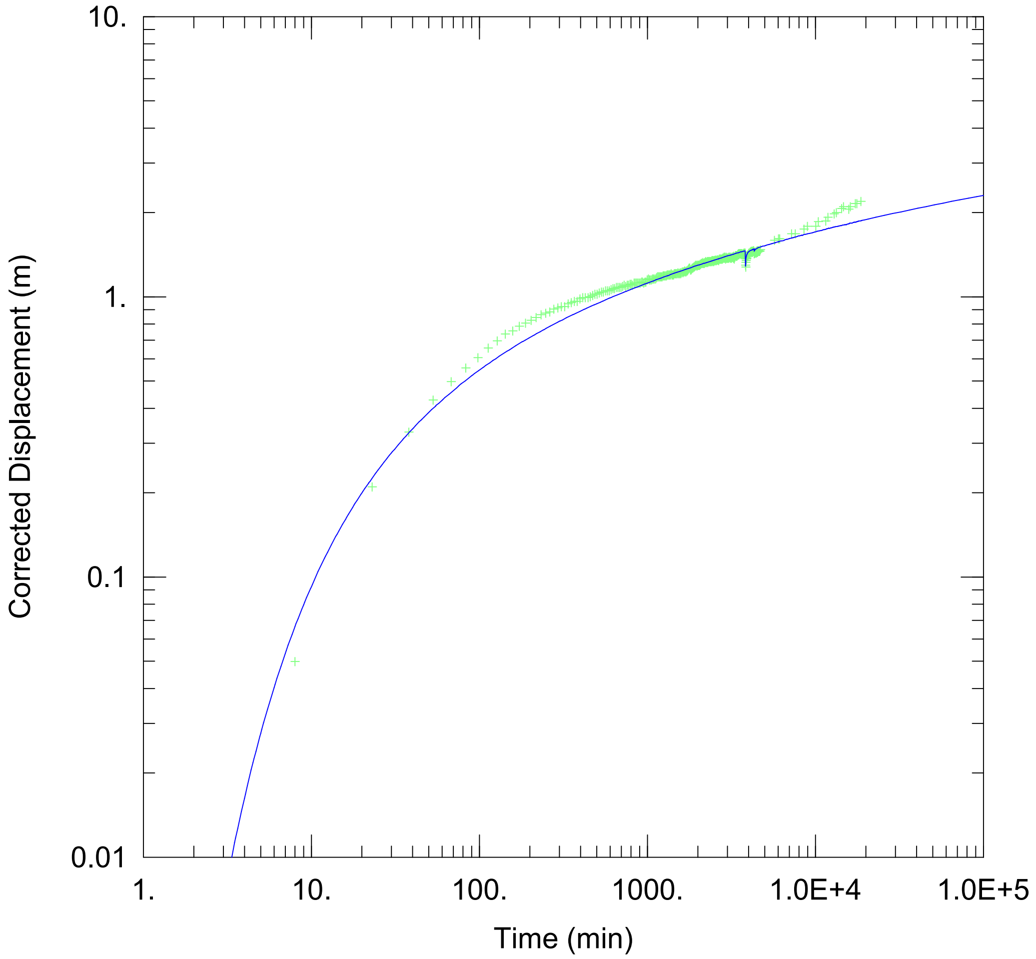
Observation Wells

Well Name	X (m)	Y (m)
○ Pumping Well	315892.987	258108.891

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 181.7 m^2/day S = 0.03161



WELL TEST ANALYSIS

Data Set: \...\BH05.aqt
Date: 05/07/19 Time: 15:56:59

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

Observation Wells

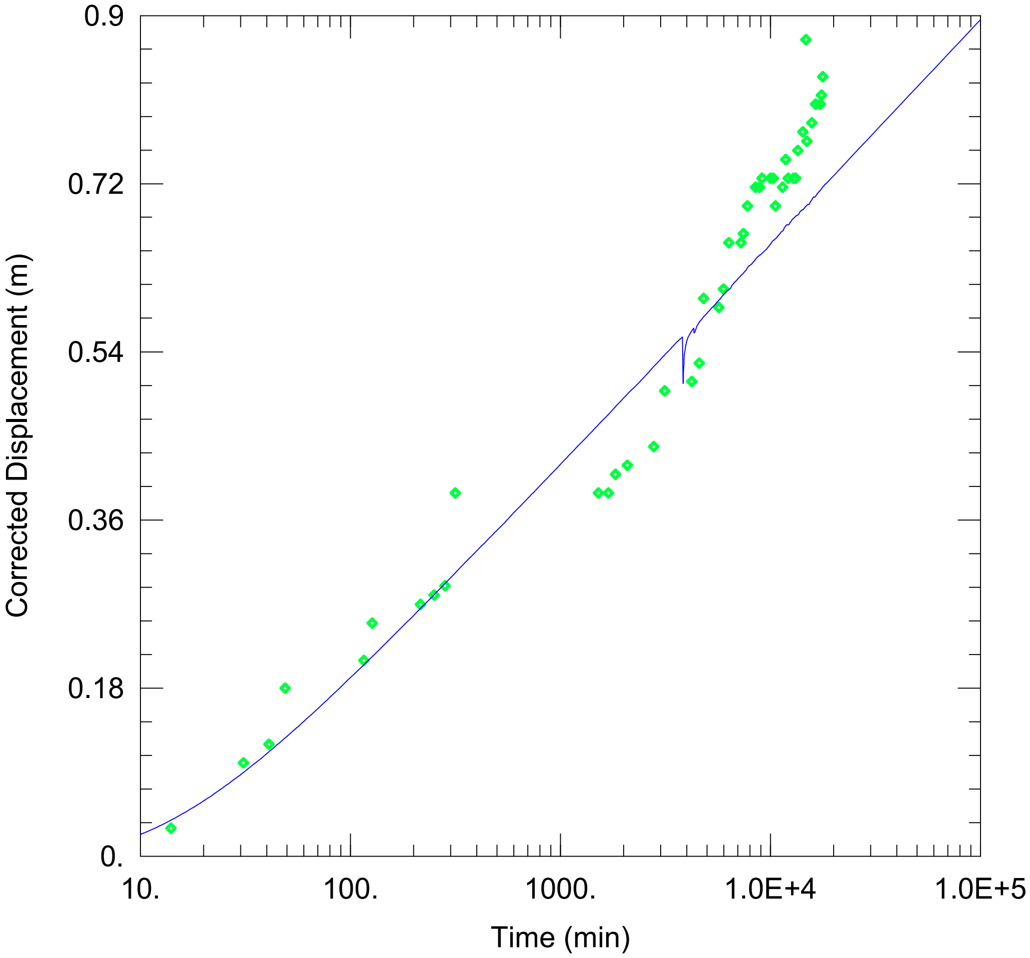
Well Name	X (m)	Y (m)
+ BH05	315796	258328

SOLUTION

Aquifer Model: Unconfined Solution Method: Theis

T = 164.8 m^2/day
Kz/Kr = 1.

S = 5.72E-5
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH17.aqt
Date: 05/07/19 Time: 15:57:46

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

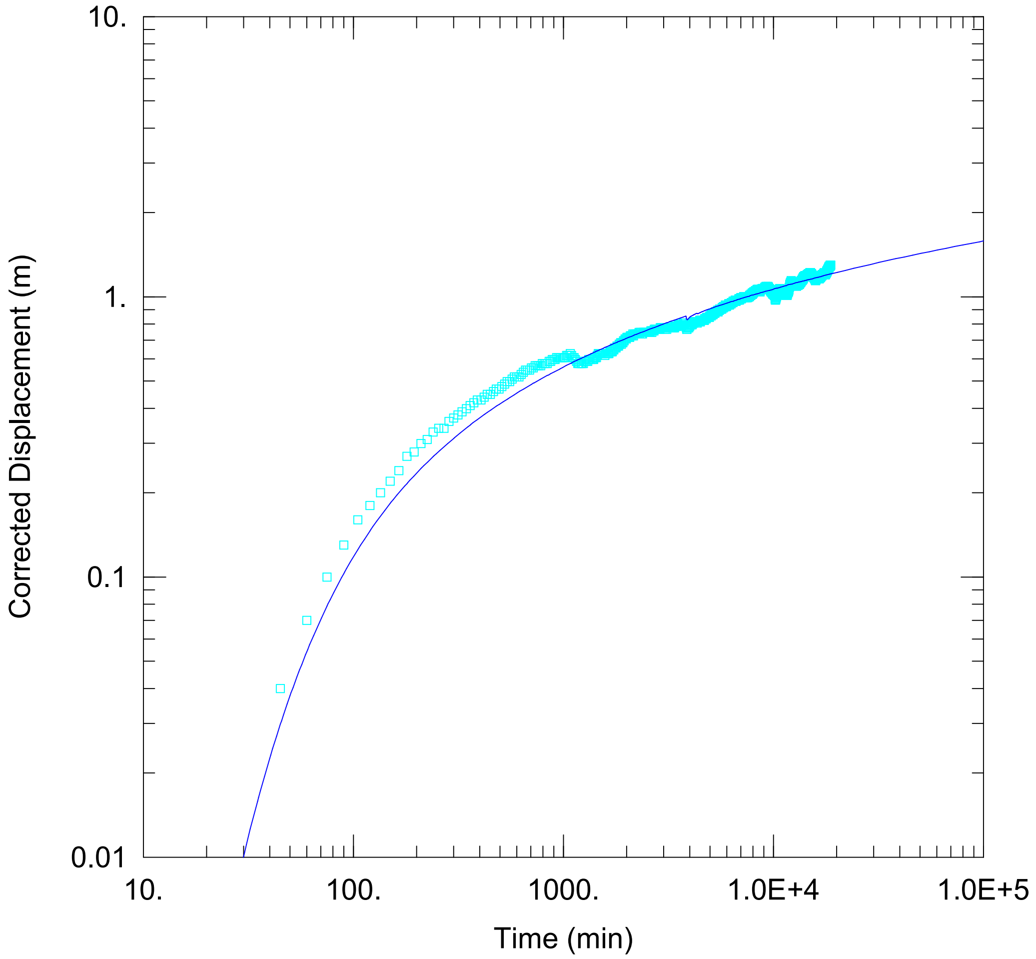
Observation Wells

Well Name	X (m)	Y (m)
◇ BH17	315795	258003

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 408.5 m^2/day
S = 0.0005351
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH19.aqt
Date: 05/07/19 Time: 15:59:09

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

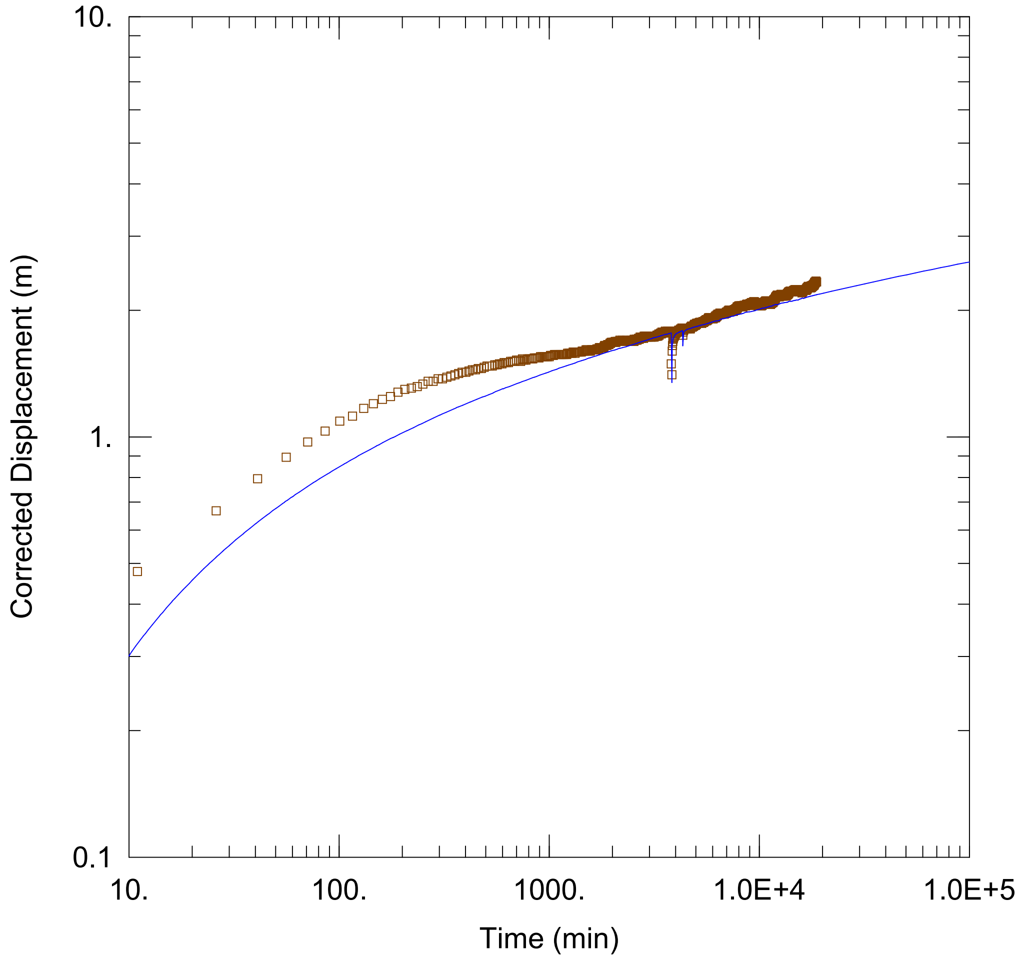
Observation Wells

Well Name	X (m)	Y (m)
□ BH19	315887	258059

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 189.4 m^2/day
S = 0.0079
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH20.aqt
Date: 05/07/19 Time: 16:01:17

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

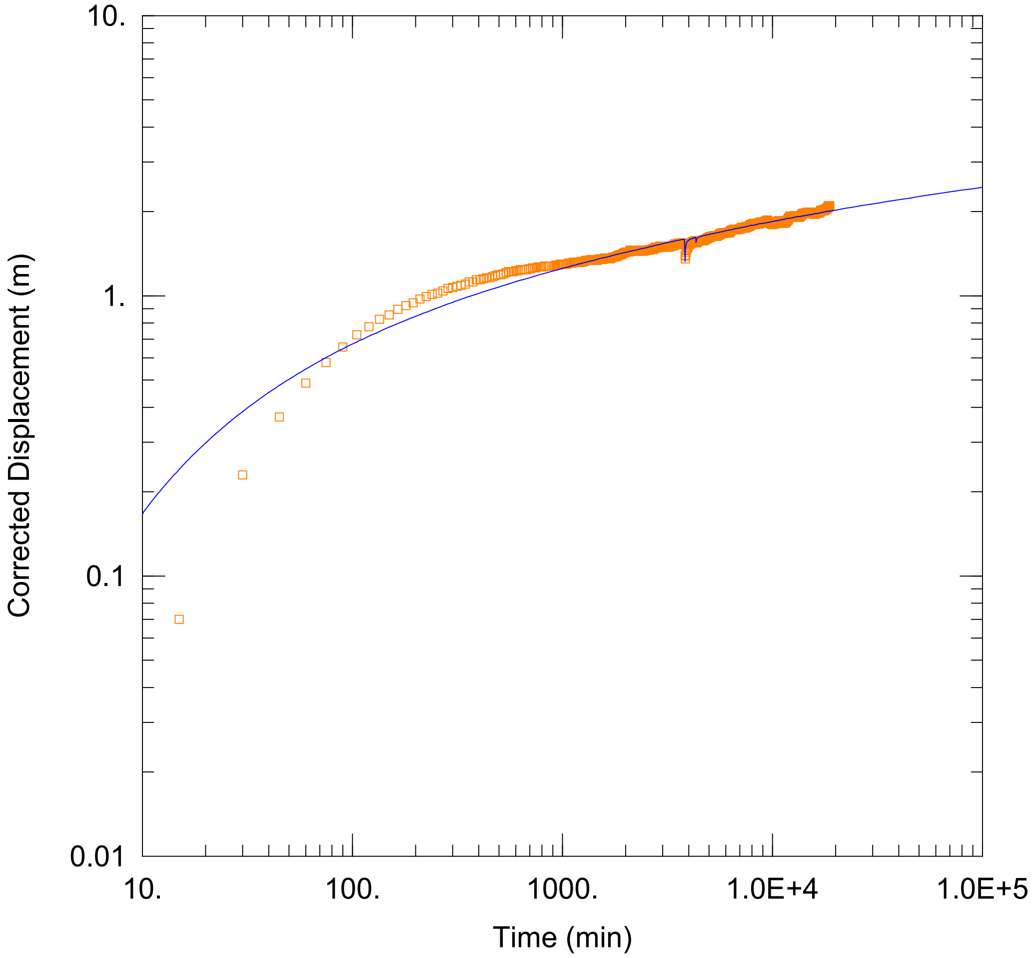
Observation Wells

Well Name	X (m)	Y (m)
□ BH20	315862.6	258102.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 165.3 m^2/day
S = 0.001
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH24.aqt
Date: 05/07/19 Time: 16:02:23

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

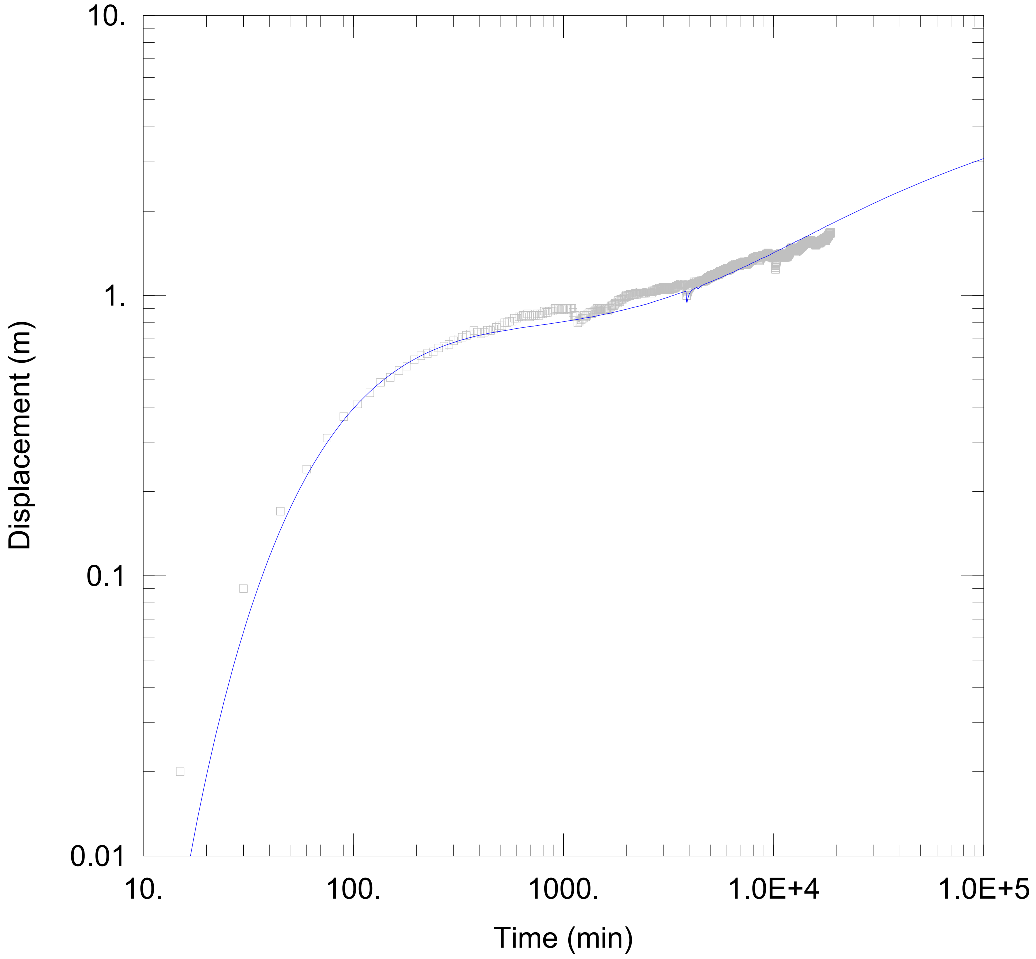
Observation Wells

Well Name	X (m)	Y (m)
□ BH24	315955	258209

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 164.2 m^2/day
S = 0.000143
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH26_hm.aqt
Date: 05/09/19 Time: 16:18:33

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

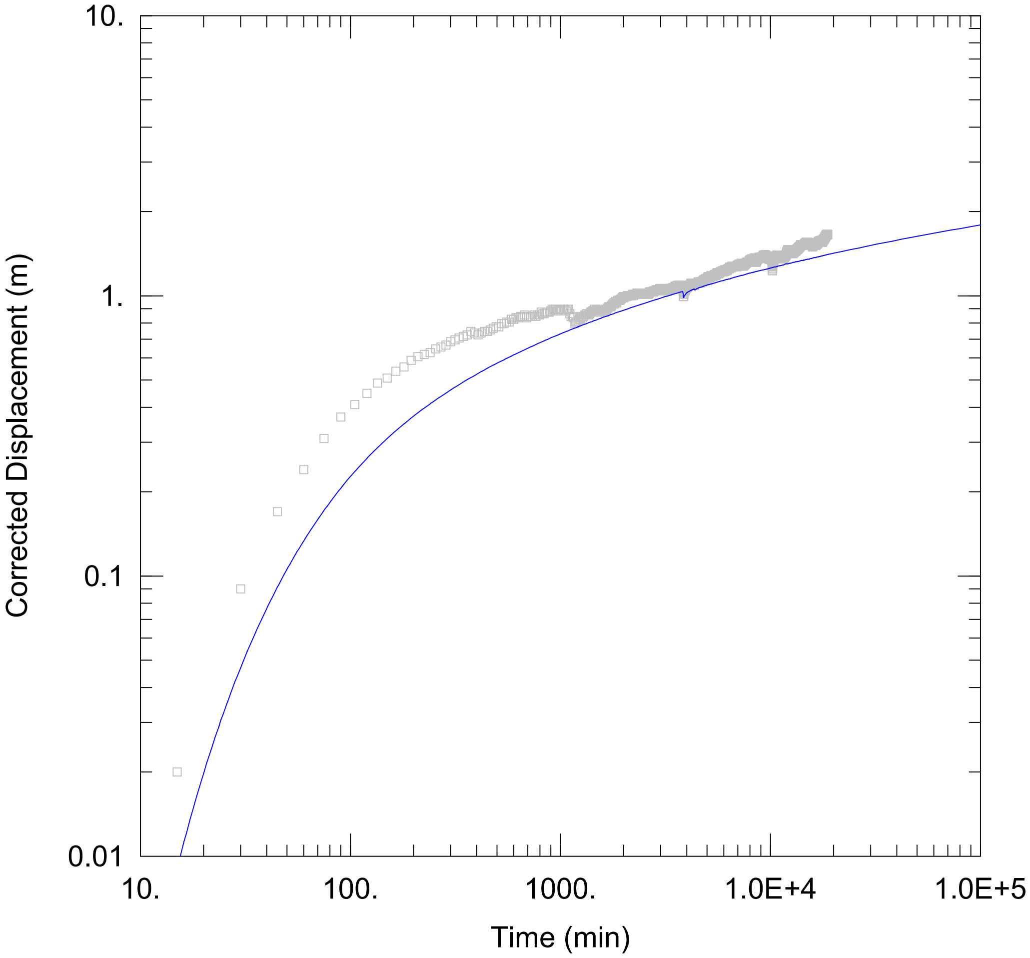
Observation Wells

Well Name	X (m)	Y (m)
□ BH26	315881	258086

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 51.09 m^2/day
S = 0.002741
Sy = 0.1
ß = 0.1



WELL TEST ANALYSIS

Data Set: \...\BH26.aqt
Date: 05/07/19 Time: 16:03:45

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

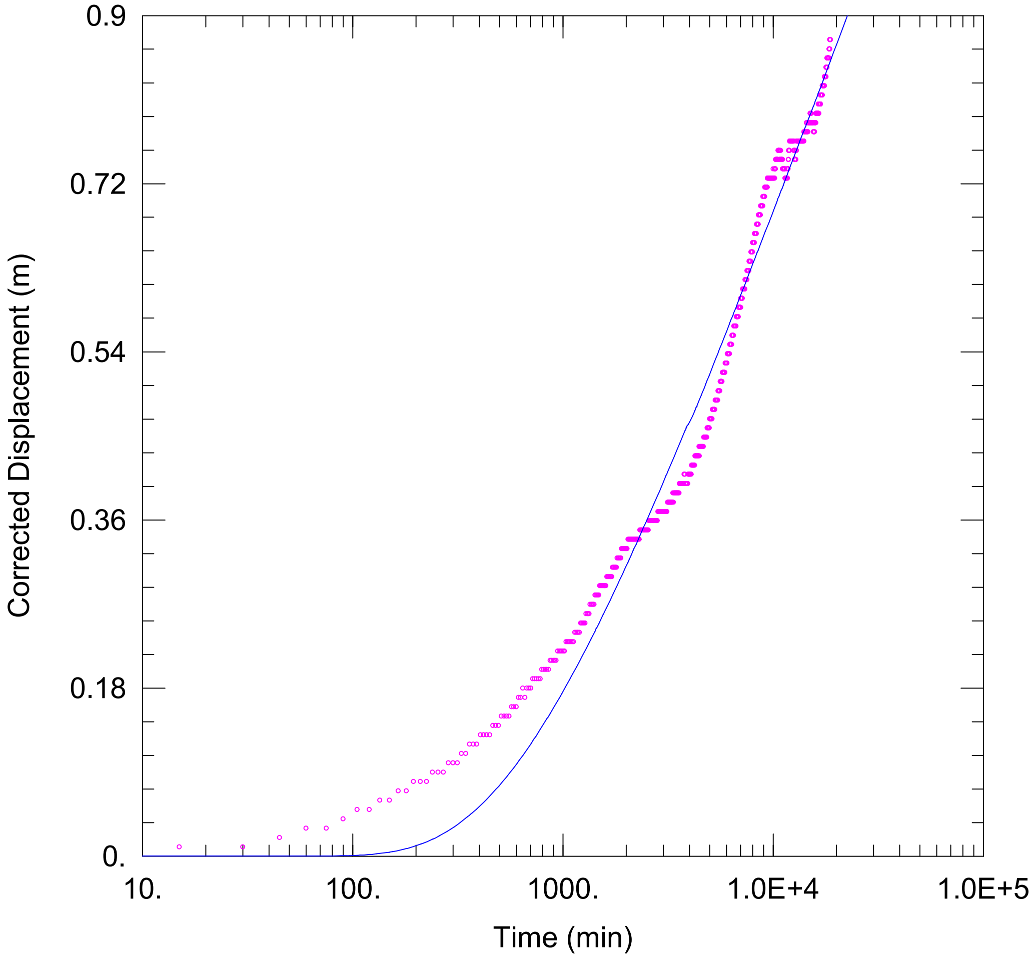
Observation Wells

Well Name	X (m)	Y (m)
▫ BH26	315881	258086

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 183.6 m^2/day
S = 0.008485
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH27.aqt
Date: 05/07/19 Time: 16:04:51

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

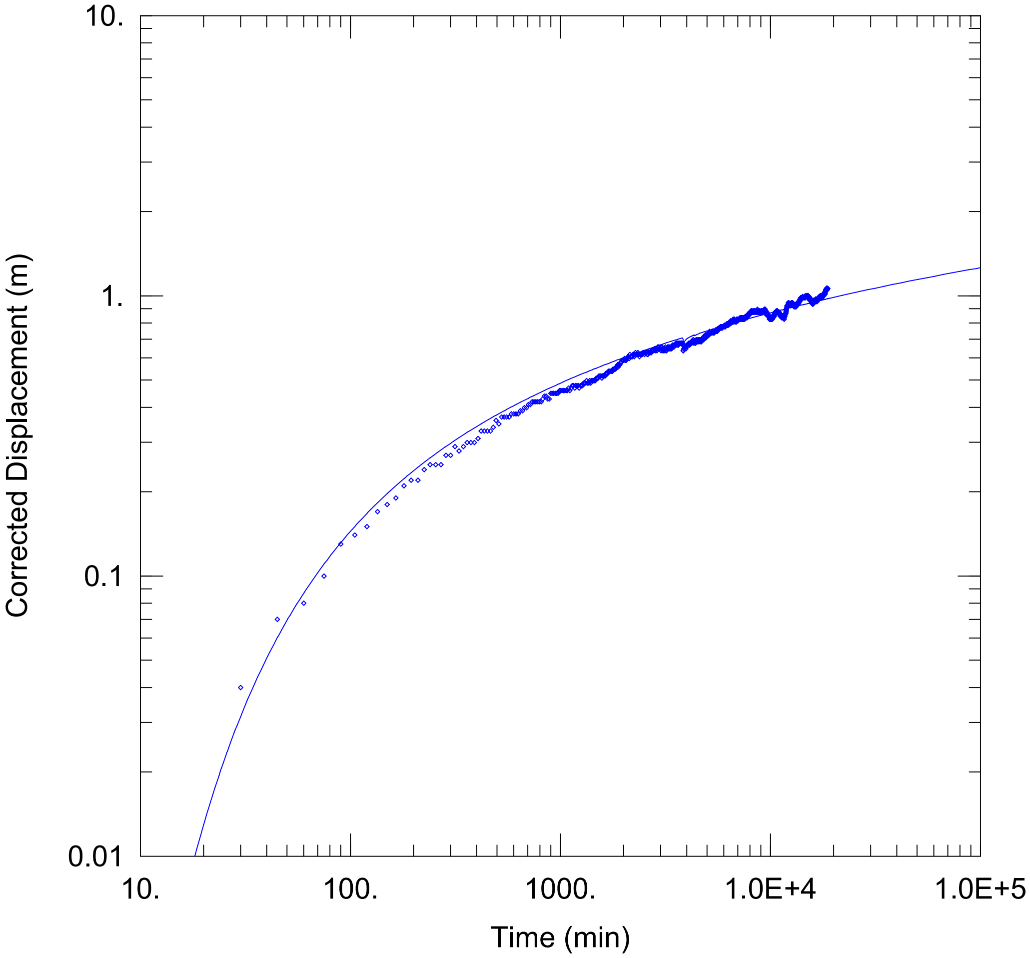
Observation Wells

Well Name	X (m)	Y (m)
◦ BH27	315757	258018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 160.7 m^2/day
S = 0.007011
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH29.aqt
Date: 05/07/19 Time: 16:05:44

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

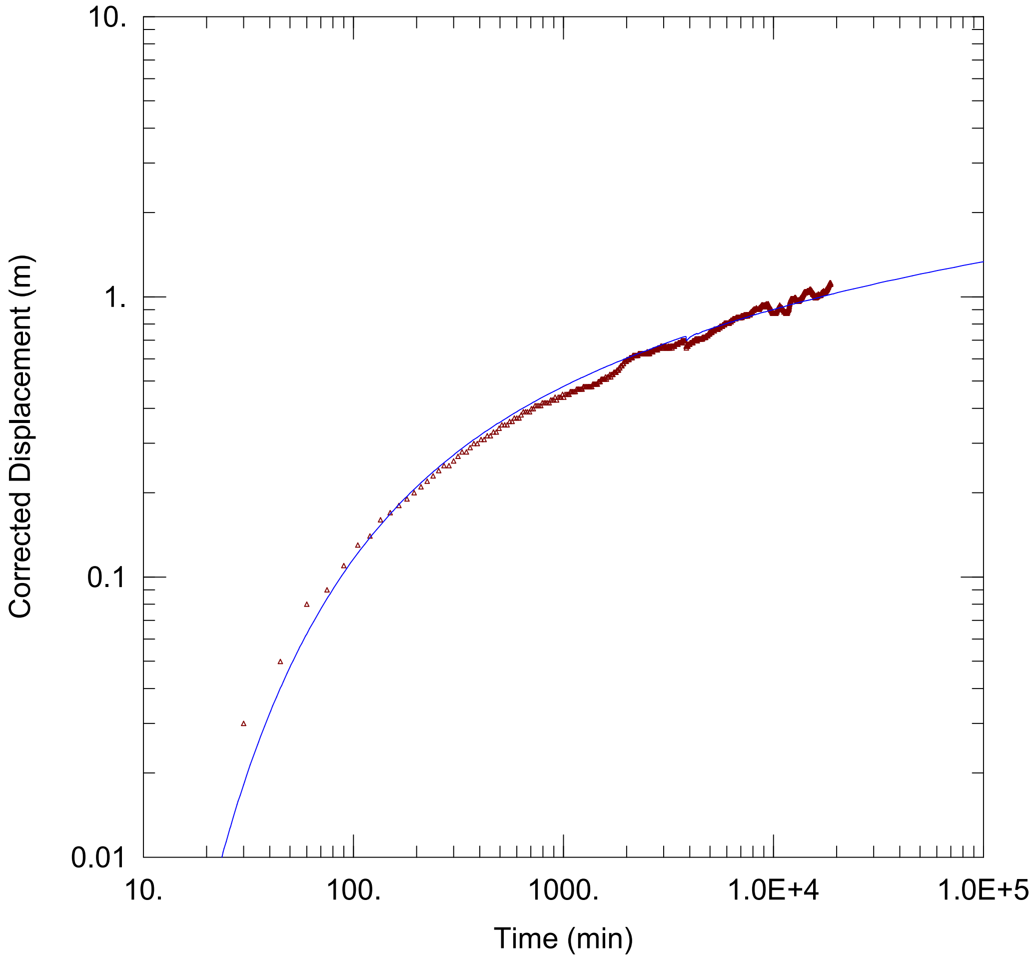
Observation Wells

Well Name	X (m)	Y (m)
◇ BH29	315986	258071

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 250.8 m^2/day
S = 0.002184
Kz/Kr = 1.
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\BH30.aqt
Date: 05/07/19 Time: 16:06:44

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

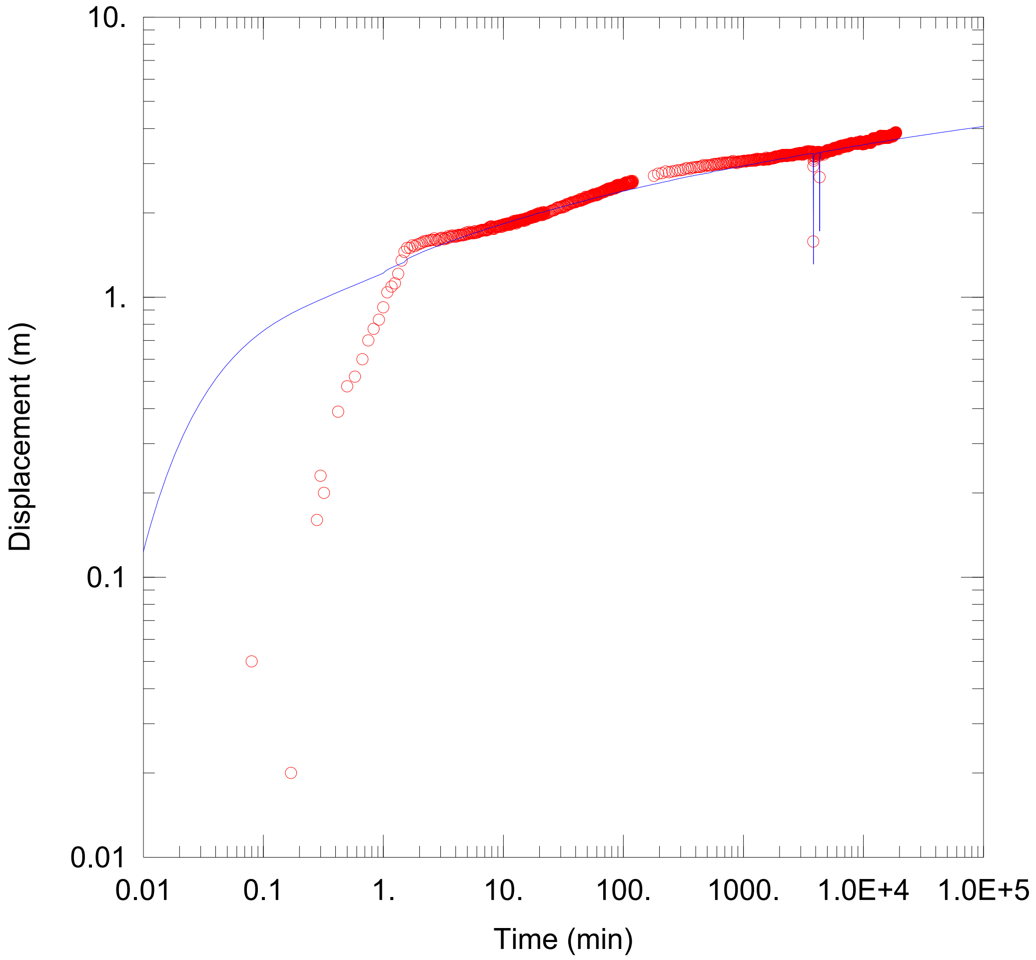
Observation Wells

Well Name	X (m)	Y (m)
▵ BH30	315970	258073

SOLUTION

Aquifer Model: Unconfined Solution Method: Theis

T = 225.3 m^2/day
S = 0.003981
Kz/Kr = 0.7586
b = 66. m



WELL TEST ANALYSIS

Data Set: \...\1. pumping well_hm.aqt
Date: 05/09/19
Time: 16:19:52

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

AQUIFER DATA

Saturated Thickness: 66. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

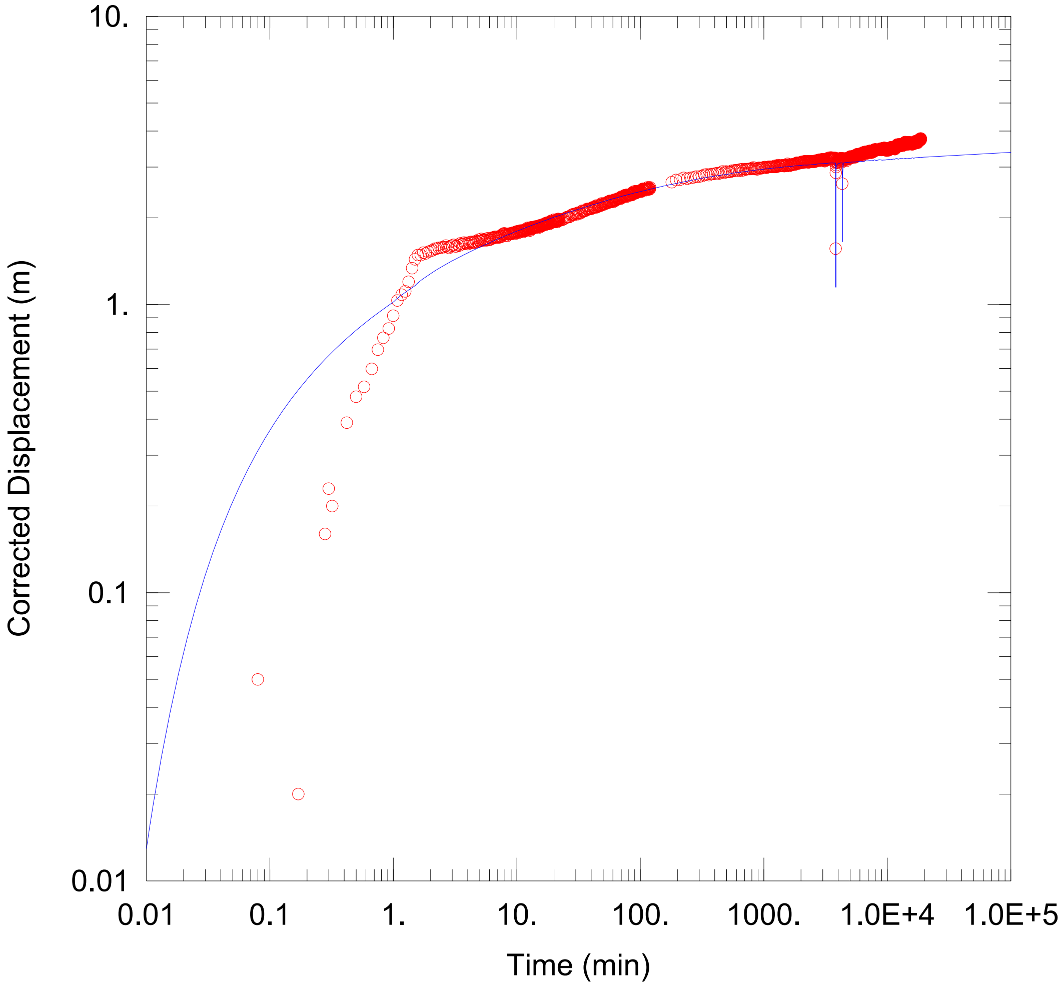
Observation Wells

Well Name	X (m)	Y (m)
○ Pumping Well	315892.987	258108.891

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 173.2 m^2/day
S = 0.2281
Sy = 0.1
ß = 0.1



WELL TEST ANALYSIS

Data Set: \...\1. pumping well.aqt
Date: 05/09/19 Time: 16:16:50

PROJECT INFORMATION

Company: CDMSmith
Client: Intergrated Material Solutions
Project: 118113
Location: Naul, North County Dublin,
Test Well: Pumping Well
Test Date: 19/11/2018

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumping Well	315892.987	258108.891

Observation Wells

Well Name	X (m)	Y (m)
○ Pumping Well	315892.987	258108.891

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 539. m^2/day
S = 1.338
Kz/Kr = 1.
b = 66. m

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Appendix D

Historical Reporting

INDUSTRIAL MINERALS
KARST & CAVES
BIOSTRATIGRAPHY
RENEWABLE ENERGY

CONODATE

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Windy Arbour,
Dublin 14, Ireland
Tel + 353.1.296 51 51
e-mail: conodate@mac.com

Report No. 2009/41

To Murphy Environmental Hollywood Ltd.

Report on the

Geology of the

Landfill Site
Hollywood, Naul
Co. Fingal

EurGeol Gareth Ll. Jones
BSc, MSc, PGeo

5th November 2009

Contents

Figures

APPENDIX

Introduction

The Murphy Environmental Holywood Ltd. (MEHL) Landfill Site at Hollywood, The Naul, Co. Fingal (Figs 1,2) is an old rock quarry. A geological study of the site was undertaken in order to understand the rock types present and their structural relationship. Micropalæontology and palynology was carried out on five samples to help determine their biostratigraphic age levels.

Summary

The rock sequence consists of a succession of lithologies progressing from the oldest Loughshinny Formation limestones and shales in the bottom of the south-west corner of the site, through overlying Donore Formation shales, limestones and sandstones, then Balrickard Formation sandstones, shales and rare micrites to Walshestown Formation black shales, siltstones and sandstones at the northern end of the site.

There is folding seen in the middle of the succession, but the upper beds are mostly undisturbed.

A major feature is the 2-3m wide, near-vertical Hollywood Fault vein / breccia crossing through HN-8, HN-11, HN-28, HN-27 to HN-25 along 034°. No evidence of water movement was seen on the fault, but adjacent water wells will display any hydrological influence, if it exists.

Rocks to the east of the fault have probably been downthrown some tens of metres.

Proposed Investigations

1) Adjacent observation water wells should be reviewed to ascertain whether the Hollywood Fault has any influence on the movement of groundwater in the area.

2) In order to understand the geology of the rock below the surface of the North-East cell, a borehole should be drilled at the southern end of the cell to a depth of c.100m.

3) The borehole beneath the North-East cell should be logged to assess the subfloor geology and biostratigraphic studies carried out as required.

4) Down–the-hole hydrogeological investigations might usefully be carried out on this borehole to determine the permeability of the bedrock below the North-East cell.

Fig. 1 Location of the MEHL Hollywood site, the Naul, part of Discovery sheet 43. Kilometre grid

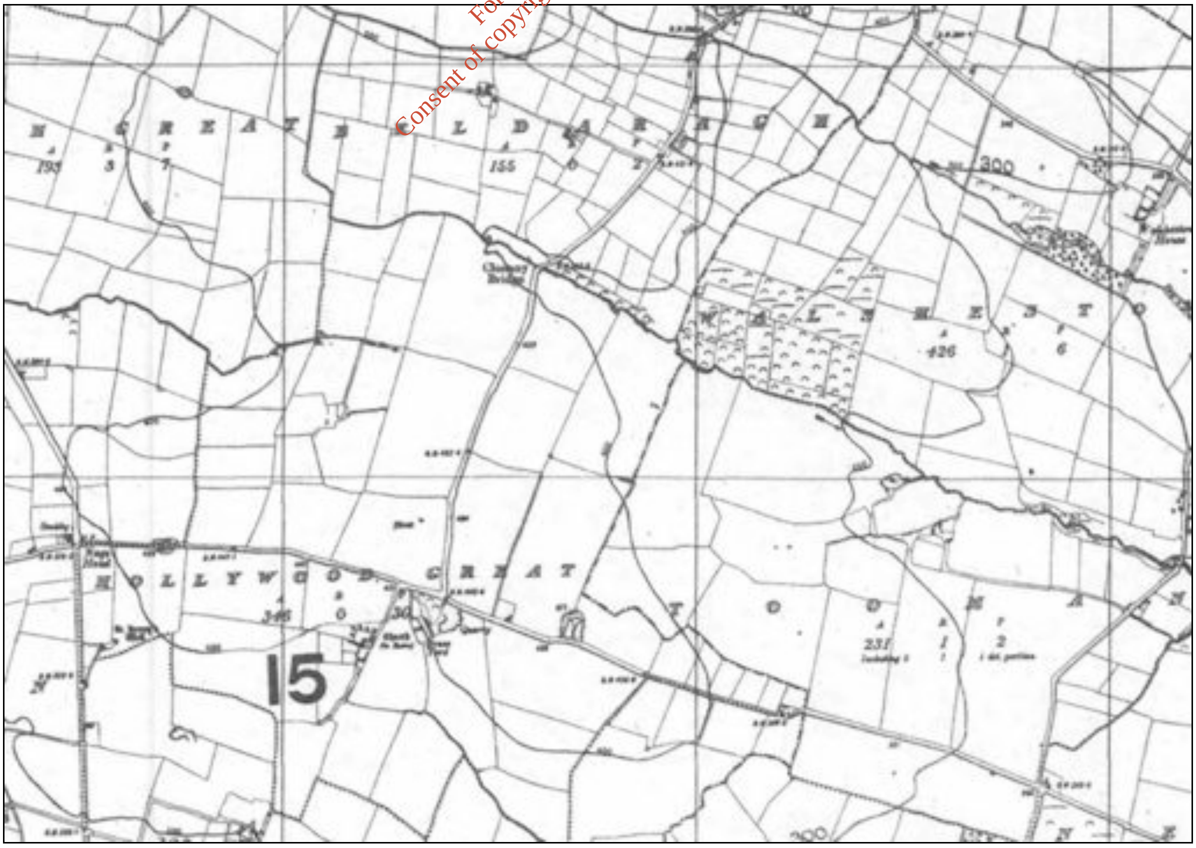

Fig. 2. Location of MEHL site in Hollywood Great townland. Part of OS 6" sheet. Kilometre grid.

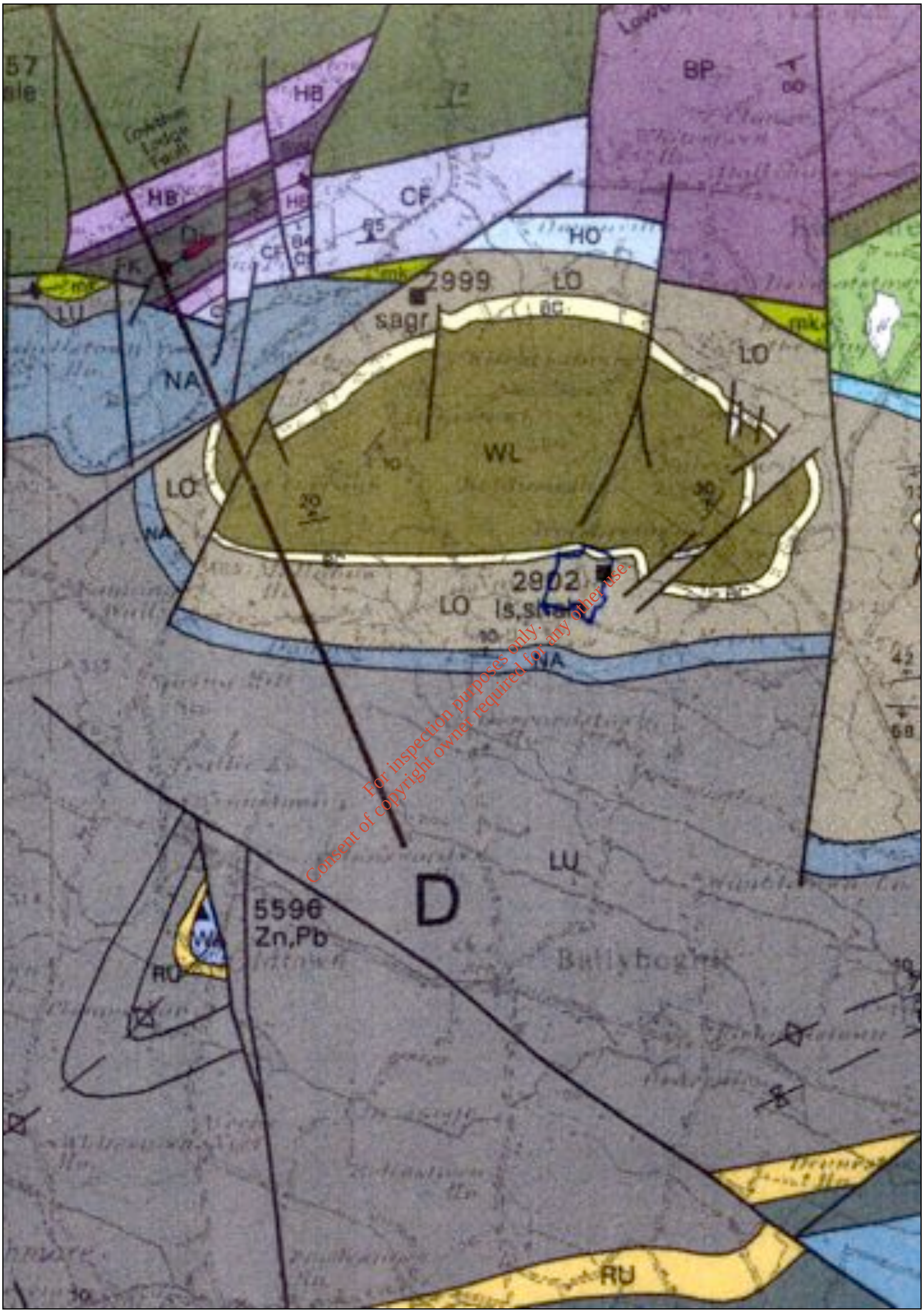

Fig. 3. Geology of the Hollywood area from G.S.I. memoir for sheet 13.

LU Lucan Formation, NA Naul Formation, LO Loughshinny Formation, BC Balrickard Formation, WL Walshestown Formation.

Geology

The Geological Survey of Ireland memoir for sheet 13 (McConnell *et al.* 2001) shows that the Holywood site lies on the south side of the Namurian outlier south-east of The Naul, Co. Fingal (Fig. 3.). The sequence progresses from Loughshinny Formation in the south of the site to Walshestown Formation in the north. A fault trending slightly east of north is shown to lie immediately north of the site, heading in the direction of the quarry. Pickard *et al* (1994) show the relationship of these formations in the Fingal area.

Geological investigation of the Hollywood site confirms these indications. It should be noted that many of the mudstones, shales, siltstones and sandstones are heavily weathered and accurate identification is difficult.

The major north-north-east striking Hollywood Fault (new name used here) is seen to pass through the quarry.

As the quarry removed upper layers of rock from a northward dipping sequence, the effect is to expose older layers of rock further to the north.

Comparison of the geology of the site with the GSI memoir map (McConnell *et al* 2001) suggests that the Namurian rocks extend further to the south than is shown on the memoir map.

Fig 4. Shows the mapped geology of the site following this study, with figs. 5 & 6 showing interpretive sections across the site. Many of the boundaries are not well constrained. Nevertheless it appears that the Loughshinny Formation outcrop is limited to an exposure further south than is indicated in the published GSI geological map.

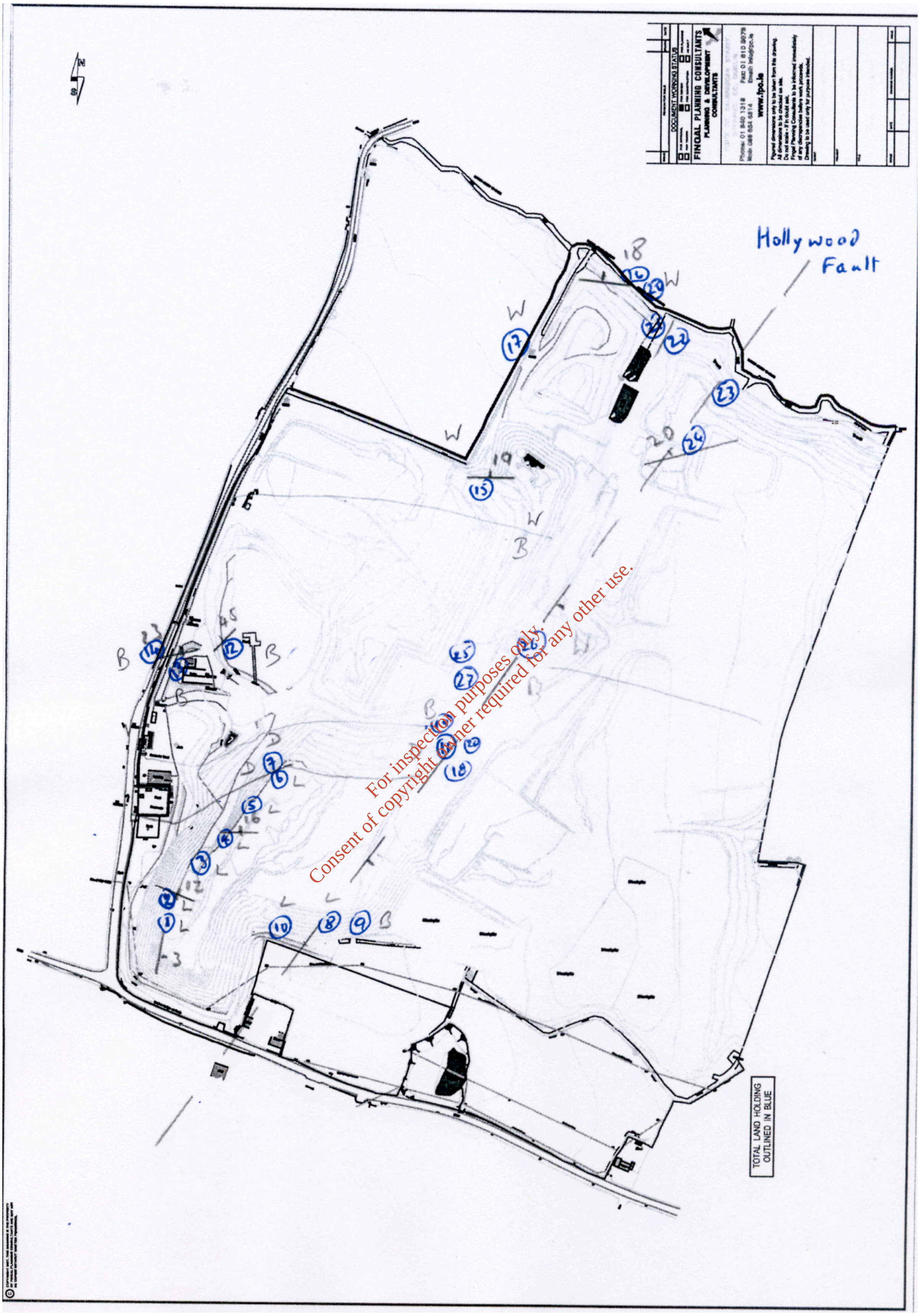

Fig. 4. Hollywood Site with Field locations and measured dips and strikes of bedding and fault, drawn on the 2007 Site Survey.
LU Lucan Formation, NA Naul Formation, LO Loughshinny Formation, DR Donore Formation, BC Balrickard Formation, WL Walshestown Formation

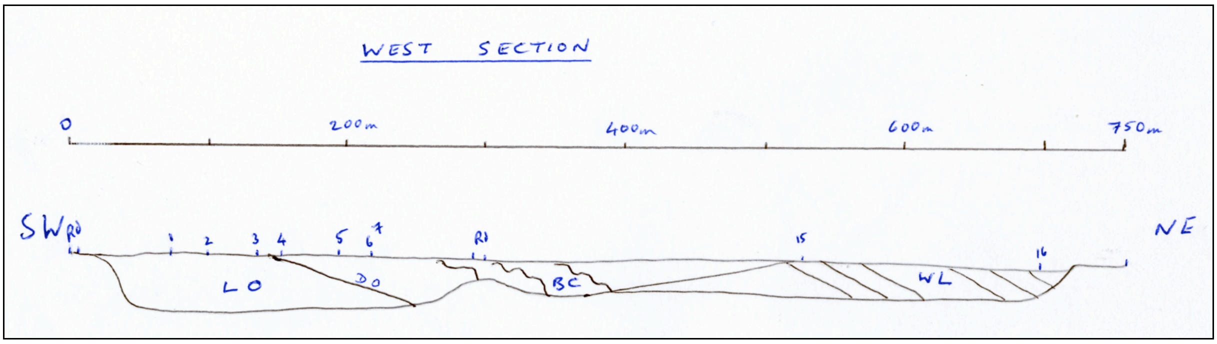

Fig. 5. South-west to north-east section on the west side of the Hollywood Fault

Fig 5. Shows that the rocks dip northwards.

Fig. 6 shows that the rocks to the east have been downthrown by an unknown amount, probably tens of metres (not to scale)

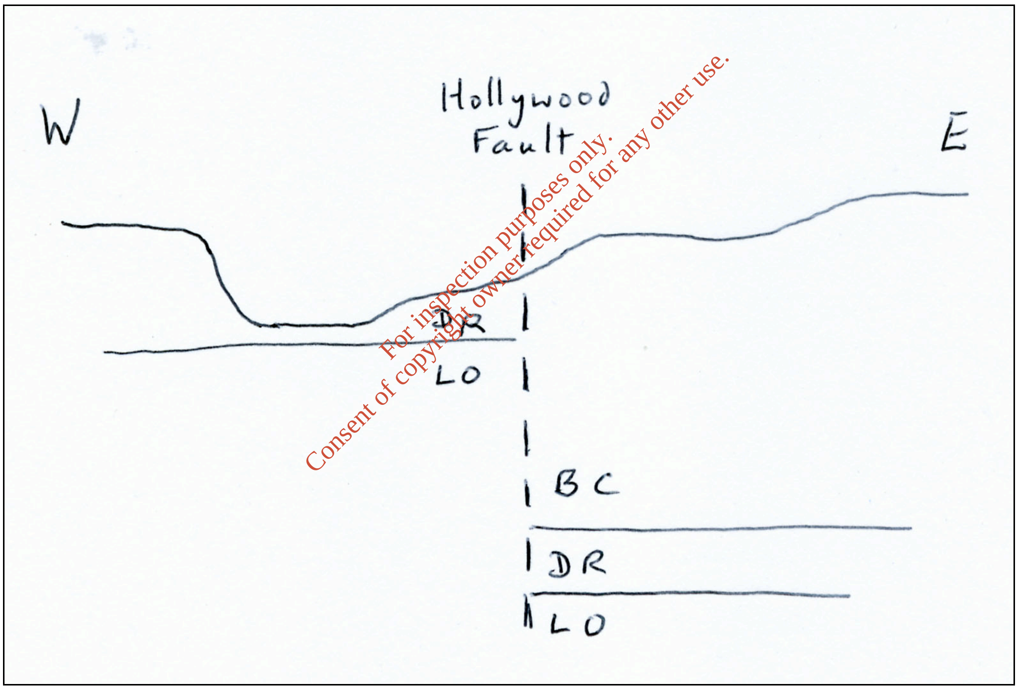

Fig. 6. West to east section across the Hollywood Fault.

Geology of the site areas

Deep Area

In the south-west corner of the site, the west face of the deep area shows a continuous succession of interbedded limestones and shales ascribed to the Loughshinny Formation. In the south wall, these are close to flat lying (HN-1), but dip more steeply and consistently to the north or north-north-west progressing to the north. At HN- 4, 5, 6, 7, the upper beds have been brought down to floor level and are seen to carry more shales and some siliceous influence. At localities HN-6 and HN-7, there is a change from these beds to overlying thin fissile shales, siltstones and sandstone taken to belong to the Donore Fmn., though no limestones are recorded. Micropalæontology samples from HN-2,4,6

On the western side of the Deep area, there is a series of benches that contain an extensive sequence of beds. The western ones (HN-8 and HN-10) are believed to belong to the Loughshinny Fmn. & Donore Fmn. They are folded to varying degrees in places. The eastern end (HN-9) consists of thin bedded shales and sandstones and chert beds with varicoloured weathered mud and clay ascribed to the Balrickard Fmn. since no limestones were found. The two sequences are separated by a major fault striking ~034°, near vertical, with a downthrow to the east. This is occupied by a 3.5m wide vein or breccia.

Bund Area

Situated one third of the way up the west side of the site, the Balrickard beds are now seen on the western side in three sections around the Bund area (localities HN-12,13,14) where they show significant folding, but continue to dip to the north-north-westwards.

North-West Cell

Finally on the western and northern sides of the North-West cell, there is a sequence of sandstones, siltstones and black shales that belong to the Walshestown Fmn. These continue to dip northwards, so that the youngest beds of the site are found at the top of the section HN-16 seen in the north wall of the North-West cell.

Palynology samples from HN-15,16

North-East Cell

Exposure in the proposed North-East cell is limited, but enough is seen to tie it in to that seen in the North-West cell. Exposures in the north-west HN-21,22,24 are on strike from those in the North-West cell. In the south wall at HN-25 there is a sequence of 3-4m of siltstones and sandstones with minor faulting, nearly 10m wide However, in the south-east, associated with the access ramp, evidence of the major Hollywood Fault is found on the outer edge of the ramp at HN-26. This is also recorded at HN-27 and in the main roadway at HN-28.

Biostratigraphy

See Detailed Biostratigraphy section p11.
The two locations HN-2 and HN-4 have been shown to lie within the Cf6 foraminiferal Biozone of Asbian-Brigantian, which accords with belonging to the Loughshinny Formation.
The two locations HN-15 and HN-16 lie within the CN Miospore Biozone of late Brigantian to Pendleian, which accords with the sequence from the upper Loughshinny Formation to the Walshestown Formation.

Structure

As mentioned, the general dip of the beds is from south to north, but there is also a broad anticlinal structure visible in the southern aspect of the deep area. It is not clear whether there may be any other structures present that cut across this general northward dipping sequence.

The Balrickard beds in the Bund area (localities HN-12,13,14) show significant folding, but continue to dip to the north-north-westwards. Further to the east at HN-25, a couple of small normal faults are present which display small throws to the east and show no evidence of water movement.

The main structure observed is the Hollywood Fault striking 034° from HN-8 through HN -11, -28, -27 to HN-26. This is near vertical and varies from 2 to 3.5m in width. Where exposure is relatively fresh it appears to be quartz filled with a partially vuggy nature. There is a significant downthrow to the east that may amount to some tens or hundreds of metres. This is probably a continuation of the fault that the GSI shows on their sheet 13 (McConnell *et al* 2004) immediately north of the Hollywood site.

The downthrow is to the east and is visible at locations HN-8 and HN-11. This downthrow may be of the order of several tens to perhaps a hundred metres or more. The fault passes through the south-east corner of the proposed North-East cell. This indicates that the floor of the North-East cell lies within the Walshestown Formation, with perhaps some Balrickard Formation at the southern end.

Detailed proposed Investigations

1) The groundwater flow pattern as determined from adjacent observation water wells should be reviewed to ascertain whether the Hollywood Fault has any influence on the movement of groundwater in the area.

2) In order to understand the geology of the rock below the surface of the North-East cell, it is proposed that a borehole should be drilled at the southern end of the cell to a depth of c.100m. This borehole will ascertain the minimum depth of the arenaceous dominated sequence of the Balrickard and Walshestown Formations below the floor of the North-East cell.

3) The borehole beneath the North-East cell should be logged to assess the subfloor geology and biostratigraphic studies carried out as required.

4) Down–the-hole hydrogeological investigations might usefully be carried out on this borehole to determine the permeability of the bedrock below the North-East cell.

Detailed Micropalæontology and Petrography

HN-2

THIN SECTION

Petrography :

Fine-medium –grained (argillaceous) wackestone with argillaceous wisps and occasional Lithoclasts.

And a dark mineralised layer of limonite with fine coarse pyrite crystals

Very fine <0.05mm veins cross perpendicular to bedding

Bioclasts :

Brachiopods, ostracods, crinoid

Foraminifera :

Archædiscids at angulatus stage.

Archædiscus sp.

Date : Cf6, Asbian - Brigantian

Fig. 7. HN-2 Field of view 3mm. Note fine-grained wackestone with argillaceous wisps and a lithoclast. Very fine <0.05mm veins cross perpendicular to bedding

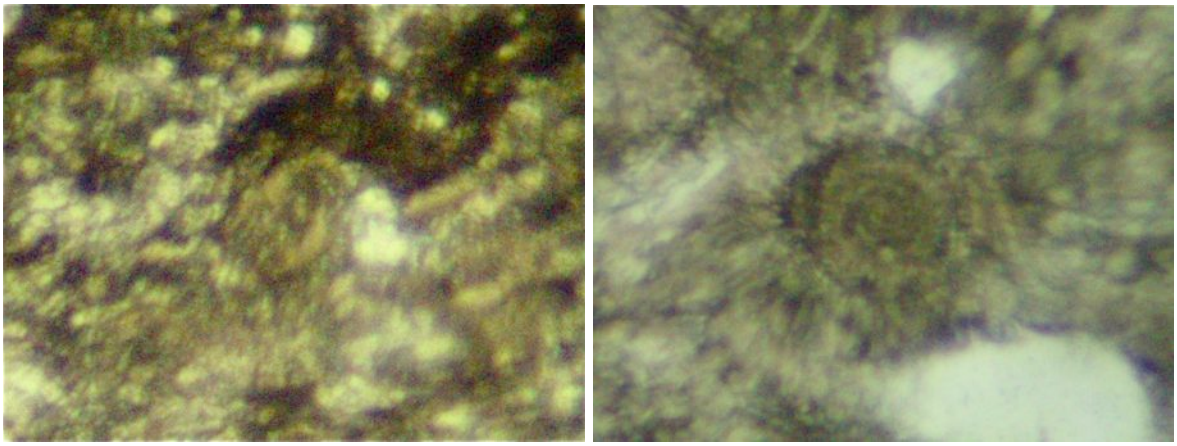

Fig. 8,9 Archædiscid foraminifera from HN-2

HN-4

THIN SECTION

Petrography :

Medium –grained packstone with argillaceous wisps and medium-grained sub-angular quartz grains.

Very fine <0.05mm veins, 2 sets at 40*, cross perpendicular to bedding

Bioclasts :

crinoid

Foraminifera :

Archædiscids at angulatus stage.

Archædiscus sp.

Date : Cf6, Asbian - Brigantian

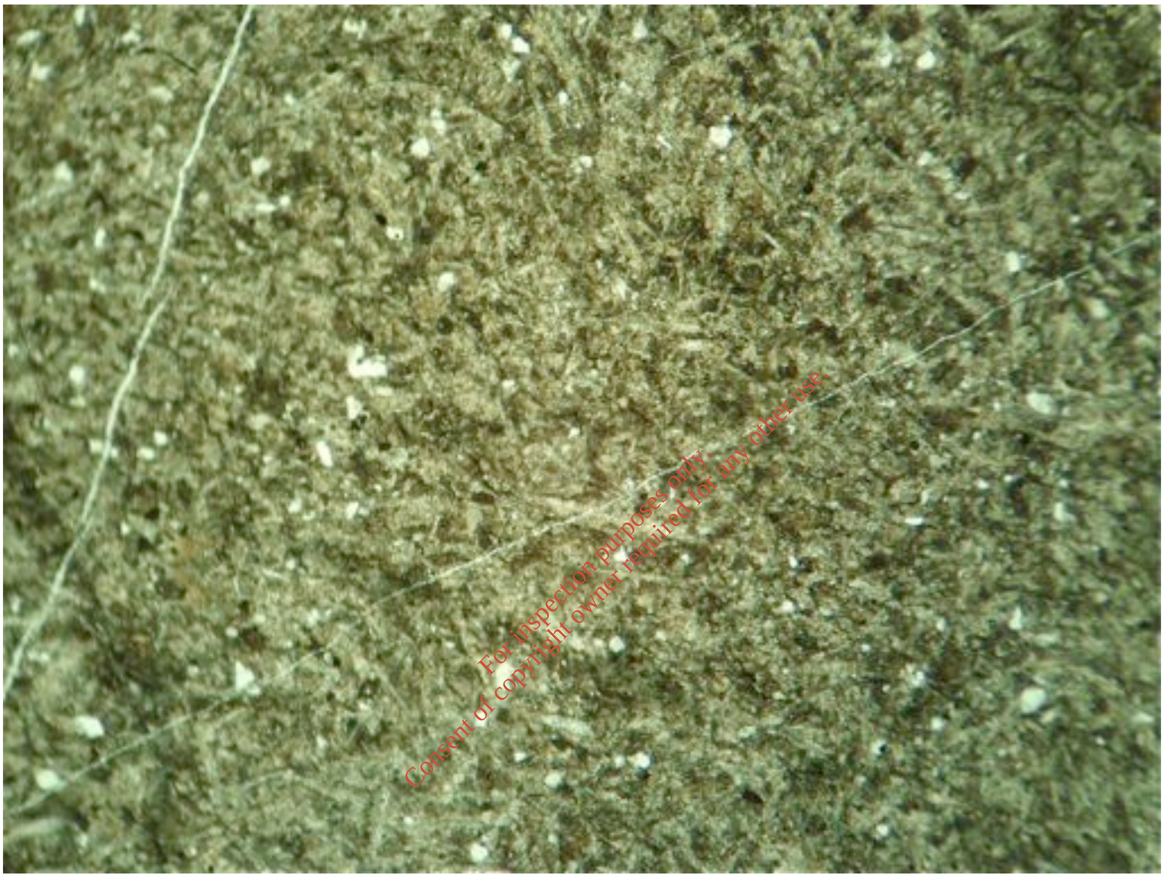

Fig. 10. Field of view 3mm. See medium-grained sub-angular quartz grains.

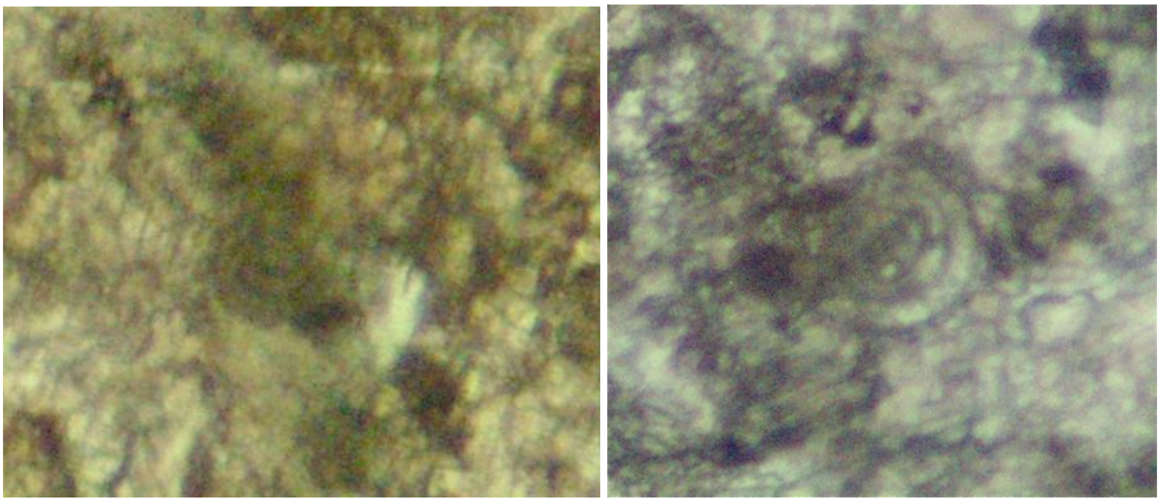

Fig. 11,12 Archædiscid foraminifera from HN-4

HN-6

THIN SECTION

Petrography :

Dark argillaceous packstone / wackestone with strong bedding orientation

Many medium spicules

Very fine <0.05mm calcite veins, 2 sets at 20*, cross roughly perpendicular to bedding

Bioclasts :

Brachiopods, ostracods, crinoid

No foraminifera or algæ recorded.

No age determined

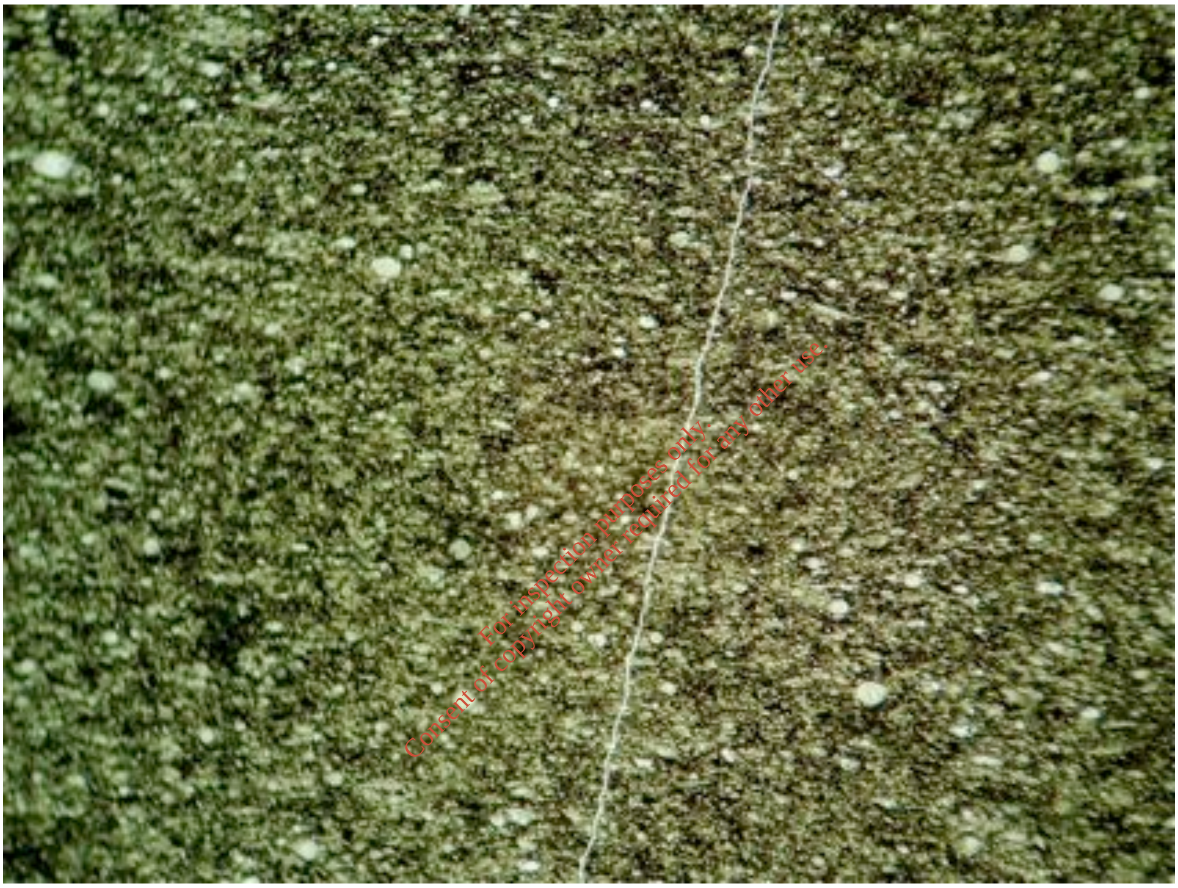

Fig. 13. Field of view 3mm. NB many spicules in cross-section.

Summary foraminiferal biostratigraphy

Two of these three locations are demonstrated to lie within the Cf6 foraminiferal biozone, the uppermost part of the Viséan sequence (Jones & Somerville 1996). This accords with belonging to the Loughshinny Formation.

PALYNOLOGY

Dr. K. T. Higgs

UCC

The two samples HN-15,16 from north Co Fingal, both yielded abundant organic matter that is dominated by Amorphous Organic Matter (AOM).

Palynomorphs are rare and poorly preserved and the spores for the most part can only be identified to generic level.

Nevertheless, the presence of the zonally significant taxon *Cingulizonates* cf *capistratus* indicates the samples belong to the C. capistratus - B. nitidus CN Biozone (Owens *et al* 2004).

This biozone is late Visean to Pendleian (mid P1 – E1) in age

Rare scolecodonts in the samples confirm the marine nature of the sediments

Summary palynological biostratigraphy

These two locations are demonstrated to lie within the CN Miospore biozone, this lies within the top P1 Viséan or late Brigantian to E1 Pendleian sequence. This accords with belonging to the sequence from the Loughshinny Formation to the Walshestown Formation.

Fig. 9. Vertical view of the MEHL landfill site at Hollywood, The Naul, Co. Fingal.

APPENDIX I

Field notes

Locality	Notes	Plates
	Panorama of west side from HN 1-7 round to HN 15-17	1
	Panorama of deep end from HN 8-10 to HN 1-5	2
	Closer panorama west side deep locs HN 1-3	3
	Panorama of west side from HN 2-7 (HN 14,13,12 top right)	23
	Panorama of north wall of North-West & North-East cells	33,34
WESTERN SIDE DEEP AREA		
HN-1	Base of 30m face	
	Clean pyritic fine-grained limestone <80cm, possibly siliceous, occasional minor chert	
	LOUGHSHINNY Fmn	
	AND Dark shales 1-10cm (at base 3m thick)	
	Bedding in corner further south 010° 3°E	
		13
HN-2	Some 3m up succession	
	Bedding 292° 12°NE	
HN-3	Middle beds now at ground level (start steep road)	15
	Same as above, fine-grained ?siliceous - a "laminated" sample	
HN-4	8m top of section now at ground level after steep road junction	16, 9
	More shales in sequence, but limestones are similar – more "laminated"	
	Bedding 089° 16°E	17-18, 9
HN-5	Western section in deep area	10,11
	Thin fissile shale dominant with thin <15cm limestone beds, clean coarse limestone with shale laminæ	
HN-6	As for HN-5 but more limestones, which are all dark fine -grained. LOUGHSHINNY Fmn	19, 9
HN-7	Overlying weathered shale section	19, 9
	Thin fissile shales, siltstones, ?limestone/sandstone	
	DONORE Fmn ?	

EASTERN SIDE DEEP AREA 21,20

MIDDLE BENCH

HN-8 Weathered Thin fissile shales & rotten medium-grained sandstones

LOUGHSHINNY Fmn 23, 26, 28

Small folds, then dipping steeply into a fault / vein 3-5m wide. 29

? vein or breccia

SKETCH 21-26

Bedding on west side of fault 9° 44°E

From vein looking north, a yellow feature (HN-11) is on 034° 40

near vertical.

HN-9 On east side of fault, thin bedded shales and sandstones <6cm and chert beds <12cm

Varicoloured weathered to mud/clay 32,31

Orange band at 4m is layered mud with loading, sagging features 34,33

UPPER BENCHES WEST OF FAULT

HN-10 Top (on left) is more of same, some cherty

Strongly folded. Folds are partly brittle 28, 35-37

LOUGHSHINNY Fmn

NORTH SIDE SOUTHERN AREA

HN-11 Yellow feature is probably the Fault / Vein of HN-8. Beds on west dip down, beds on east dip up into it. 40,41

HN-18 Succession in north-east corner, east of fault. Interbedded <15cm soft red siltstones & <12cm grey siltstones with weathering patterns. Bed 043° 28NW.

HN-19 Interbedded grey siltstones and sandstones with rotten mudstones. These north-west dipping beds become near horizontal approaching the fault due to fault drag on the upthrown side. Bed 054° 24NW

BUND AREA

BELOW BUND AREA

HN-12	Thin bedded 0.5-5.0cm, siltstones, shales, sandstones, all rotten, heavily folded	42-44
	SKETCH	
	Fold axes ~ 050°	

BACK OF BUND AREA

HN-13	5m of Interbedded sandstones, cherts, shales 0.5-40cm thick	
	DONORE Fmn. Steady dip, minor folds	47,46
	Bedding 077° 23°N	

ROAD CUT ABOVE BUND AREA

HN-14	Another 2m of these sandstones, thin shales, siltstones	

NORTH-WEST CELL

PROMINENT CORNER ON WEST SIDE

HN-15	<6m section of flat bedded 3-15cm sandstones, 40cm at base; dark 2-15cm sandstones / shales, 60cm at base	49-50
	Section continues upwards with 2-20cm sandstones and 0.5-1.0cm shales to top	
	WALSHESTOWN Fmn.	Palyno sample
	Bedding 093° 19°N	

NORTH END OF CELL WALL

HN-16	Interbedded brown & grey medium-coarse sandstones <20cm, and black soft shales <15cm.	51
	Bedding 097° 18°N	Palyno sample

WEST SIDE OF NORTH-WEST CELL

HN-17	This wall connects HN-15 to HN-17. Steadily dipping north, many metres of (faintly-visible) section exist here between the two measured sections.	
HN-20	Continuation of HN-16 to the east in northern wall of cell. Beds peter out beneath collapsed till.	

NORTH-EAST CELL

HN-21	In the drain between the north-west cell and the north-east cell Hard siltstone and black shale. WALSHESTOWN Fmn.
HN-22	North-west corner of North-East cell, adjacent to Drain. Black shales
HN-23	No outcrop visible
HN-24	Grey thin hard siltstones. Bed 075° 20°N
HN-25	In wall of south end of cell at HN-25 there is a sequence, some 10m wide, of 3-4m of siltstones and sandstones with minor normal faulting
HN-26	South-east corner by roadway ramp. Rotten siltstones on either side of a vein exposed as quartz breccia with vuggy crystallisation. Fault strikes 34° to HN-26 and HN-8
HN-27	In upper wall of south end of cell. About a metre thickness of breccia visible within black shales, which are also included in the breccia.
HN-28	In major Roadway running east, see 2m width of vuggy crystallised quartz breccia material. On fault line of 34°

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AGL9313_01

REPORT
ON THE
GEOPHYSICAL SURVEY
AT THE PROJECT PHOENIX SITE
IN
NAUL, CO. DUBLIN
FOR
MEHL.

18 February 2010

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

AGL9313_01

PROJECT NUMBER	AGL9313		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
EURGEOL SHANE O`ROURKE P.GEO., M.SC. (GEOPHYSICS)	EURGEOL PETER O`CONNOR P.GEO., M.SC. (GEOPHYSICS)	VERSION 1	18TH FEBRUARY 2010

18 February 2010

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DRAWINGS

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18 February 2010

1. INTRODUCTION

Development of an integrated waste management facility is proposed on the site of the Murphy Environmental Hollywood Landfill in Naul, Co. Dublin. The existing landfill is located in a disused rock quarry. Geological mapping and a topographical survey have been recently carried out on the site. The geological data indicates that the stratigraphy changes from younger shale-sandstone bedrock in the north to older limestone/shale in the south. The mapping also indicates that there is a NNE striking fault which passes through the east-centre of the quarry.

A trial geophysical survey has been carried out on site which successfully demonstrated the use of geophysical surveying on site and a full geophysical surveying was then carried out for Arup Consulting Engineers, on behalf of MEHL. across the remainder of the survey area in order assist in compiling a geological model for the area. This report details the results of the main geophysical survey and incorporates the results of the trial survey. The report of the trial survey is included in Appendix III.

1.1 Survey Objectives

The objectives of the main survey were to:

1. Map the variation across the site of the geological formations and units present.

2. Provide additional information on any geological structures present.

3. Provide information of the weathering and quality of the bedrock.

1.3 Survey Methodology

The following program of geophysical surveying was carried out:

- 2D-Resistivity Profiling to investigate the nature of lithological variations and map any fault zones, and to provide information on overburden and weathered rock thickness.

- Seismic Refraction Profiling to confirm overburden and weathered rock thickness, and provide information on the nature of the underlying fresh bedrock.

- Electromagnetic Ground Conductivity (EM31) was carried out to further map lithological variations from 0-6m bgl across the site.

1.3 Site Background & Geological Setting

Naul Landfill is located in a disused rock quarry situated at Hollywood approximately 4 km south-east of Naul. The site is bounded by local roads to the south and west and by a stream in the north. There are green fields adjacent to the site in the east. The site is located on a local topographic high with steep decrease in topography to the east.

The Geological Survey of Ireland (GSI) 1:100,000 Bedrock Series Map for the area indicates that the site is predominantly underlain by Loughshinny Formation dark micrite and calcarenite interbedded with shale. The GSI Bedrock Series map also indicates Balrickard Formation coarse sandstone, shale and Walshestown Formation shale, sandstone and limestone in the north of the site.

The GSI Soils Map indicates that overburden across the site comprises shale and sandstone till (Namurian). The GSI Soils Map indicates rock outcrop/subcrop in the south and west of the site.

The recent geological survey of the site by Jones (2009) described a sequence of lithologies with limestones and shales of the Loughshinny Formation at lower levels in the south-western part of the quarry overlain by shales, limestones and sandstones of the Donore Formation overlain by sandstones, shales and rare micrites of the Balrickard Formation and then by Walshstown Formation black shales, siltstones and sandstones in the northern portion of the site. This report also noted a NNE trending fault with vein/breccias, with beds of the Balrickard Formation exposed to the east of the fault and the Donore Formation and underlying Loughshinny Formation exposed to the west, with probable downthrow to the east of some tens of metres.

The report by Jones indicates that the Loughshinny Formation outcrop is restricted to an area further south than indicated on the GSI Bedrock map.

Much of the exposed rock is highly weathered with accurate identification difficult.

The majority of quarried material in the quarry has come from the more competent rock on the west side of the quarry with extraction terminating close to or at the NNE-trending fault. The position of the NNE-trending fault where exposed in the southern portion of the quarry was recorded during the survey and is shown on Drawing 9313_01.

Figure 1 **Looking to the south-west in the southern part of quarry along a NNE-trending fault.**

2. INTERPRETED RESULTS

2.1 EM31 Conductivity

The EM31 conductivity survey locations are shown on Drawing 9313_04, with the interpretation included in Drawing 9313_05. Recorded EM31 conductivity values ranged from 14.0 mS/m to 48.0 mS/m. The conductivity data has been interpreted on the following basis, and is indicative of the material from 0 – 6.0m bgl.

Conductivity (mS/m)	**Interpretation**
14.0 – 21.5	Limestone / Sandstone bedrock
21.5 – 35.5	Shale / Calcareous Mudstone Bedrock
35.5 - 48	Shale / Calcareous Mudstone Bedrock with Influence of bund material

Values of 14.0 – 21.5 mS/m have been interpreted as indicative of areas underlain by mainly limestone bedrock of the Loughshinny formation or sandstone bedrock of the Donore/Balrickard formations. The interpreted boundary between these two formations is indicated in Section 2.3.

Values of 21.5 – 35.5 mS/m have been interpreted as areas underlain by mainly shales/calcareous mudstone of the Loughshinny/Donore/Balrickard /Walshtown formations.

The results indicate that lower values of conductivity (14.0 – 21.5 mS/m) are generally present on the western side of the NNE-trending fault, and on the southern side of a smaller W-E trending fault (Drawing 9313_05) that will be discussed later, and that higher values (21.5 – 35.5 mS/m) are generally present to the east of the NNE-trending fault and the north of the W-E trending fault.

Values of 35.5 – 48.0 have been interpreted as mainly shales/calcareous mudstone of the Donore/Balrickard /Walshtown formations and also show the influence of the waste cell bund in the north-west of the site.

One area of high conductivity (23.5 – 26.0 mS/m) near the base of the entrance ramp in the west of the site has been interpreted as indicative of clayey infill material.

2.2 Seismic Refraction Profiling

Twenty-five seismic refraction profiles were recorded (S1-S2, S4-S26) in the survey area (Drawing 9313_02 & 9313_03 and Appendix II). The seismic data outlined two, three or four velocity layers and has been interpreted on the following basis.

Layer	**Seismic Velocity (m/s)**	**Average Seismic Velocity (m/sec)**	**Interpretation Estim**	**ated Stiffness/ Rock Quality**
1	176 - 1129	538	Overburden Material / Infill / Completely Weathered Bedrock	Firm / Medium Dense / Poor
2	541 - 1815	1099	Completely – Highly Weathered Bedrock	Poor-Fair
3	1031 - 2533	1749	Moderately - Slightly Weathered Bedrock	Fair
4	2163 - 5888	3196	Slightly Weathered – Fresh Bedrock	Good

2.3 2D Resistivity Profiling

Fourteen resistivity profiles (R1-R14) were recorded (Drawings 9313_02 & 9313_03). The resistivity data were interpreted on the following basis:

Apparent Resistivity (ohm-m)	**Interpretation**
25 - 250	Saturated / Clayey Rock INFILL
250 - 883	Highly weathered and fractured rock INFILL, non saturated
25 - 250	Predominant SHALE / CALCAREOUS MUDSTONE
250 - 1200	Predominant LIMESTONE / SANDSTONE

2.4 Discussion

Overburden

Material with a resistivity of 25 – 250 Ohm-m has been interpreted as saturated or clayey rock infill or cell cap material. Material with a resistivity of 250 – 883 Ohm-m has been interpreted as broken rock infill. Overburden is generally very thin or absent throughout the site.

Overburden is generally thin throughout the site, with the exception of the south-western corner of the quarry floor and the area of the newly constructed cell in the north of the site. A thickness of approx. 10.0m of saturated rock infill material has been interpreted along Profile R4 in the south-west of the quarry floor, and a zone of clayey/saturated infill material which is approx. 15.0m thick has been interpreted for the eastern part of Profile R6, upon the lower side of the quarry entrance ramp.

Overburden within the grass fields in the south of the survey area has been interpreted as thin (0.5 – 1.5m) soil over completely weathered bedrock.

Overburden in the east of the site has been interpreted as infill or spoil material which is generally 3.0 – 7.0m thick, underlain by completely weathered bedrock.

Bedrock & Faulting

Material with a resistivity of 25 – 250 and 250 – 1200 Ohm-m have been interpreted as predominantly shale/mudstone and predominantly limestone/sandstone respectively.

Two faults have been interpreted within the survey area, and these control the distribution of the main lithologies at the site. The NNE-trending trending fault has been interpreted on Profiles R9, R2, R1, R14, R12, R13 and R3 (Drawing 9313_02). The results indicate that this fault is dipping at approx. 60-70º to the east for Profiles R14 to R3 in the north of the site and the trend of the fault approaches 4º (almost due North-South) from Profiles R13 to R3. The fault is sub-vertical for Profile R1 in the centre of the site, and is then interpreted to divide into two splays in the south of the site as indicated on Profile R9 & Drawing 9313_05, with the westernmost splay evident on Profile R2. The trend of the fault in the south of the site is generally NNE-SSW at approx. 35º.

The eastern side of the main fault is interpreted as the downthrown block, with a throw of approx. 25m. This is indicated by the downthrow of high resistivity limestone/sandstone towards the east as shown on Profiles R3, R13, R12, R14, R1 & R9.

A second W-E trending fault which terminates at the NNE fault has been interpreted on the western side of the quarry floor, and has been interpreted on Profiles R8, R11 & R12. Downthrow of this near-vertical fault is interpreted as up to 80m on the northern side of the fault.

<u>Loughshinny Formation</u>

Bedrock to the south and west of both of the above faults is generally interpreted as limestone of the Loughshinny Formation, with interbedded zones of shales and calcareous mudstone. This material is interpreted for Profiles R4-R6, R1-R2, R9 and the southern parts of R10 and R7. Profiles R5 and R6 indicate that the Loughshinny formation comprises some thick zones (up to 30m) of shales/calcareous mudstone.

The transition from Loughshinny Formation into Donore/Balrickard Formation is indicated by the general increase in low resistivity bedrock from south to north along Profiles R10 & R7. The area of this contact is shown on Drawing 9313_05 and is also indicated by the change from high to low conductivities in this area.

To the north of this contact (on the east of the NNE-trending fault), Loughshinny Formation limestones are interpreted to underlie shales/calcareous mudstones of the Donore/Balrickard Formation, at approx. 75 – 88 mOD.

Results for seismic profiling indicate that bedrock for the Loughshinny Formation generally comprises 5.0 – 21.0 m of completely-highly weathered bedrock underlain by moderately-slightly weathered bedrock. Zones of slightly weathered-fresh bedrock within this formation are indicated by the high seismic velocities (2163 – 5888 m/s) as interpreted for Profiles S7 (south-east of the site), Profile S26 (quarry floor) and Profile S5 (ramp near entrance).

<u>Donore/Balrickard Formation</u>

Material to the north and east of both faults and to the north of the contact as shown on Drawing 9313_05 is generally interpreted as Donore/Balrickard Formation.

Bedrock from these formations to the east of the NNE-trending fault is generally interpreted as completely-highly weathered shale/calcareous mudstone which is 8.5 – 11.5m thick underlain by moderately-slightly weathered shale/calcareous mudstone.

Bedrock from these formations to the west of the NNE-trending fault, and north of the W-E trending fault is generally interpreted as interbedded sandstones and shales/calcareous mudstones.

Results for seismic profiling upon this formation indicate that bedrock comprises completely-highly weathered bedrock which is 5.0-17.0m thick underlain by moderately-slightly weathered bedrock. A zone of slightly weathered-fresh bedrock have been interpreted for Profiles S17 in the north of the site.

Walshtown Formation

Sandstone and shale/calcareous mudstone from the Walshtown Formation has been interpreted for Profile R3 in the north of the site, with 12.0-30.0m of completely-highly weathered shale to the east of the NNE-trending fault, underlain by moderately-slightly weathered shale. 5.5-9.5m of completely-highly weathered shale/calcareous mudstone underlain by highly-moderately weathered shale/calcareous mudstone and sandstone has been interpreted for the east of the NNE-trending fault, for Profile R3.

Influence of the Bund

Parts of resistivity Profiles R8 (from 80-246m) and Profile R3 (from 0-60m) are characterized by low resistivity values to depths of approx. 20m and this is interpreted to be due to the presence of the nearby waste bund to the north-west of the quarry floor. The conductivity data in this area also show this influence, as indicated on Drawing 9313_05.

3. SUMMARY

- Two faults have been identified from the geophysical results, a NNE-trending fault and a W-E trending fault which terminates at the NNE-trending fault.

- The NNE-trending fault divides the site and is steeply dipping towards the east, with downthrow to the east of approx. 25m.

- The W-E trending fault has been interpreted in the centre of the quarry floor, is near-vertical, and shows downthrow of c. 80m to the north.

- Loughshinny Formation limestones and interbedded shales/calcareous mudstone has been mainly interpreted to the east of the NNE-trending fault, and south of the W-E fault. Loughshinny Formation bedrock is generally completely-highly weathered material to between 5-21m thickness underlain by moderately-slightly weathered material.

- Donore/Balrickard Formation shales/calcareous mudstone are interpreted to the east of the NNE-trending fault, and generally comprises completely-highly weathered material which is 5-17m thick underlain by moderately-slightly weathered material.

- The contact between the Loughshinny and Donore/Balrickard Formations has been interpreted in the south-eastern part of the survey area.

- Donore/Balrickard Formation sandstone and interbedded shales/calcareous mudstone are interpreted to the west of the NNE-trending fault, and to the north of the W-E trending fault.

- Walshtown Formation sandstones and shales/calcareous mudstones are interpreted in the north of the site.

- The EM31 conductivity readings correlate with the resistivity profiles and indicate that limestone is generally present in the south and south-west of the survey area, that shale/calcareous mudstone is present in the east and north east of the survey area, and that sandstone and shale/calcareous mudstone is present in the north and north-west of the survey area.

- Overburden is generally thin throughout the site, with the exception of the south-western corner of the quarry where zones of approx.10 and 15m of saturated/clayey infill have been interpreted.

- Overburden within the grass fields in the south of the survey area has been interpreted as thin (0.5 – 1.5m) soil over completely weathered bedrock, and overburden in the east of the site has been interpreted as infill or spoil material which is generally 3.0 – 7.0m thick.

- Resistivity and conductivity surveying in close proximity to the waste bund to the north-west of the quarry floor show anomalous values to depths of approx. 20m due to the presence of the bund, over an area of approx. 6080 square metres.

- Higher seismic velocities (20-30% higher) were recorded over the more competent rocks to the west of the NNE-trending fault.

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APPENDIX I GEOPHYSICAL METHODOLOGY

M1. Methods Used

1.1 Electromagnetic Conductivity Mapping

This method operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/metre (mS/m). As the effective penetration of this method is around 6m below ground level the measured conductivity is a function of the different overburden layers and/or rock from 0 to 6m below ground level.

1.2 2D-Resistivity Profiling

The resistivity surveying technique used for the survey makes use of the Wenner resistivity array whereby four electrodes are placed in a line in the ground and a current is passed through the two outer electrodes. The potential difference is measured across the two inner electrodes. The measured potential is divided by the current value to obtain the resistance. The resistivity is determined from the resistance using the following formula:

Resistivity = Resistance* 2 * Pi * Spacing

The 2D-resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types. The 2D-resistivity profiling method involves the use of 32 to 64 electrodes connected to a resistivity meter, using computer software to control the process of data collection and storage.

1.3 Seismic Refraction Profiling

This method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

M2. Equipment Used

2.1 Electromagnetic Conductivity Mapping

The equipment used was a GF CM31 Conductivity meter equipped with data logger. This instrument features a real time graphic display of the previous 20 measurement points to monitor data quality and results.

2.2 2D-Resistivity Profiling

The profiles were recorded using a Campus Tigre resistivity meter, imaging software, two 32 takeout multicore cables and up to 128 stainless steel electrodes. The recorded data were processed and viewed immediately after the survey.

2.3 Seismic Refraction Profiling

A Geode high resolution 24 channel digital seismograph, 12 10HZ vertical geophones and a 10 kg hammer were used to provide first break information, with two 12 take-out cables (3m spacing) and a trigger geophone. Equipment was carried in a 4WD vehicle with a three-person crew.

M3. Field Procedure

3.1 Electromagnetic Conductivity Mapping

The trial survey comprised 367 conductivity readings recorded on the 12th of January 2010. Conductivity and in-phase values were recorded along two profiles, a 580m South-North profile and a 380m East-West profile. Local conditions and variations were recorded.

The main survey comprised 5241 conductivity readings recorded on 1st and 8th February 2010.

3.2 2D-Resistivity Profiling

A total of fourteen 2D resistivity profiles were recorded throughout the site. The resistivity data was acquired on the 12th and 13th of January 2010, and 1st to 9th February 2010. The resistivity profile were acquired as follows, with an electrode spacing of 5m.

Profile	Length	Orientation	Approx. Depth of Investigation (m)
R1	315	NW-SE	52
R2	155	NW-SE	30
R3	315	NW-SE	46
R4	265	SW-NE	39
R5	155	NE-SW	30
R6	155	E-W	30
R7	635	SW-NE	51.5
R8	305	SW-NE	50
R9	315	NW-SE	52
R10	635	SW-NE	108
R11	475	NE-SW	82
R12	315	NW-SE	52
R13	315	NW-SE	52
R14	315	NW-SE	52

3.3 Seismic Refraction Profiling

Twenty-five spreads were recorded on the 13th of January 2010, and 1st-9th February 2010. Each seismic spread consisted of 24 collinear geophones at spacing of 2-3m, and was 46-69m in length. Records from five different positions were taken on each spread (2 x off-end, 2 x end, 1 x middle) to ensure optimum coverage of all refractors.

M4. Data Processing

4.1 Electromagnetic Conductivity Mapping

The data were downloaded and plotted. Assignation of material types and possible anomaly sources was carried out, with cross-reference to other data. Scaled plots of conductivity against distance were prepared (Drawing 9313_04 and 9313_05)

4.2 2D-Resistivity Profiling

The field readings were stored in computer files and inverted using the RES2DINV package (Campus Geophysical Instruments, 1997) with up to 5 iterations of the measured data carried out for each profile to obtain a 2D-Depth model of the resistivities.

The inverted 2D-Resistivity models and corresponding interpreted geology are displayed on Profiles R1 to R14. The chainage is indicated along the horizontal axis of the profile and the elevation to mOD is indicated on the vertical axis.

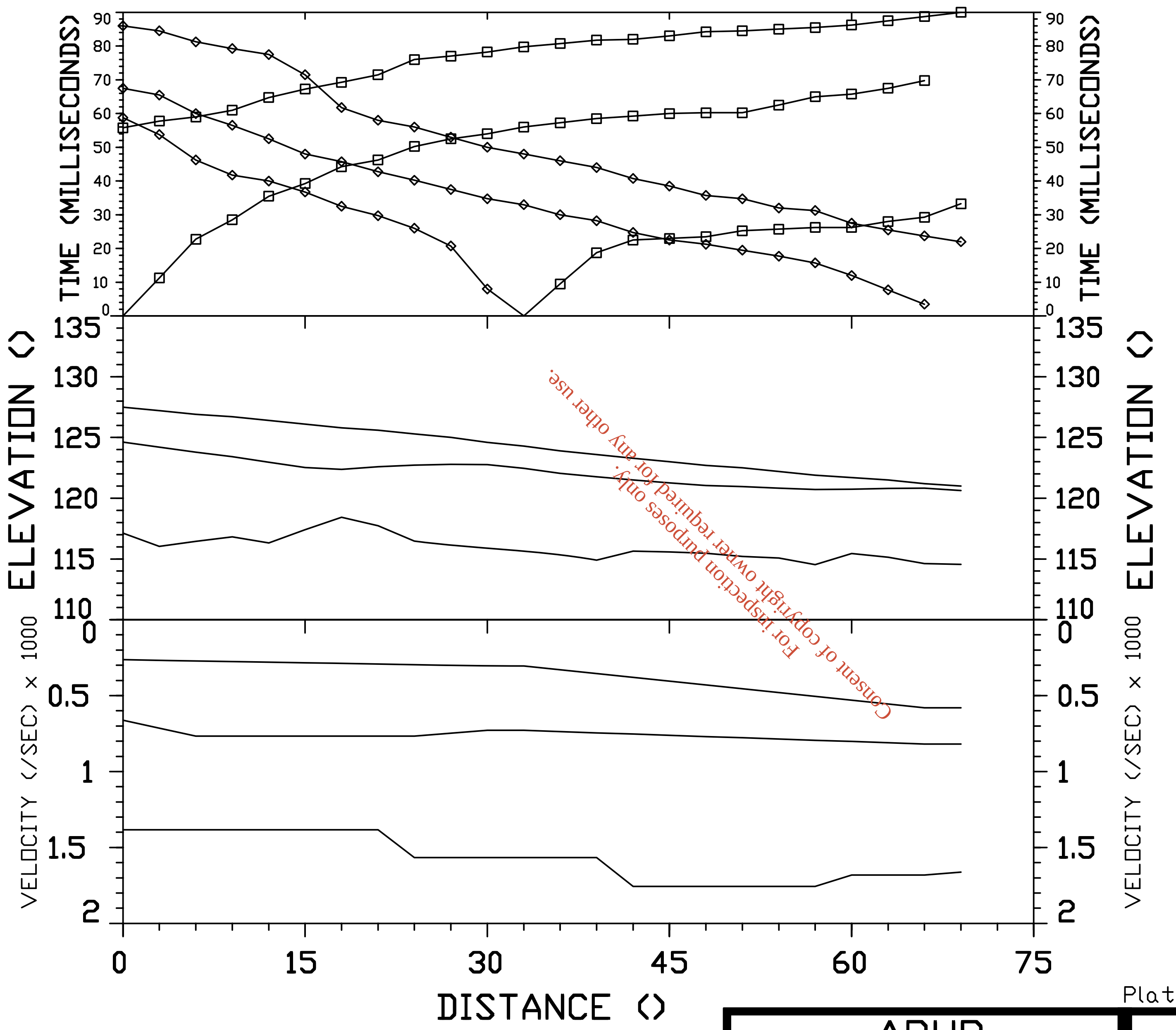
It is important to note that the data displayed on the 2D-Resistivity profiles is real physical data however interpretation of the geophysical results is required to transform the resistivities directly into geological layers.

4.3 Seismic Refraction Profiling

First break picking in digital format was carried out using the FIRSTPIX software program to construct traveltime plots for each spread. Velocity phases were selected from these plots using the GREMIX software program and were used to calculate the thickness of individual velocity units. Topographic data were input. Material types were assigned and estimation made of material properties, cross-referenced to the 2D Resistivity data. The processed seismic data are displayed in Appendix II and on Drawing 9313_02 and 9313_03.

Approximate errors for velocities are estimated to be +/- 10%. Errors for the calculated layer thicknesses are of the order of +/-20%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

APPENDIX II SEISMIC REFRACTION PLATES



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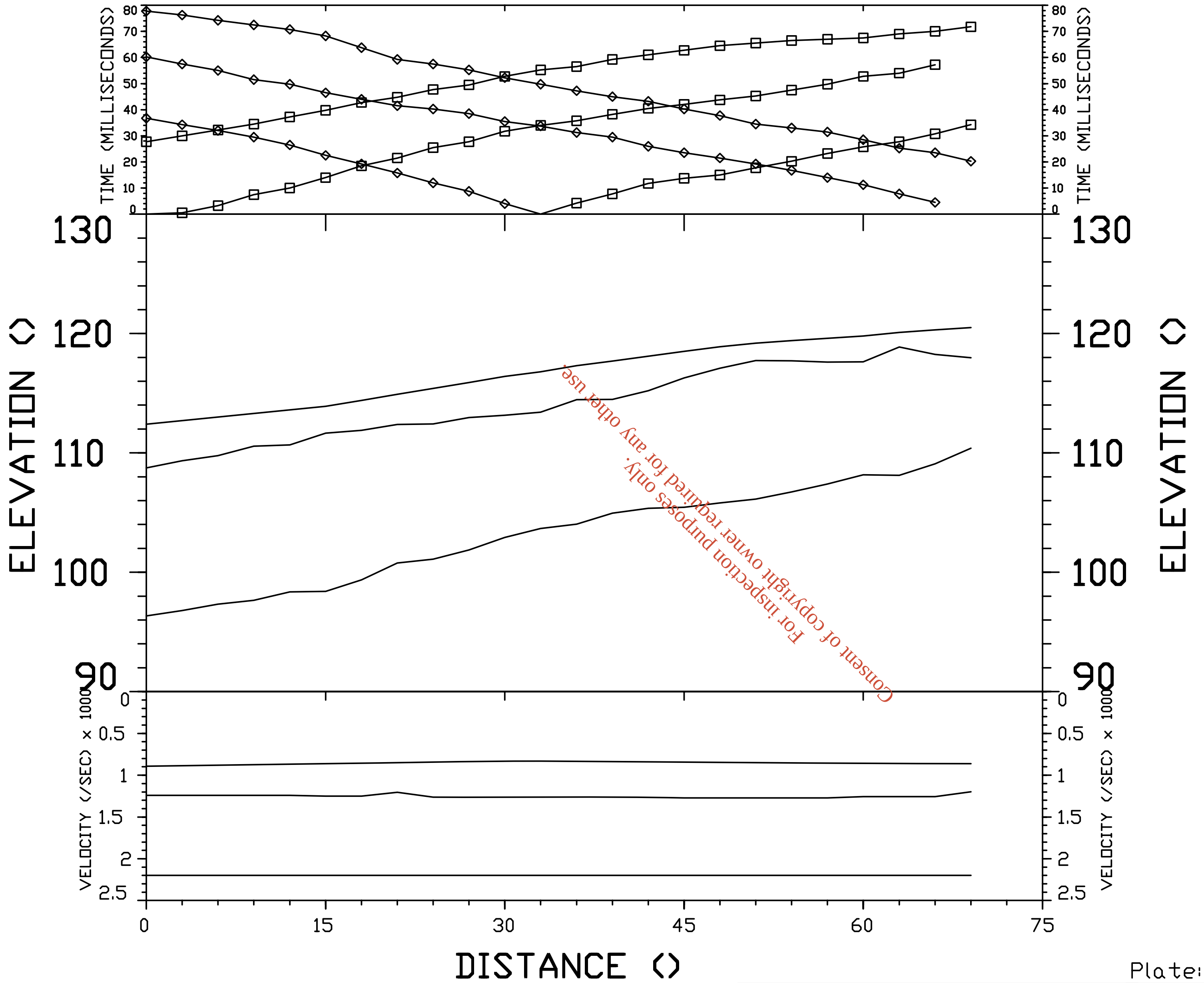

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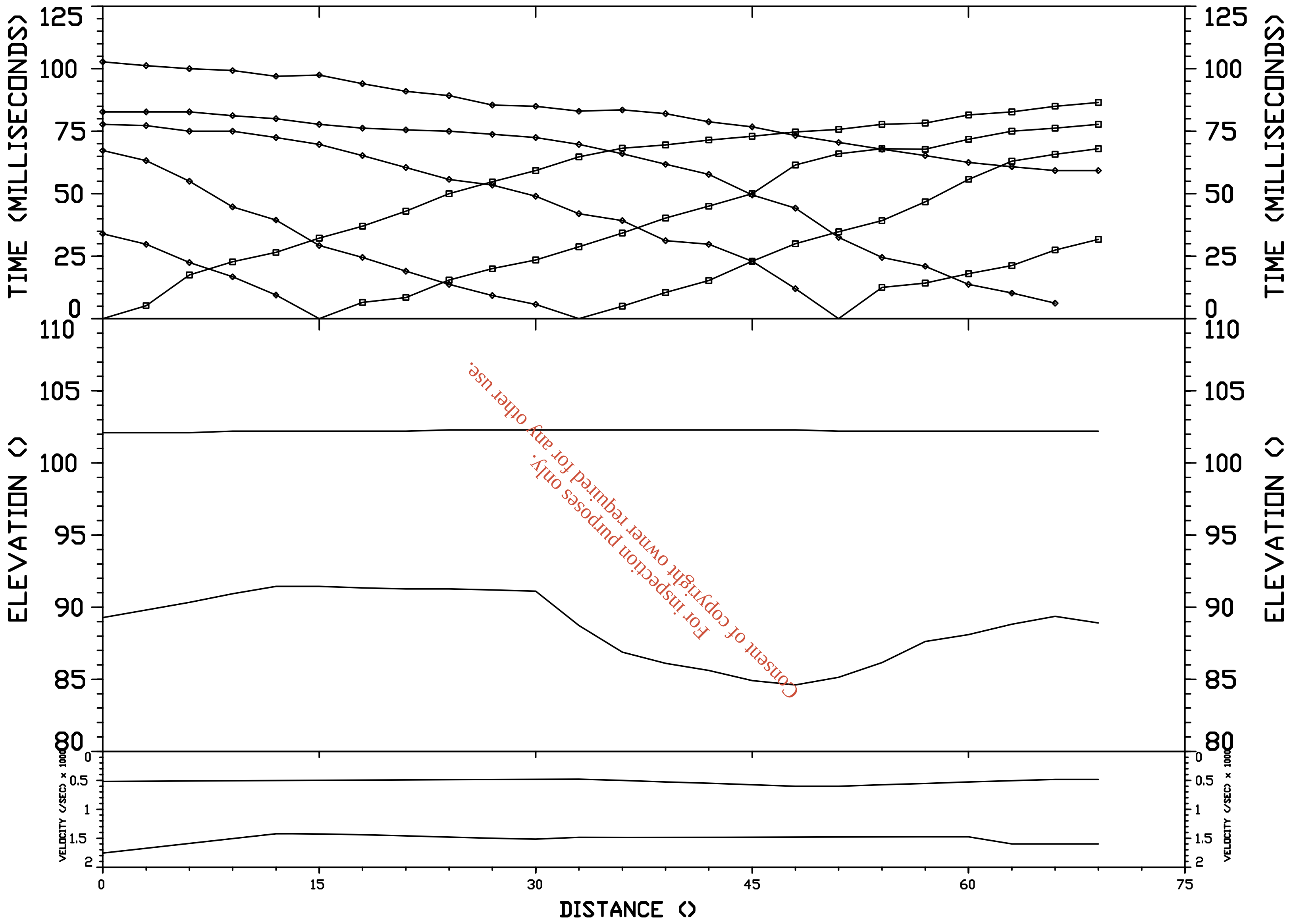

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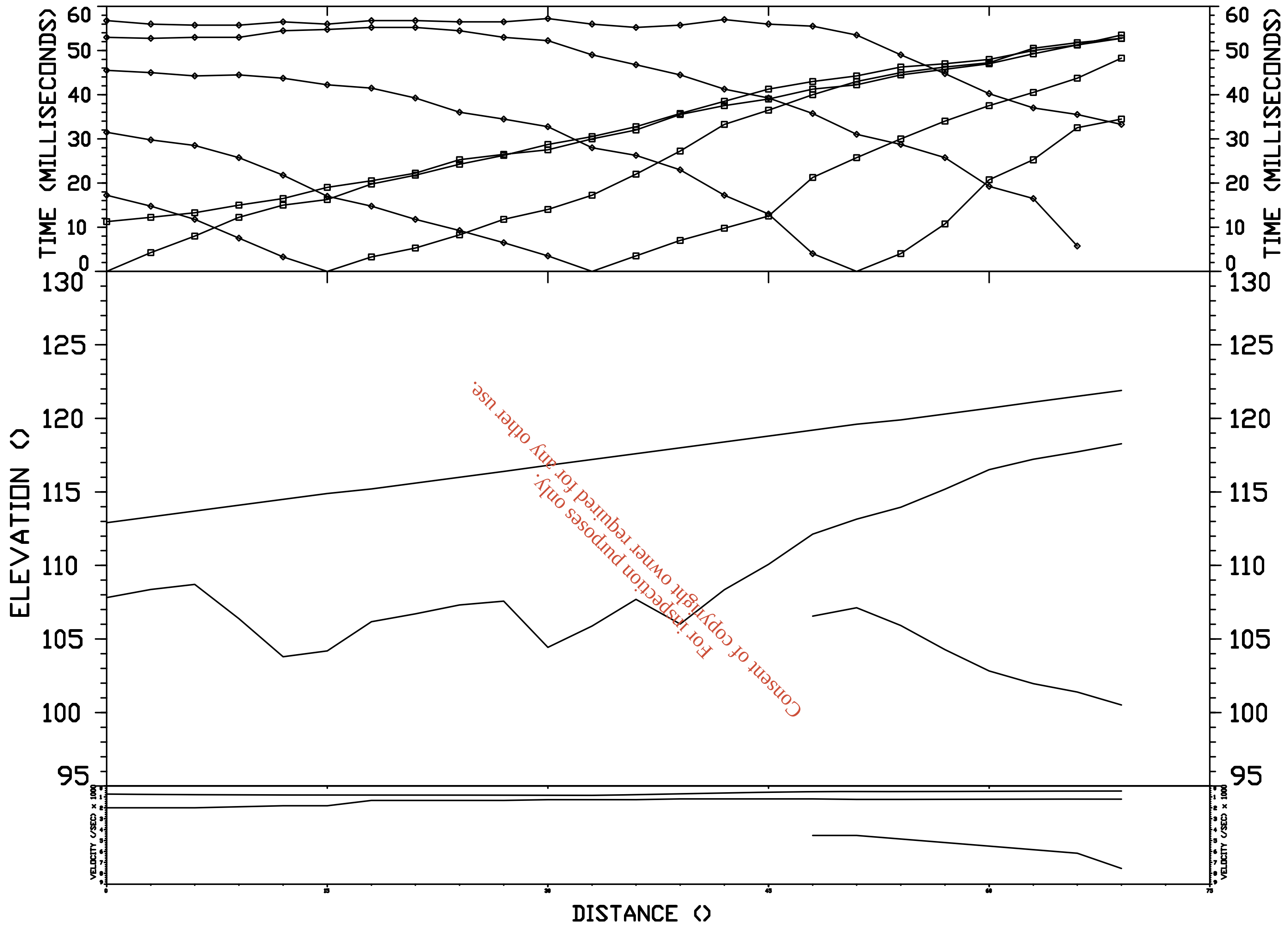

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by: APEX Geoservices Ltd.	
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Equipment: Geode	Spread: S5

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Hollywood
Dublin

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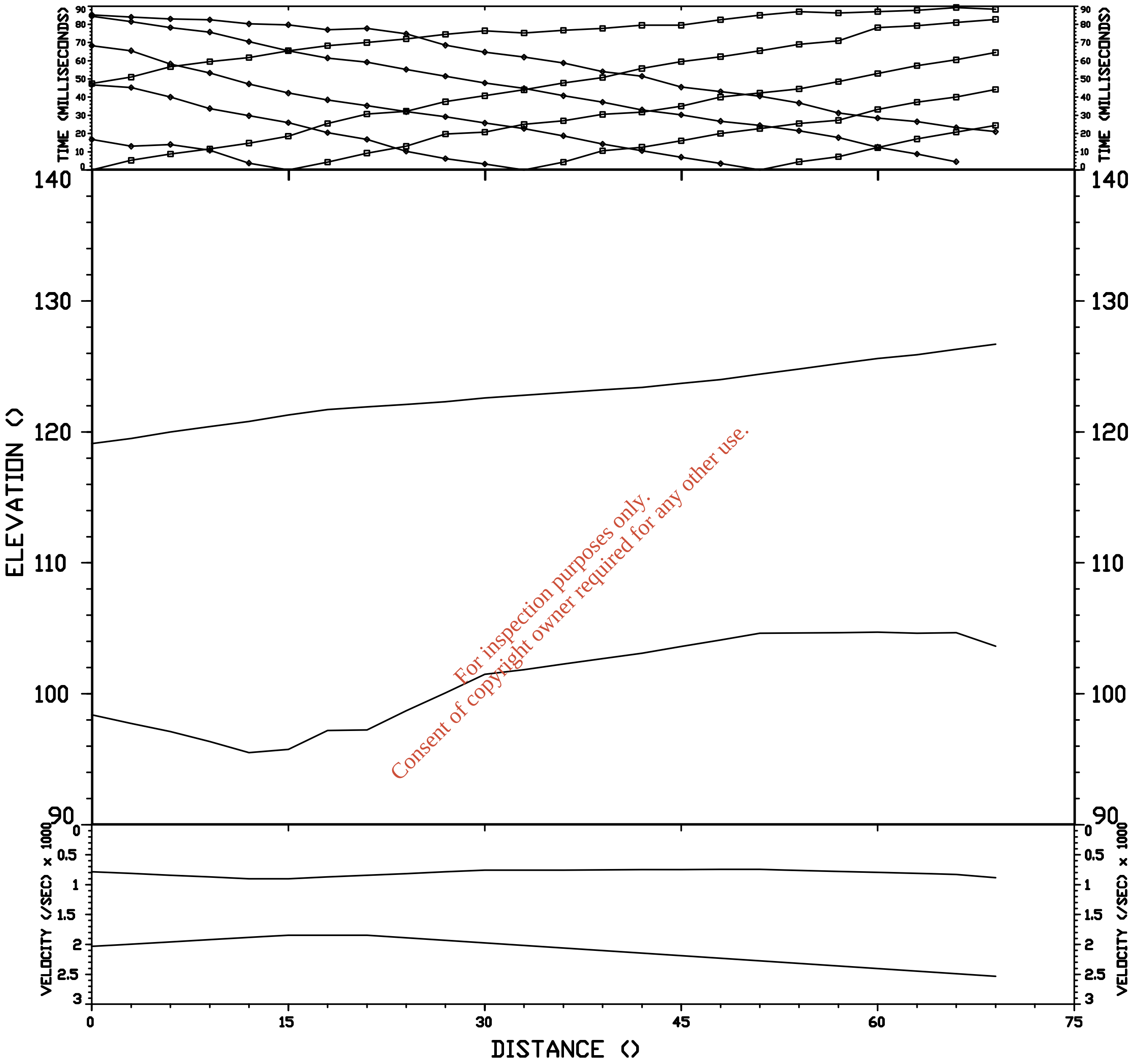

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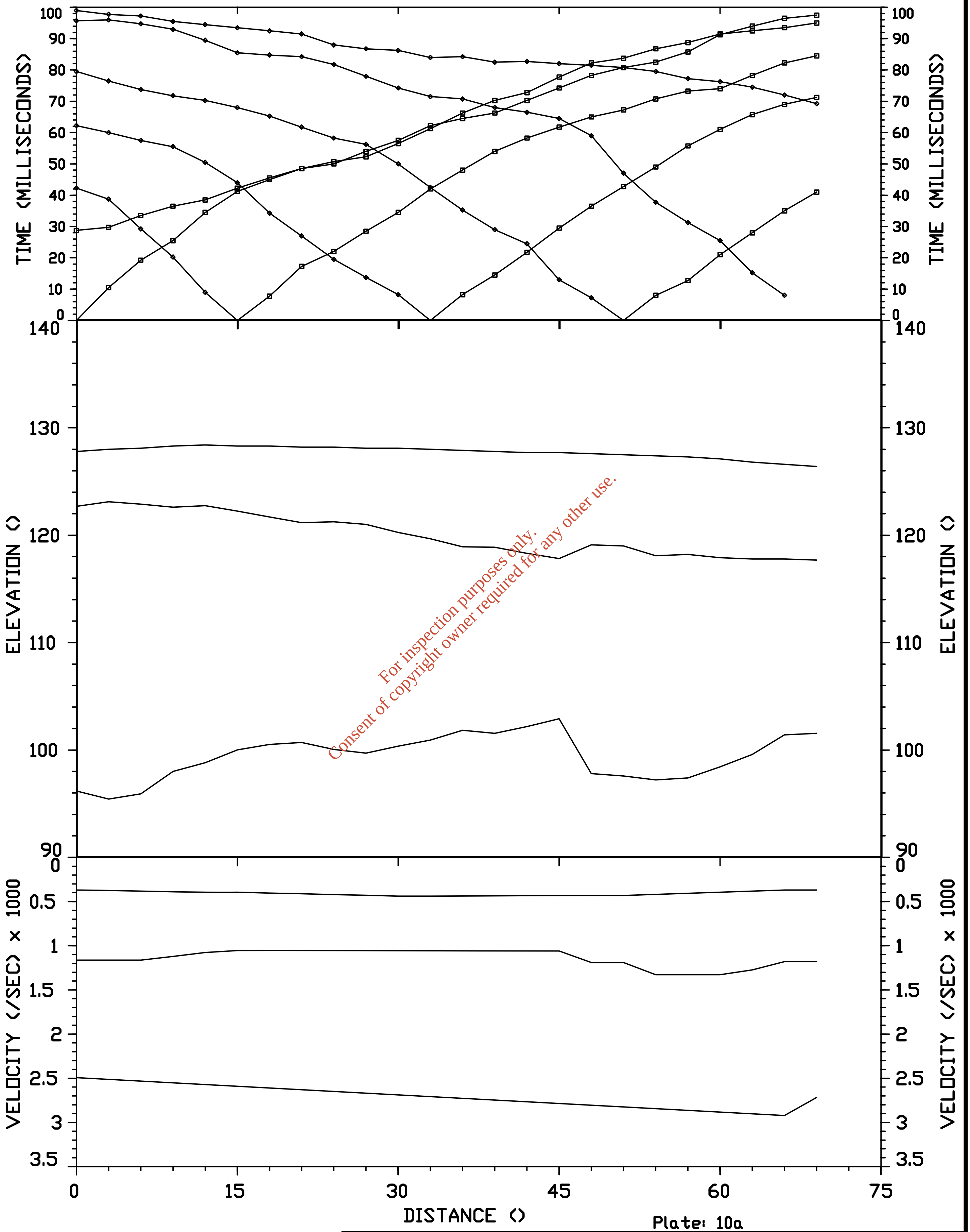

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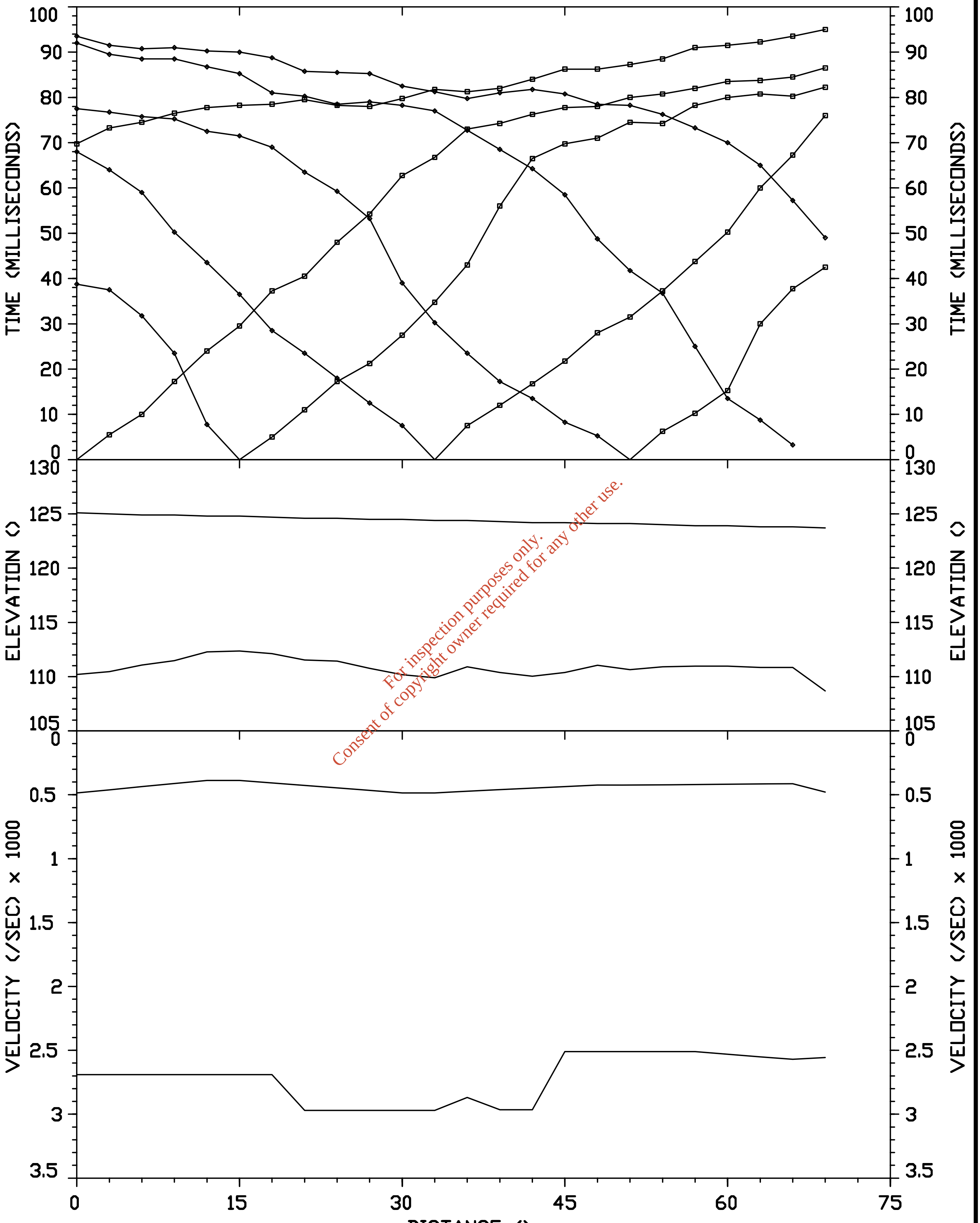

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for: Arup Consulting

by: APEX Geoservices Ltd.

Data Set S8
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Spread: S8

9313

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Dublin

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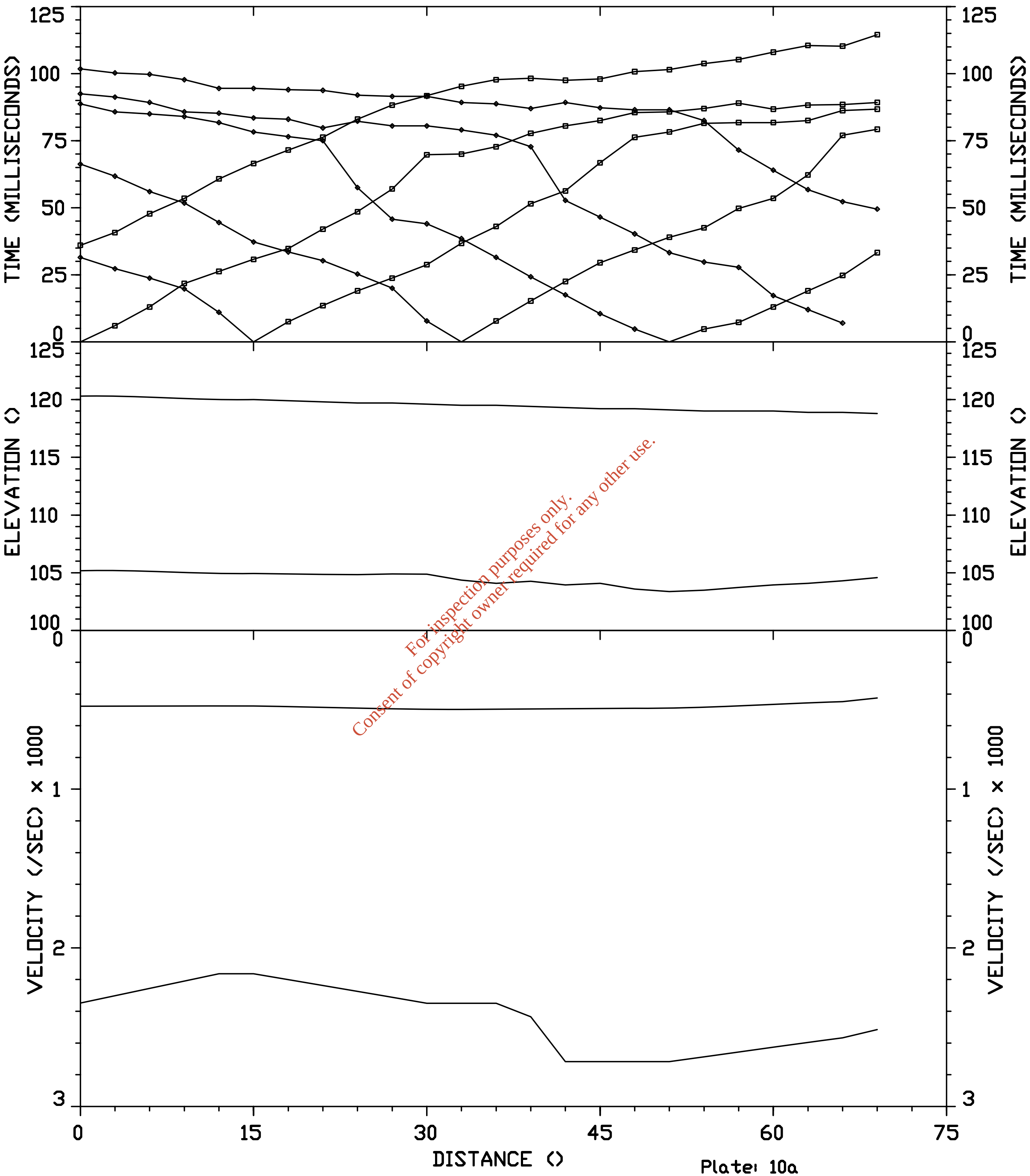

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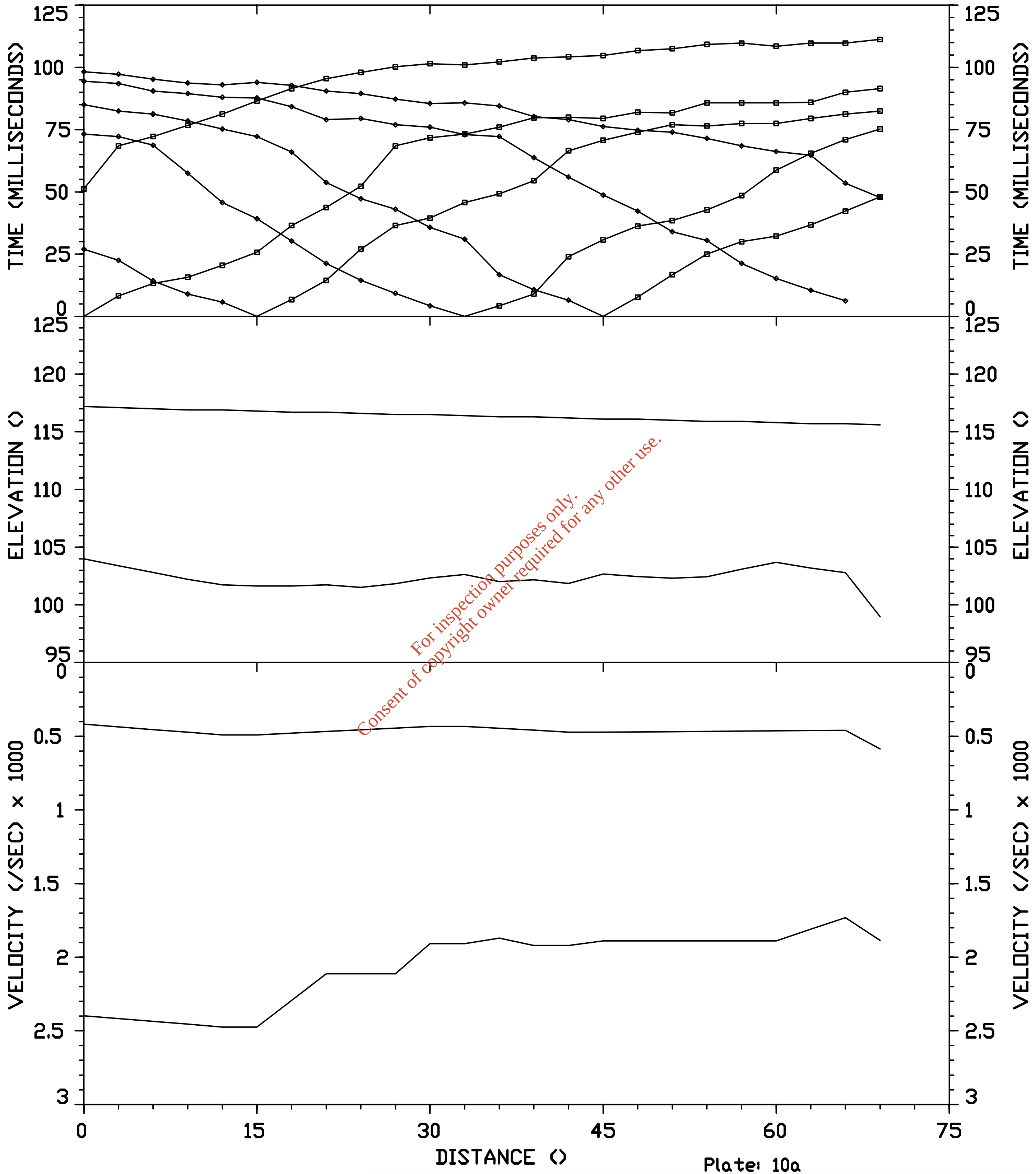

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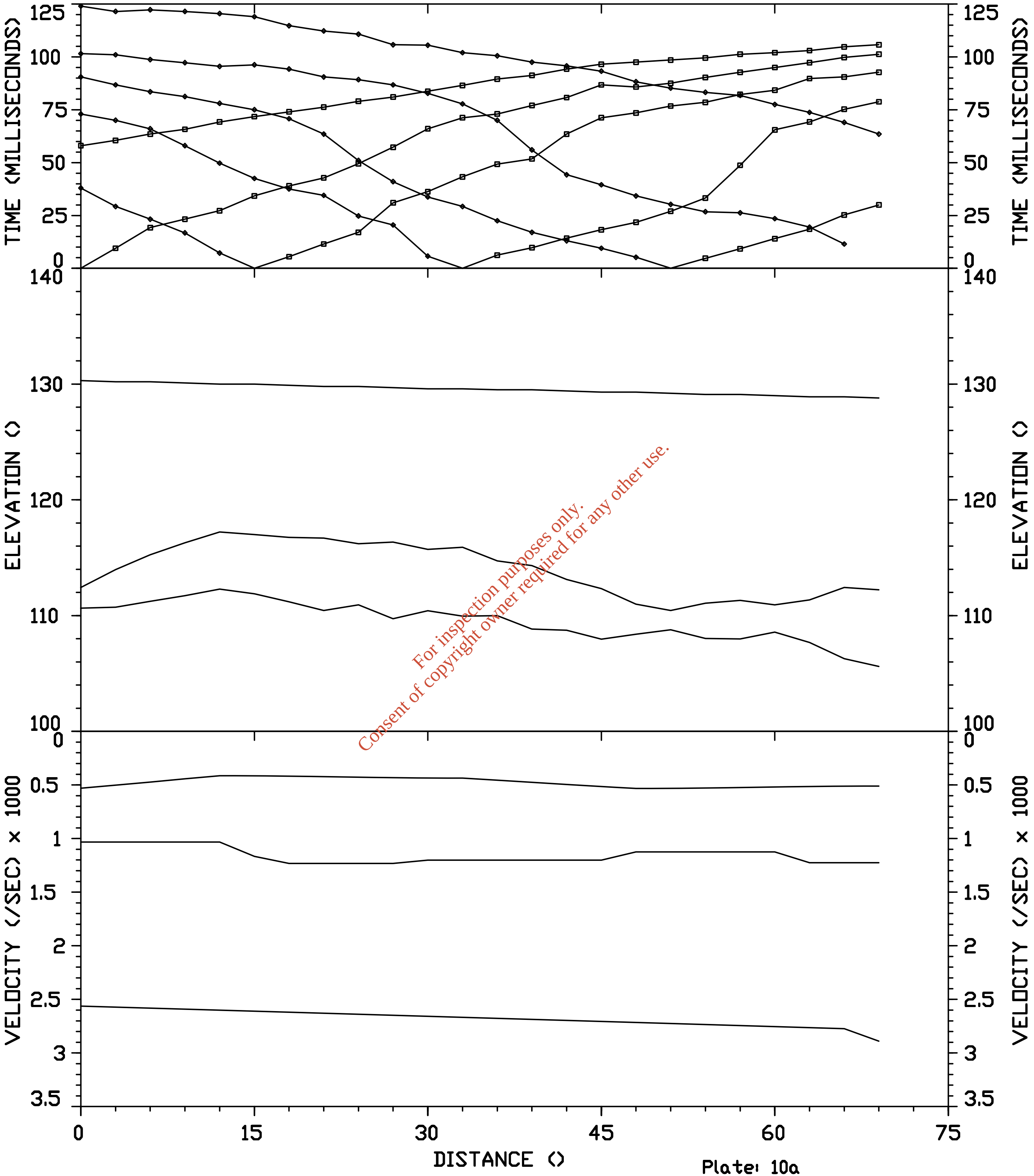

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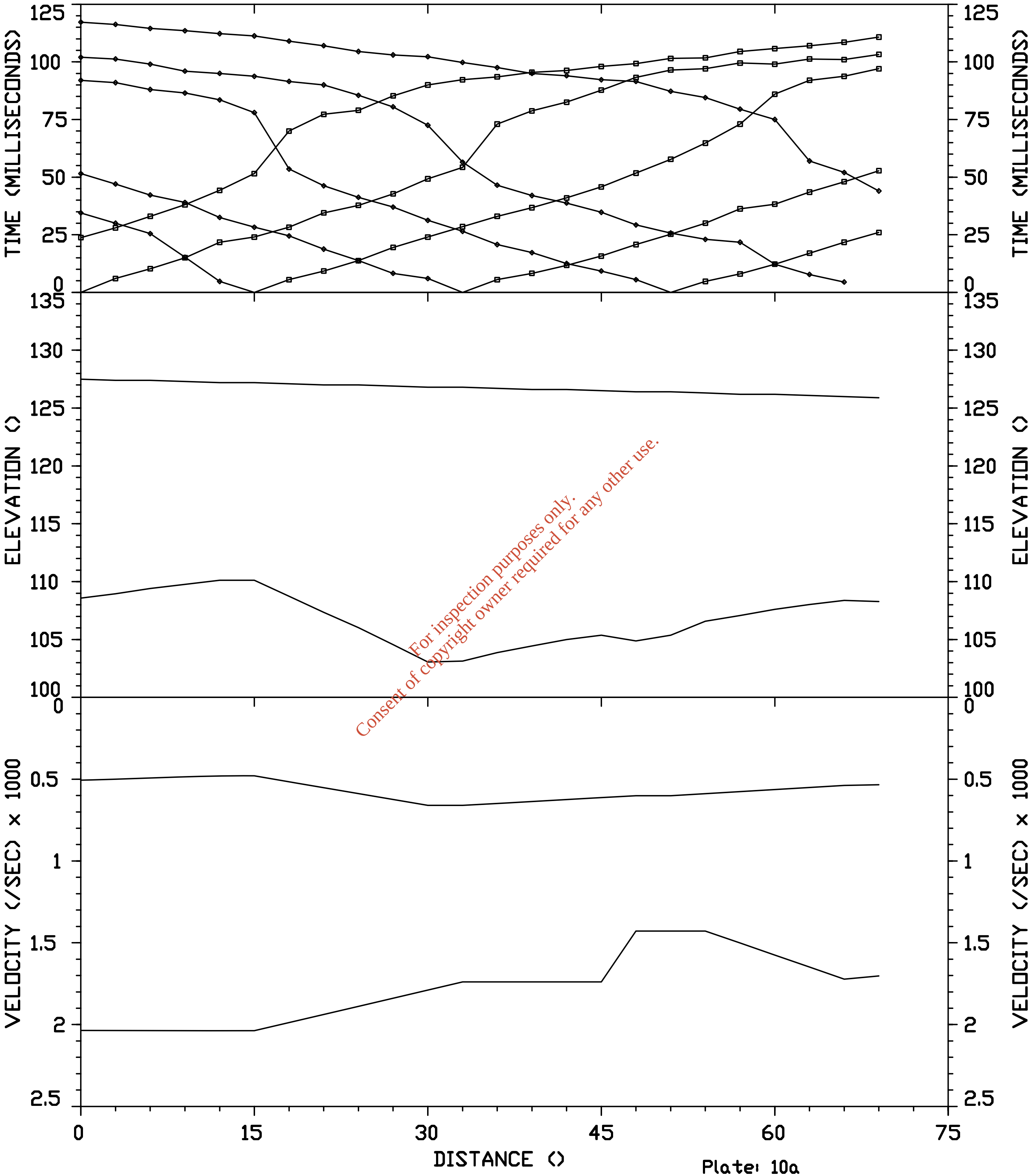

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Spread: S12

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Dublin
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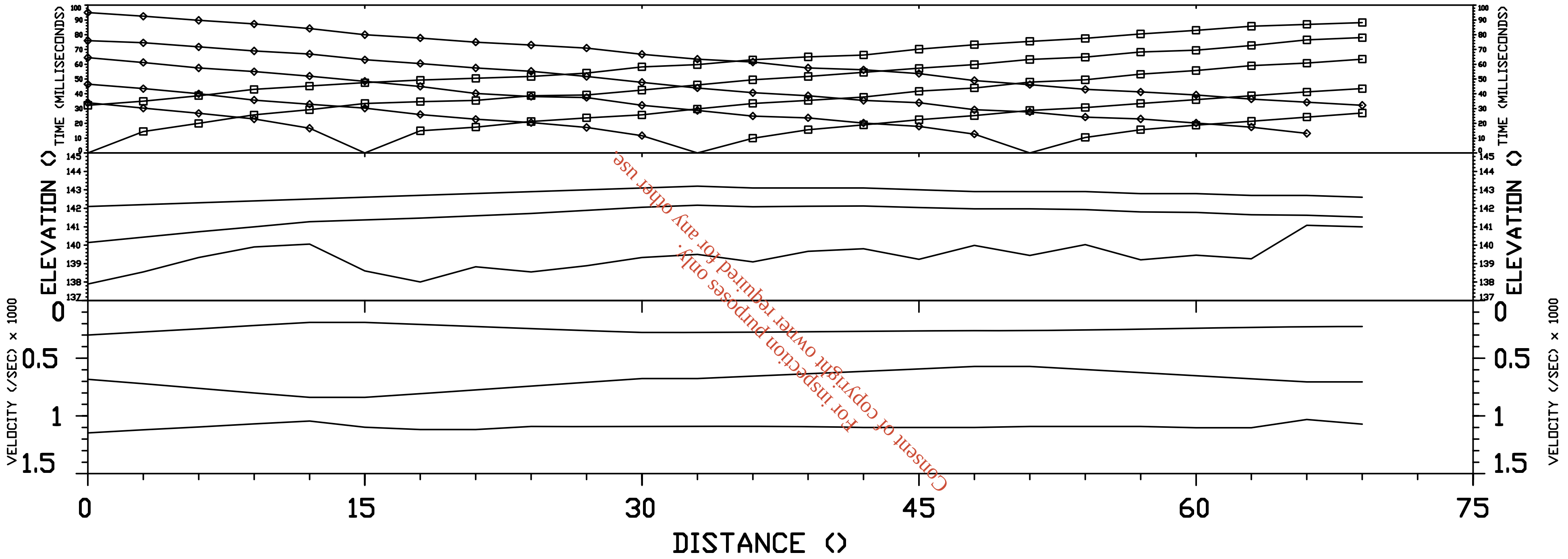

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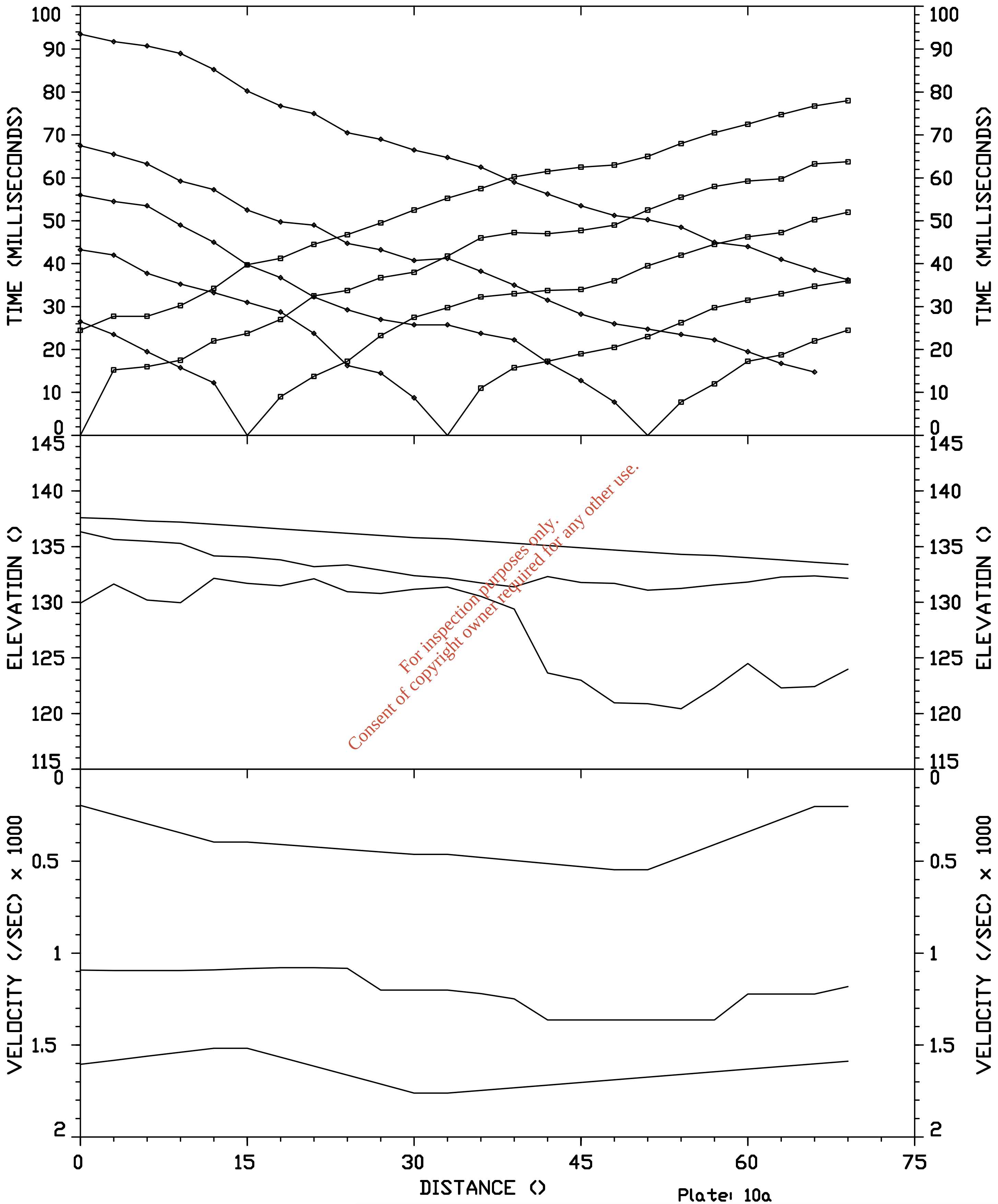

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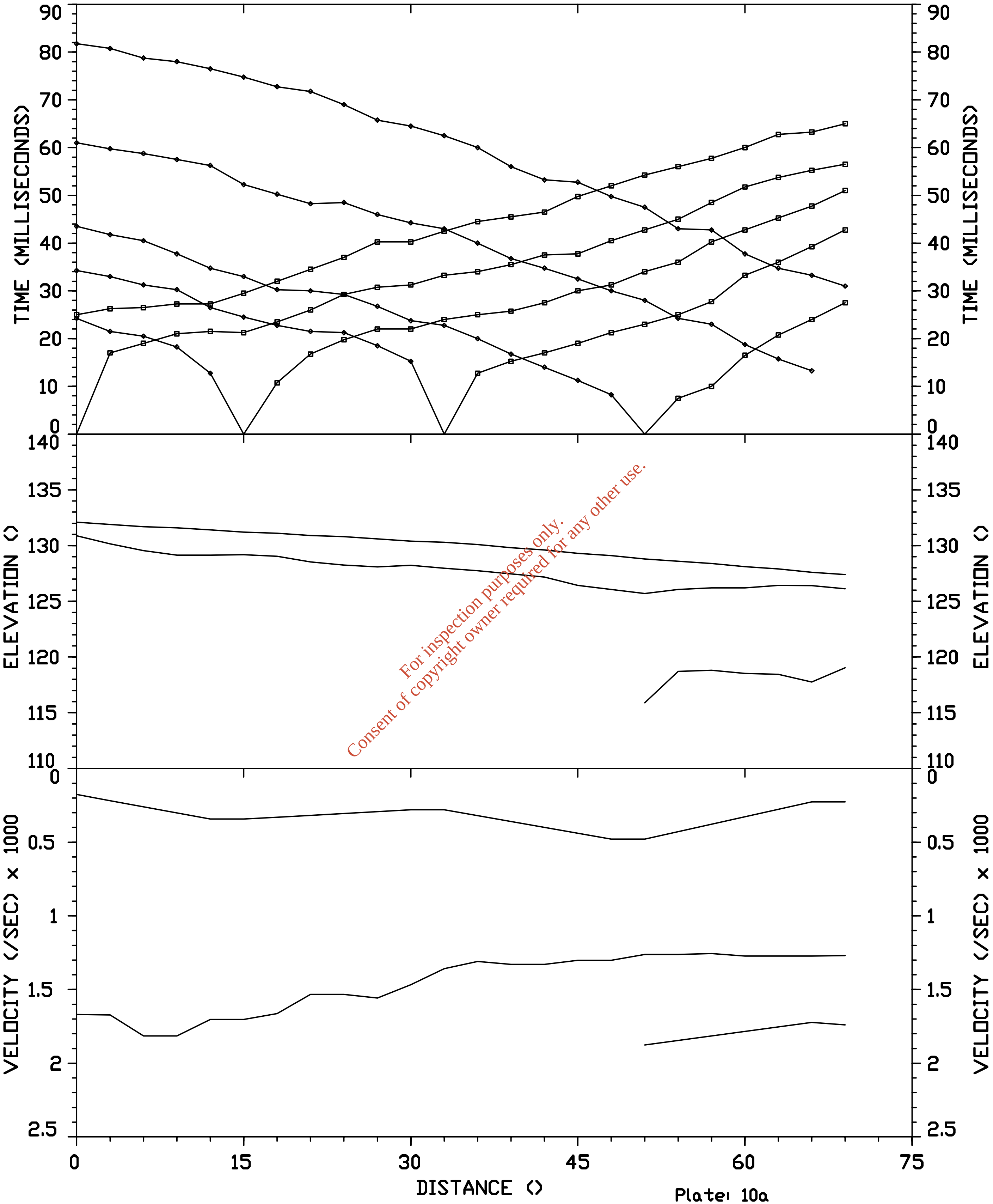

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for: Arup Consulting

by: APEX Geoservices Ltd.

Data Set S15

Date: Feb 2010

Equipment: Geode

Spread: S15

9313

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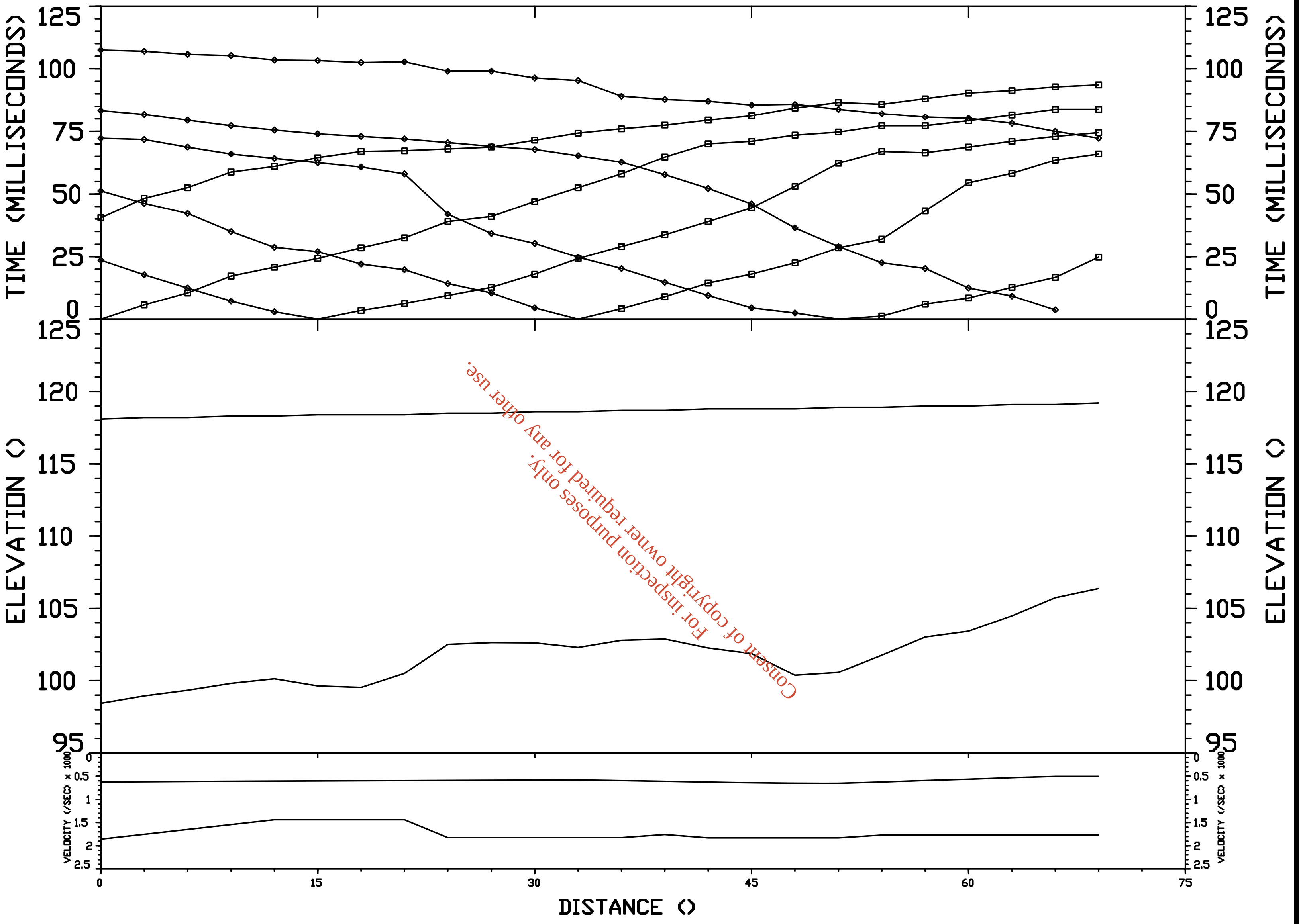

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by: APEX Geoservices Ltd.

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9313

Hollywood
Dublin

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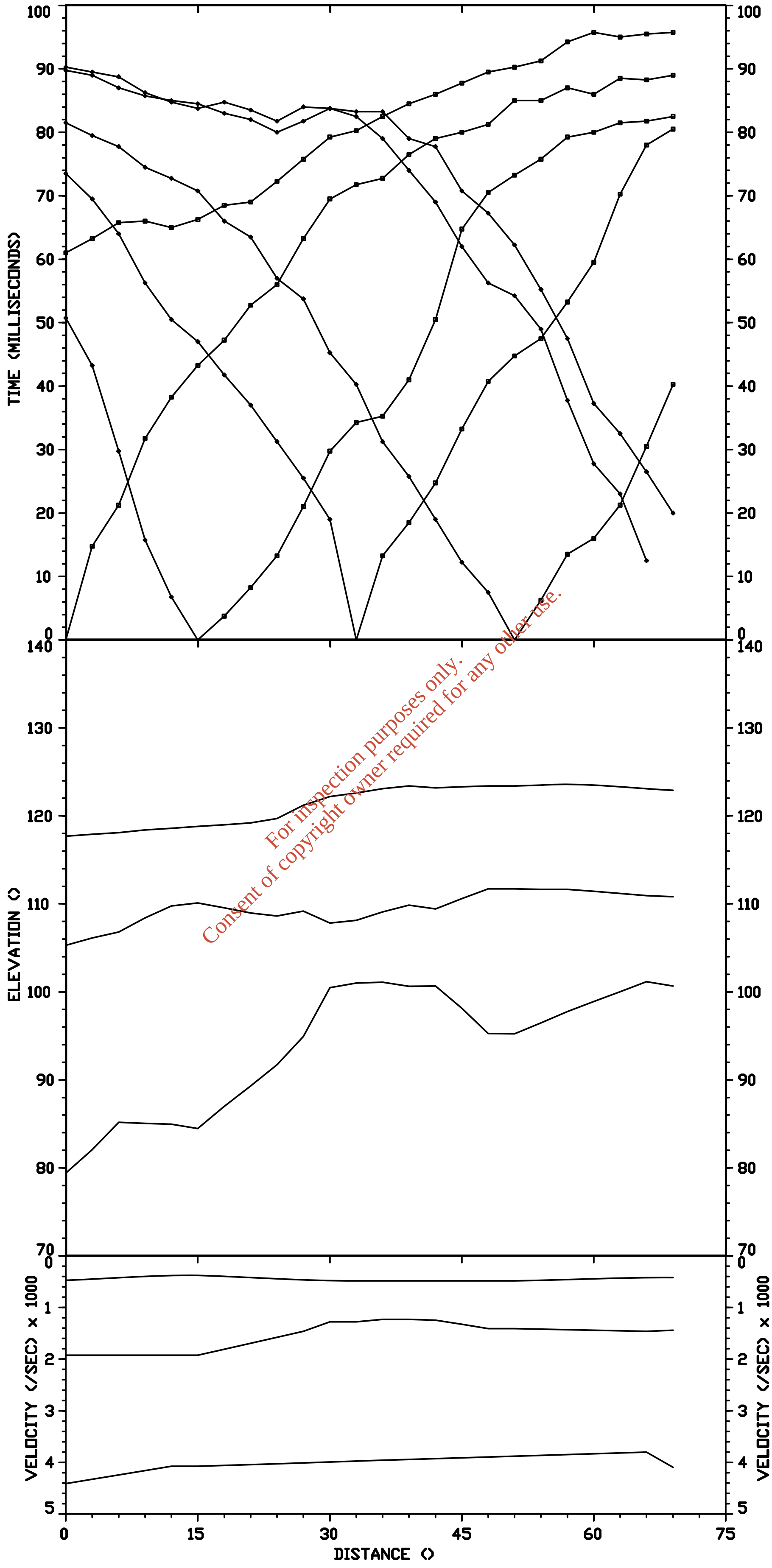

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Equipment: Geode | Spread: S17

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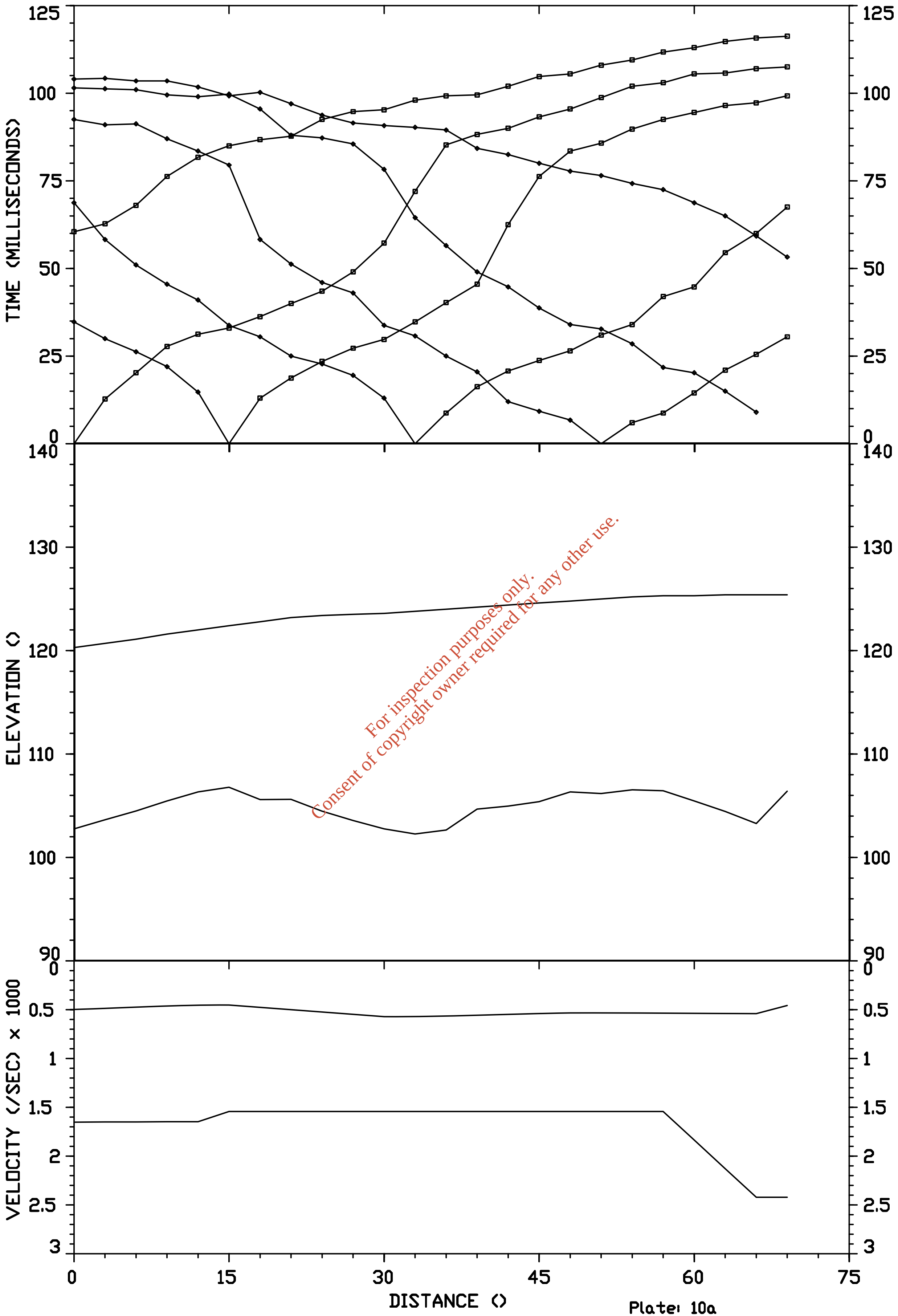

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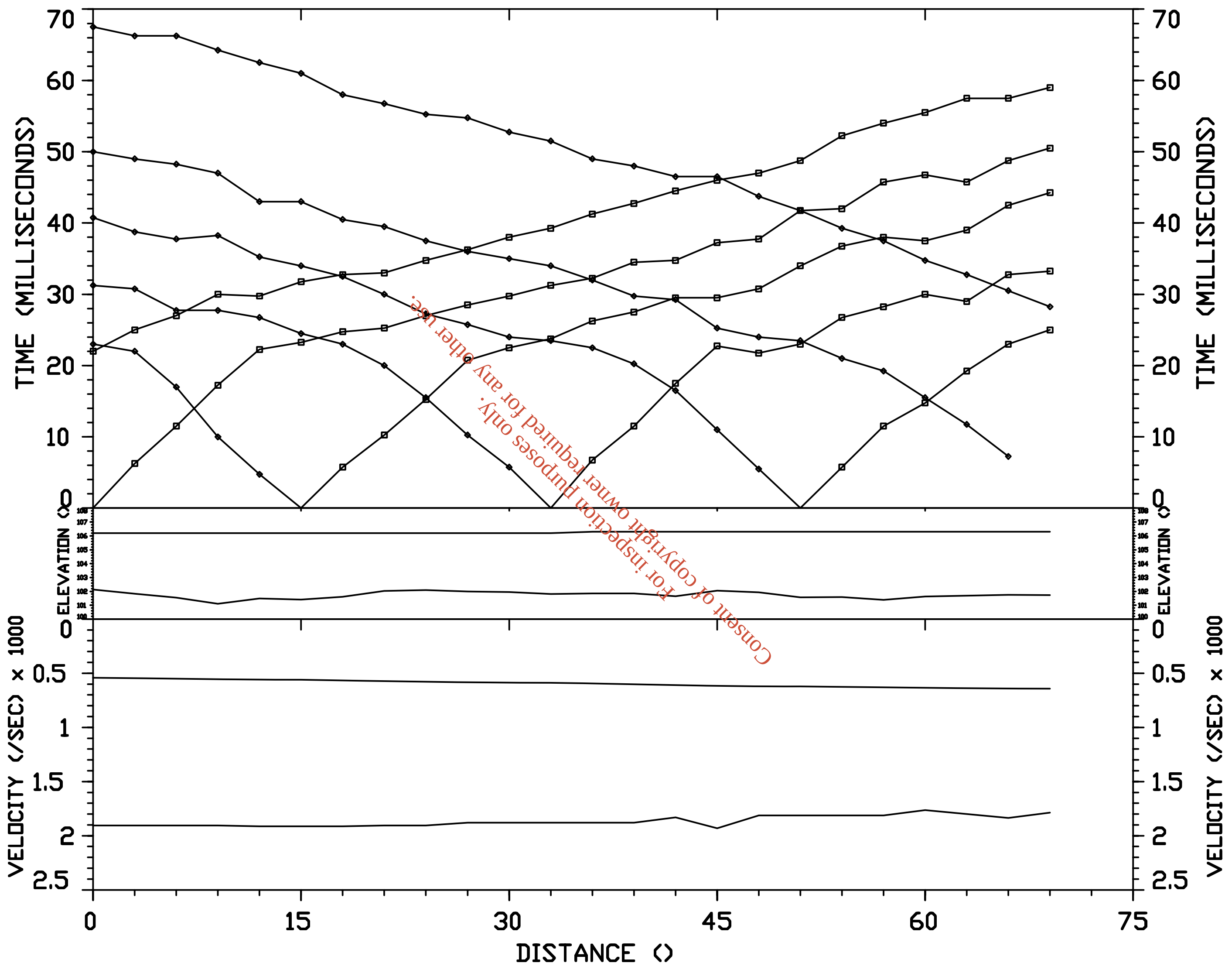

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Equipment: Geode	Spread: S19

9313

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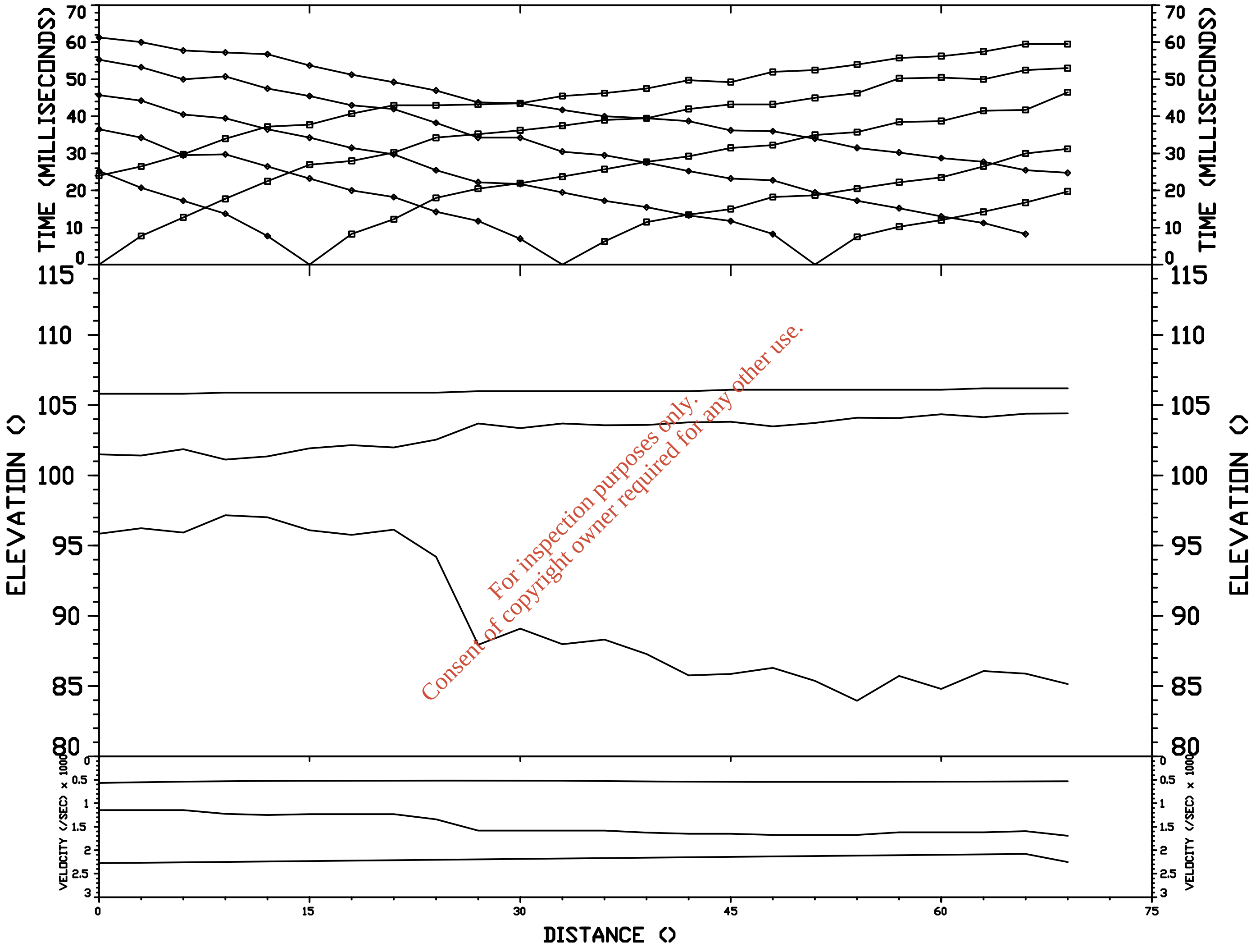
Dublin

Azimuth:



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by: APEX Geoservices Ltd.

Data Set: S20

Date: Feb 2010

Equipment: Geode

Spread: S20

9313

Hollywood
Dublin

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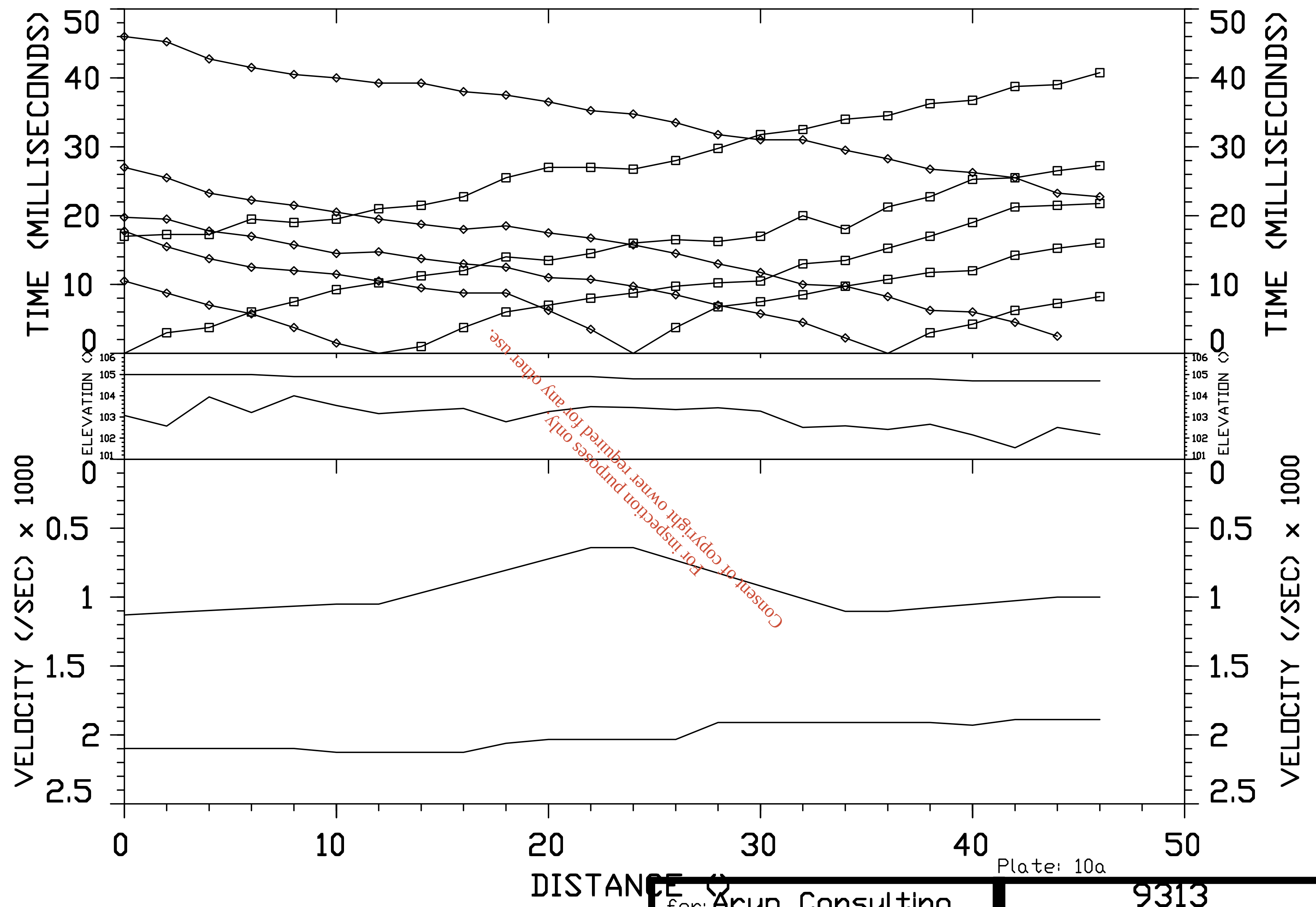

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for: Arup Consulting

by: APEX Geoservices Ltd.

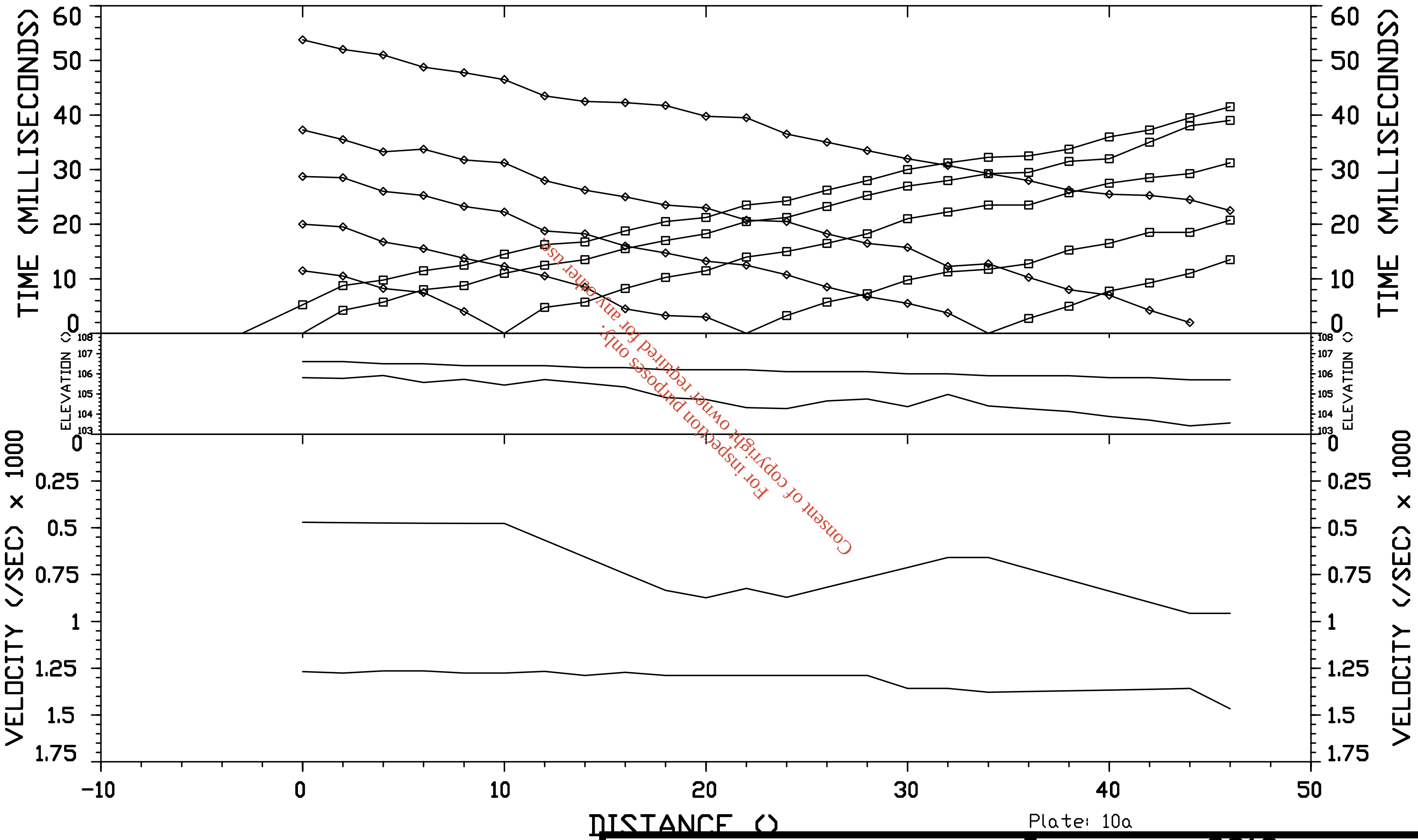
Data SetS21 Date: Feb 2010

Equipment: Geode Spread: S21

9313

Hollywood
Dublin

Azimuth:



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for: Arup Consulting

by: APEX Geoservices Ltd.

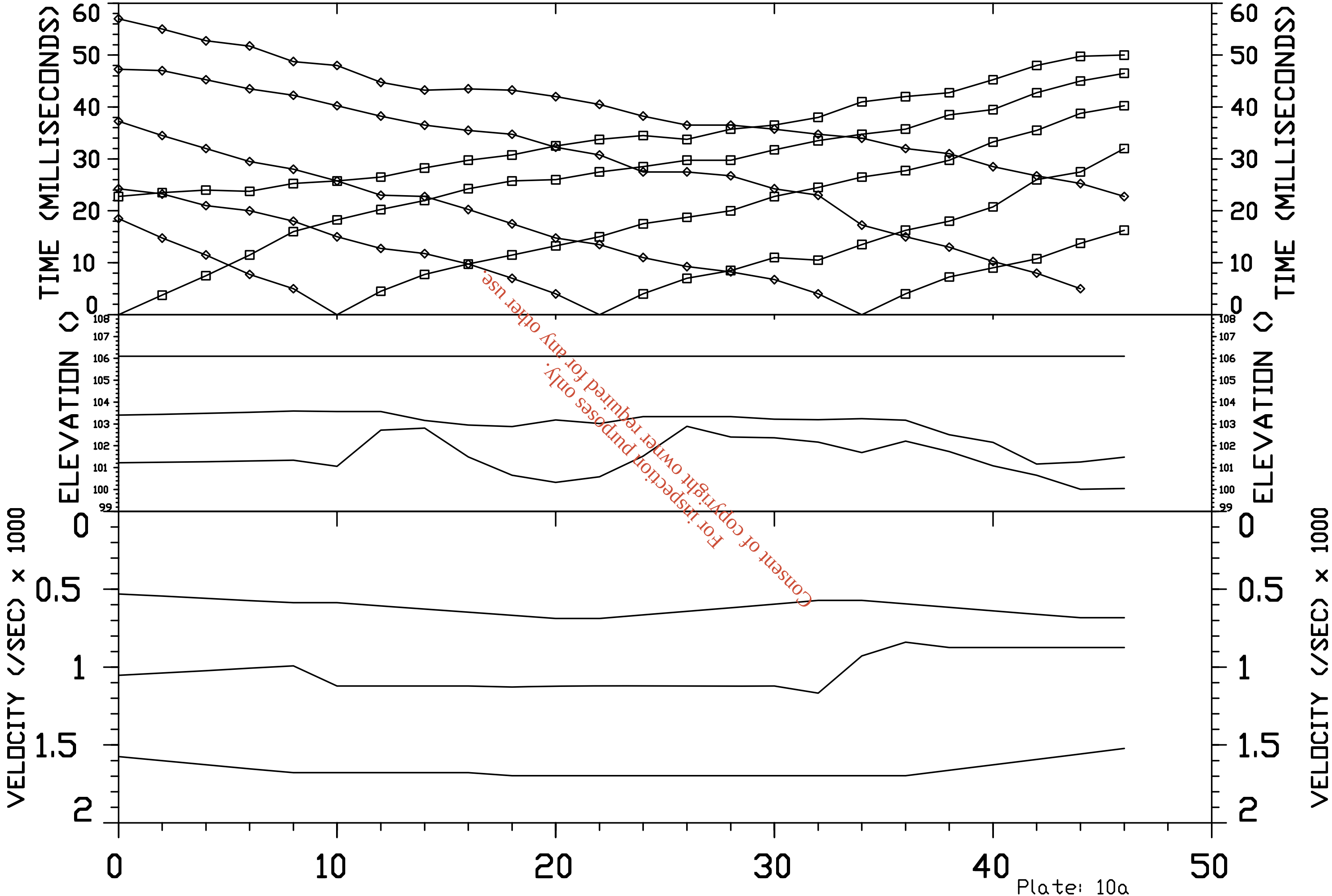
Data Set S22 | Date: Feb 2010

Equipment: Geode | Spread: S22

9313

Hollywood
Dublin

Azimuth:



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for: **Arup Consulting**

by: APEX Geoservices Ltd.

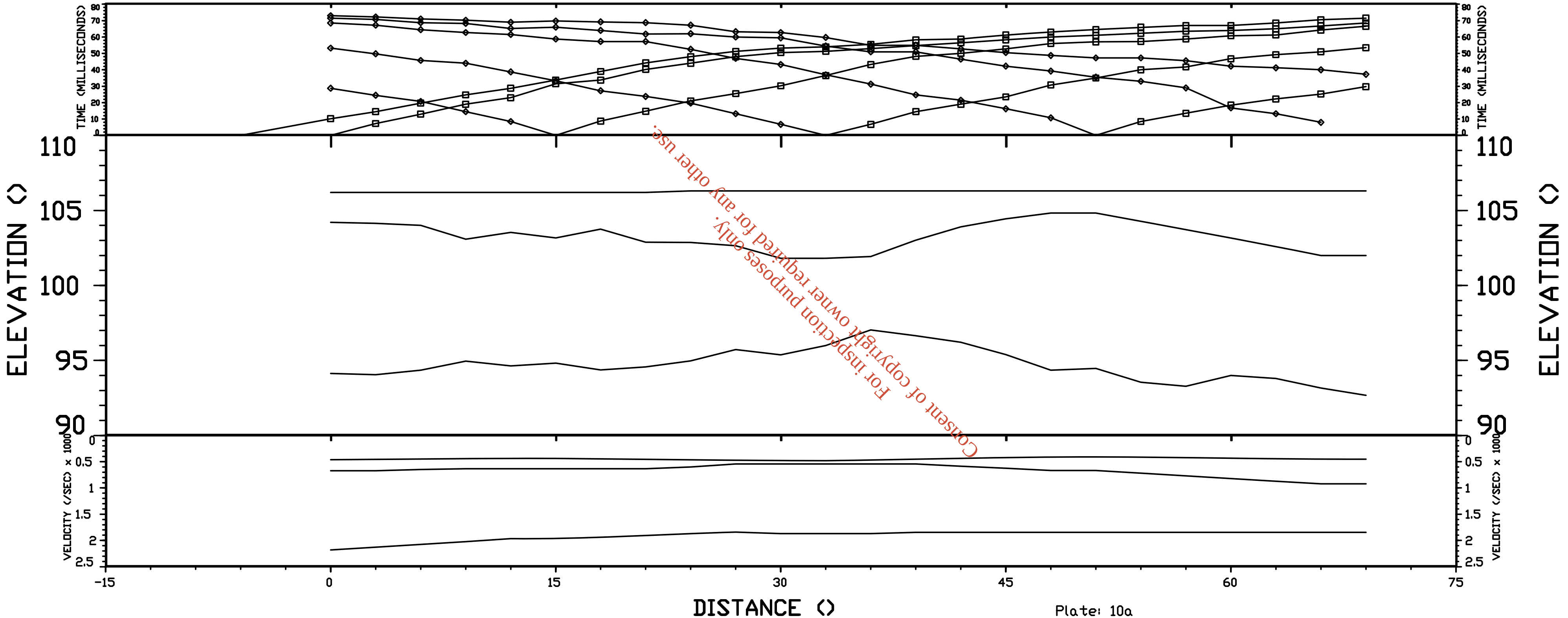
Data Set:S23 Date: Feb 2010

Equipment: Geode **Spread: S23**

9313

Hollywood Dublin

Azimuth:



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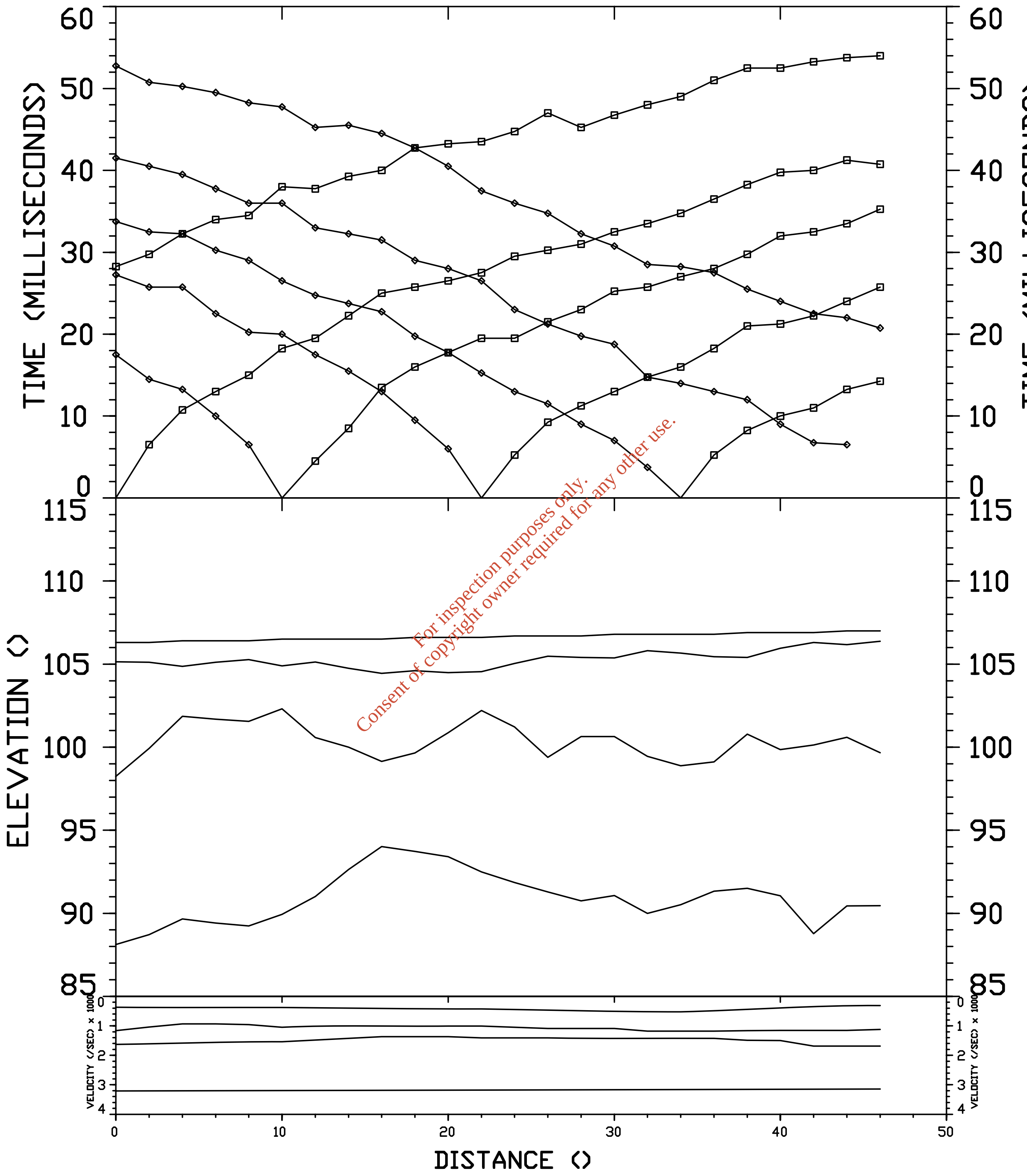

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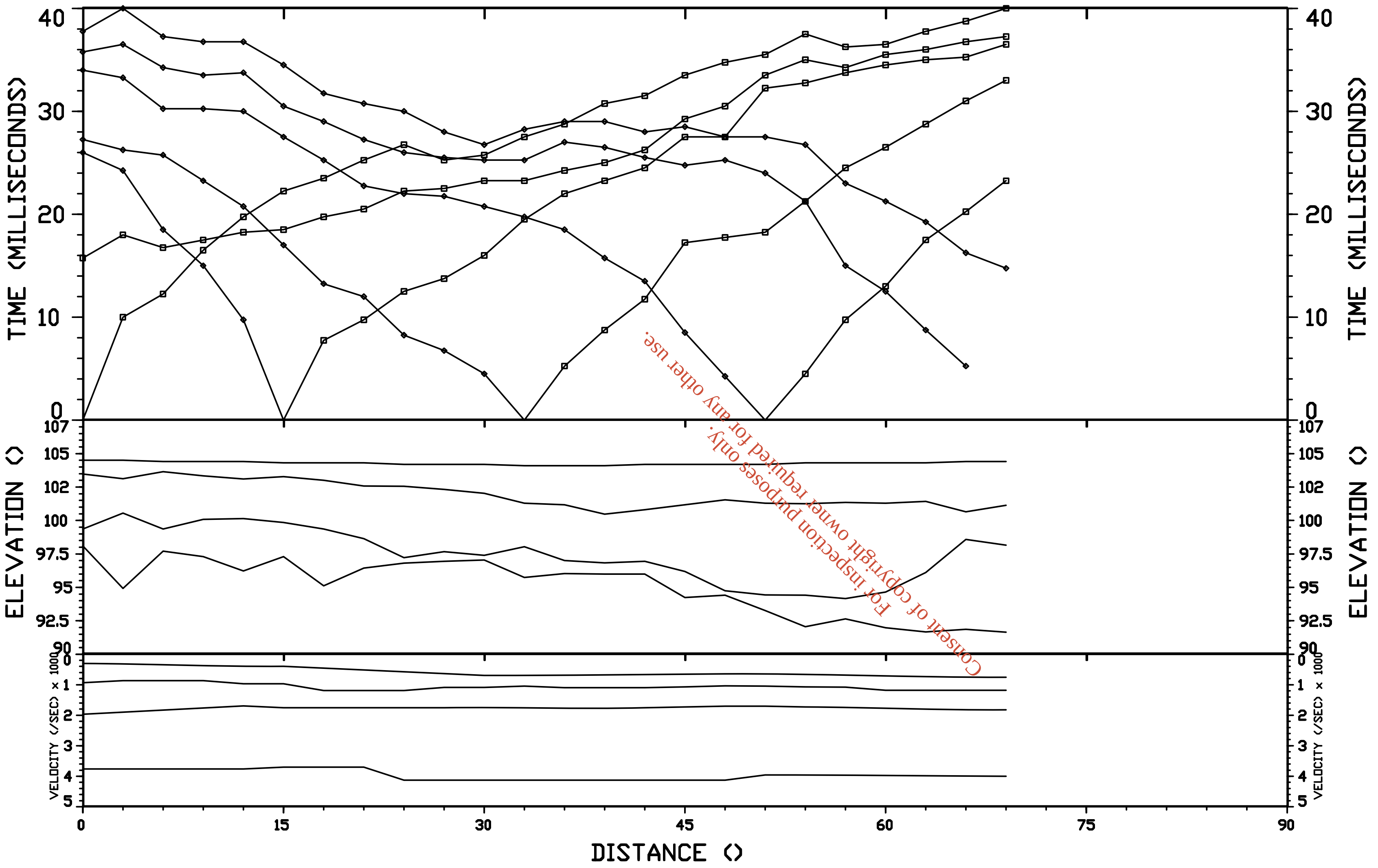

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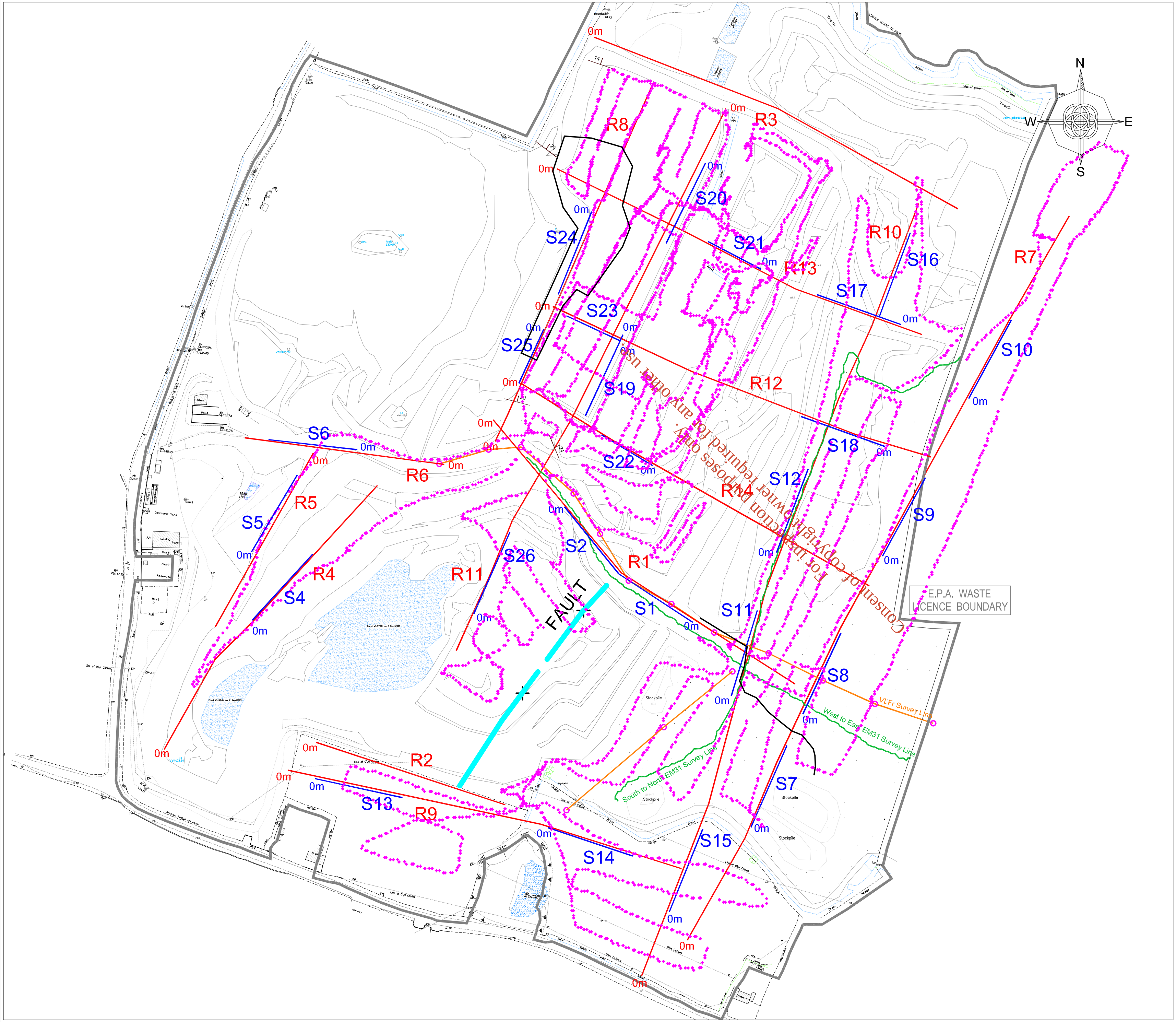
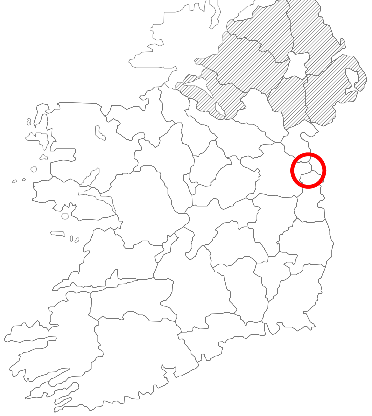
by: APEX Geoservices Ltd.	Hollywood Dublin
Data SetS26 Date: Feb 2010	
Equipment: Geode Spread: S26	Azimuth:



INDEX MAP:



LEGEND:

0m R1	2D Resitivity Profile
0m S1	Seismic Refraction Profile
	EM31 Conductivity Profile (Trial Survey)
+	EM31 Conductivity Survey Location (Main Survey)
	VLF-Resistivity Profile
20	Dip/strike (degrees) of bedding
	Fault mapped from outcrop

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PROJECT:	PHOENIX
DRAWING No.:	9313_01
DATE:	15/02/10
CLIENT:	MEHL.
SCALE:	1:4000 @A4

Version:	Date:	Drawn By:	Checked:
1	15-02-10	SOR	POC

FIGURE 1: Geophysical Location Map; Scale, 1:5000

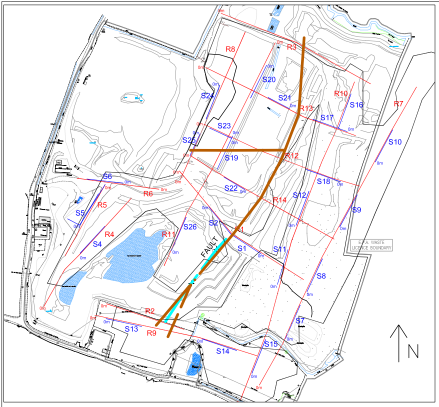
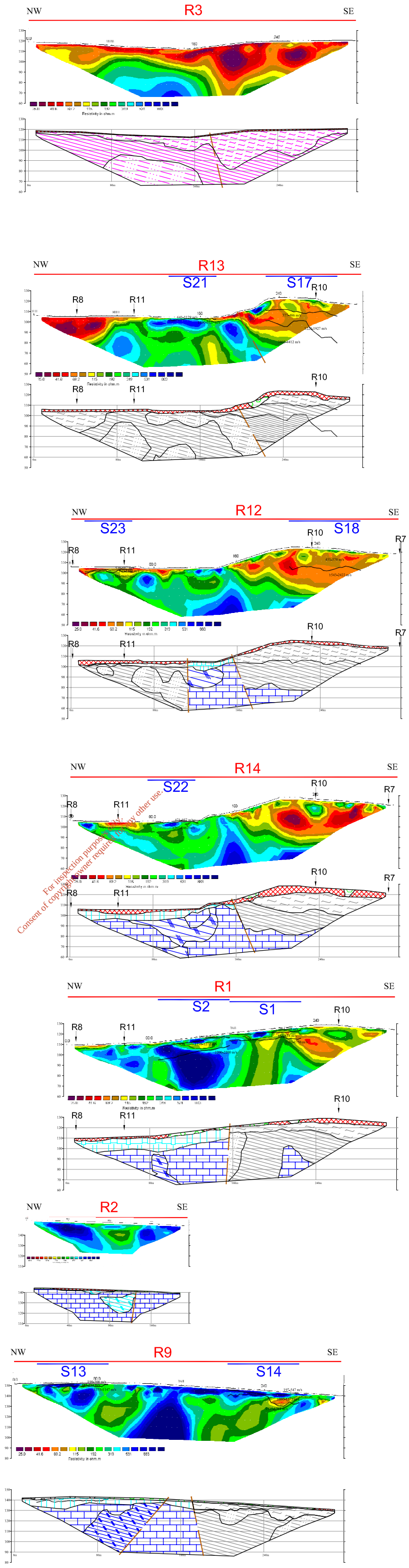


FIGURE 2: Resistivity Profiles R1-R3, R9 & R12-R14 and Seismic Profiles S1-S2, S13-S14, S17-S18 & S21-S23



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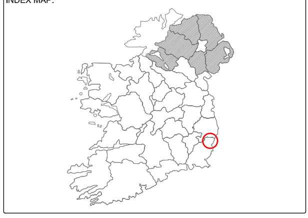

LEGEND:

- Highly to Completely Weathered Limestone (Probable Loughshinny Formation)
- Moderately Weathered - Fresh Limestone (Probable Loughshinny Formation)
- Highly to Completely Weathered Thin Shales (Probable Loughshinny Formation)
- Moderately Weathered -Fresh Thin Shales (Probable Loughshinny Formation)
- Highly to Completely Weathered Shale/Sandstone/Calcareous Mudstone (Probable Donore/Balrickard Formation)
- Moderately to Slightly Weathered Shale/Sandstone/Calcareous Mudstone (Probable Donore/Balrickard Formation)
- Slightly Weathered-Fresh Shale/Sandstone/Calcareous Mudstone (Probable Donore/Balrickard Formation)
- Highly to Completely Weathered Shale (Probable Walshtown Formation)
- Moderately to Slightly Weathered Shale (Probable Walshtown Formation)
- Slightly Weathered-Fresh Sandstone (Probable Walshtown Formation)
- Saturated / Clayey Infill or Cell Cap
- Broken Rock Infill / Gravel

Interpreted Fault Location

R8 Intersecting Resistivity Profile

TITLE:
GEOPHYSICAL SURVEY

PROJECT:
PHOENIX

CLIENT:
MEHL.

DRAWING:
RESISTIVITY & SEISMIC PROFILES

DRAWING NUMBER:
9313_02

MAIN SCALE:
1:2500

DATE:
15 FEBRUARY 2010

DRAWN: SOR
CHECKED: POC

REVISION:	DATE:	DRAWN:	CHECKED:

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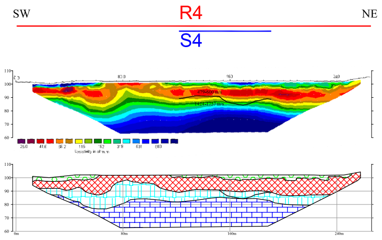
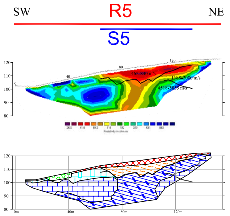
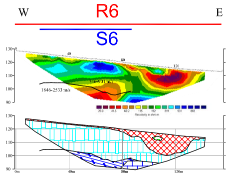
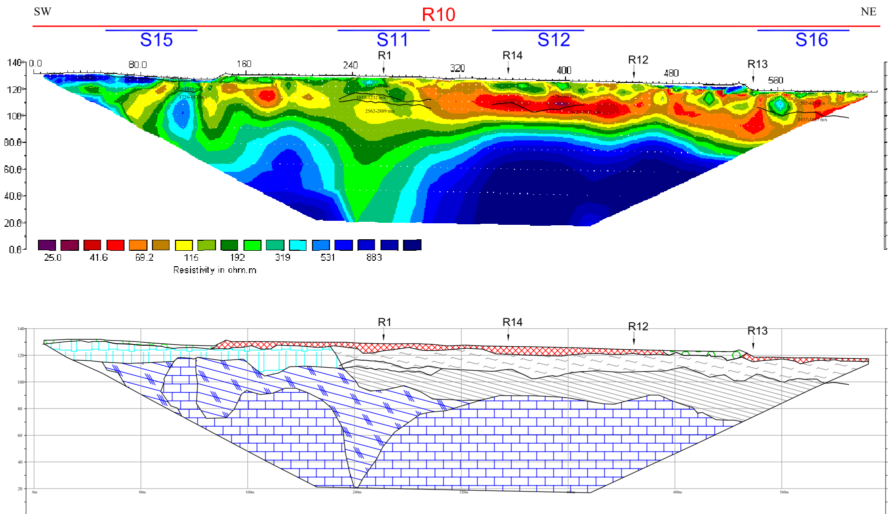
FIGURE 1: Geophysical Location Map; Scale, 1:5000

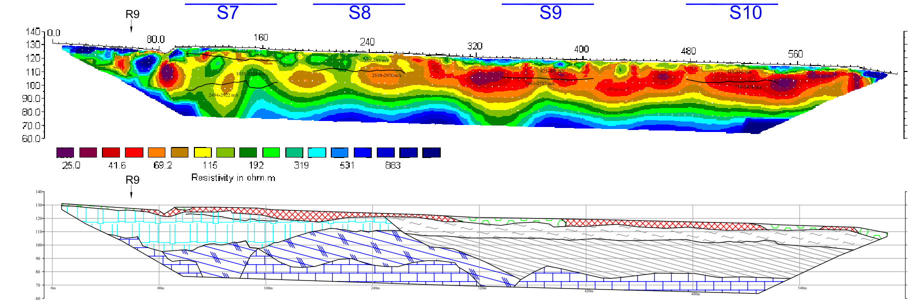
FIGURE 2: Resistivity Profiles R4-R6, R7-R8 & R10-R11 and Seismic Profiles S4-S6, S7-S12, S15-S16, S19-S20 & S24-S26

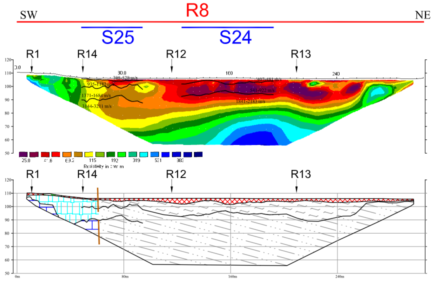


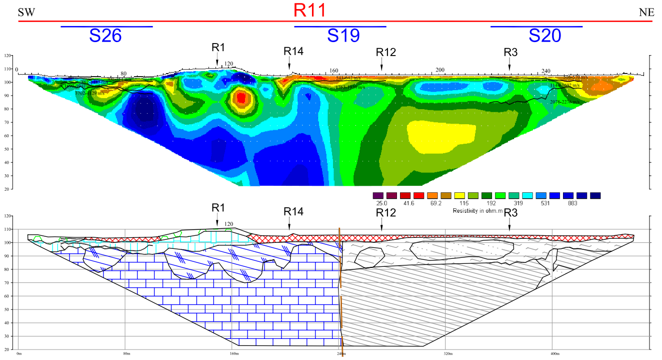












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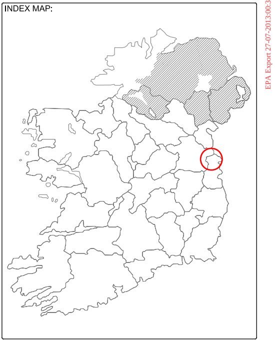

LEGEND:

▦	Highly to Completely Weathered Limestone/Thin Shales (Probable Loughshinny Formation)
▦	Slightly to Moderately Weathered Limestone/Thin Shales (Probable Loughshinny Formation)
▨	Highly to Completely Weathered Thin Shales (Probable Loughshinny Formation)
▨	Slightly to Moderately Weathered Thin Shales (Probable Loughshinny Formation)
▨	Highly to Completely Weathered Shale/Sandstone /Calcareous Mudstone (Probable Donore/Balrickard Formation)
▨	Moderately to Slightly Weathered Shale/Sandstone /Calcareous Mudstone (Probable Donore/Balrickard Formation)
▨	Slightly Weathered-Fresh Shale/Sandstone/Calcareous Mudstone (Probable Donore/Balrickard Formation)
▨	Highly to Completely Weathered Shale (Probable Walshtown Formation)
▨	Moderately to Slightly Weathered Shale (Probable Walshtown Formation)
▨	Slightly Weathered-Fresh Sandstone (Probable Walshtown Formation)
▩	Saturated / Clayey Infill or Cell Cap
▩	Broken Rock Infill / Gravel
/	Interpreted Fault Location
R8 ↓	Intersecting Resistivity Profile

NOTES:

TITLE: GEOPHYSICAL SURVEY

PROJECT: PHOENIX

CLIENT: MEHL.

DRAWING: RESISTIVITY & SEISMIC PROFILES

DRAWING NUMBER: 9313_03

MAIN SCALE: 1:2000

DATE: 15 FEBRUARY 2009

DRAWN: SOR

CHECKED: POC

REVISION:	DATE:	DRAWN:	CHECKED:

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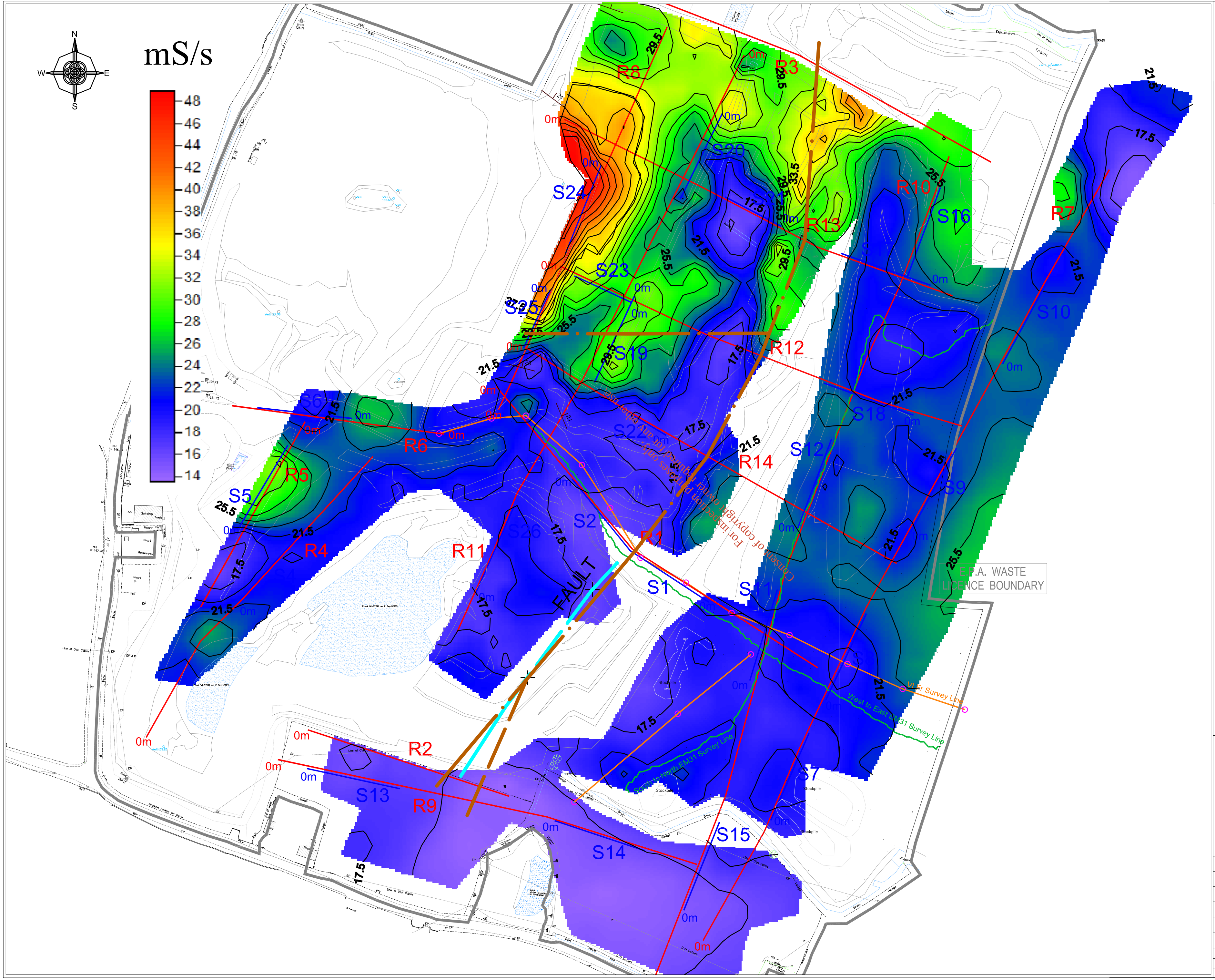

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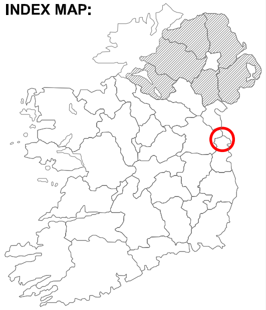

LEGEND:

21.5 Conductivity (mS/m)

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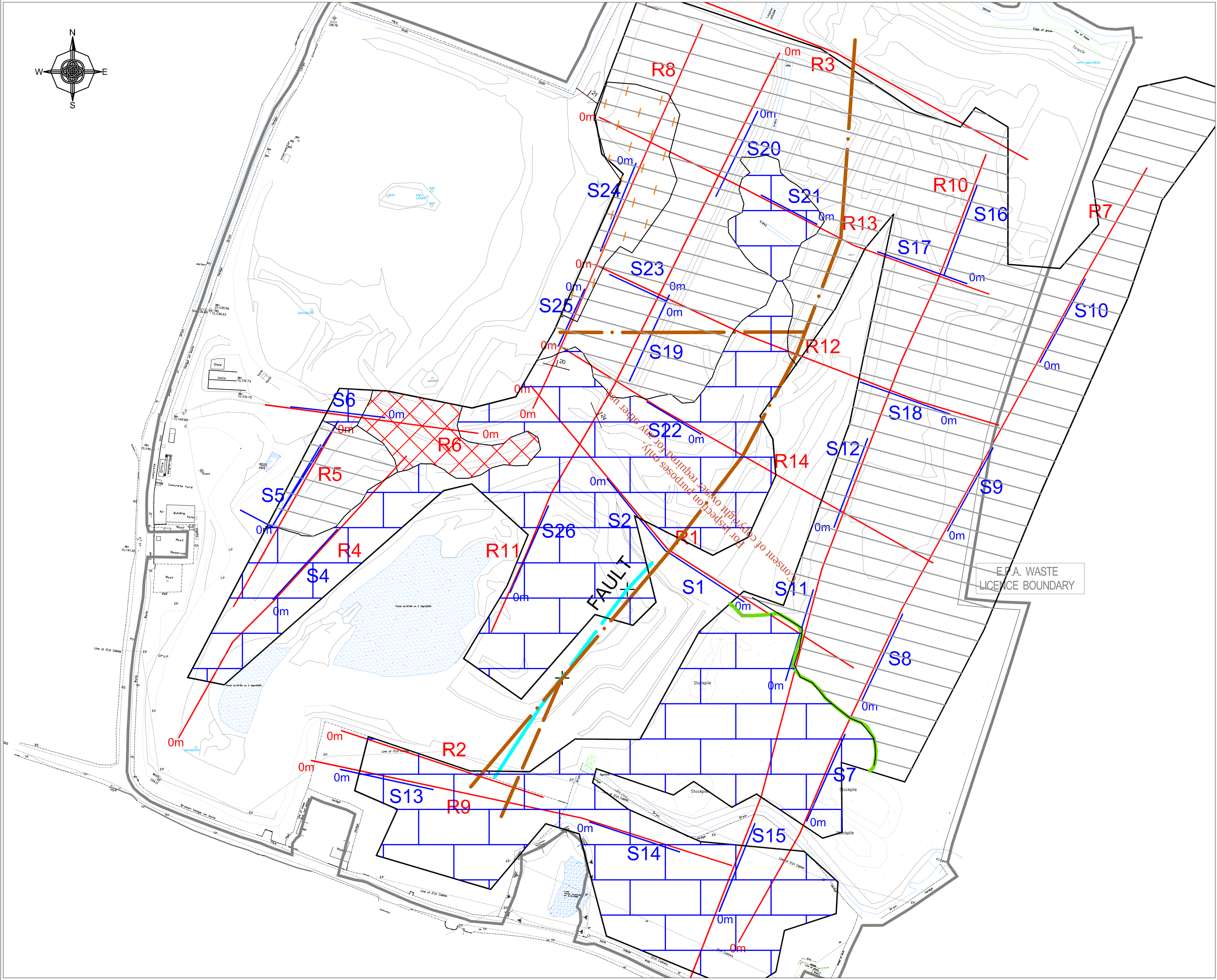
PROJECT:	Phoenix
DRAWING No.:	9313_04 EM Conductivity (Main Survey)
DATE:	15-02-2010
CLIENT:	MEHL.
SCALE:	1:2500 @ A3

Version:	Date:	Drawn By:	Checked:
1	15-02-2010	SOR	POC



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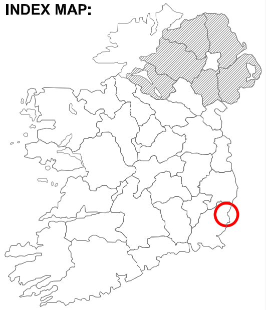

LEGEND:

EM31 Interpretation from 0 - 6m bgl

▦	Mainly Limestone / Sandstone bedrock
▨	Mainly Shale / Calcareous Mudstone Bedrock
▨	Mainly Shale / Calcareous Mudstone Bedrock with influence of Bund
☒	Mainly clayey Infill material
▬ ▬	Interpreted Fault Location
▬	Interpreted LoughshinnyFormation-Donore/Balrickard Formation contact

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PROJECT: Phoenix
DRAWING No.: 9315_05 Summary
DATE: 16-02-2010
CLIENT: MEHL.
SCALE: 1:2500 @ A3

Version:	Date:	Drawn By:	Checked:
1	16-02-2010	SOR	POC

APPENDIX III REPORT ON THE TRIAL GEOPHYSICAL SURVEY FOR PROJECT PHOENIX

AGL09313a_02

REPORT
ON THE
TRIAL GEOPHYSICAL SURVEY
FOR PROJECT PHOENIX,
AT
HOLLYWOOD LANDFILL,
NAUL, CO. DUBLIN
FOR
MEHL.

January 2010

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

PROJECT NUMBER	AGL09313A		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
EURGEOL PETER OCONNOR P.GEO., M.SC. (GEOPHYSICS)	EURGEOL YVONNE O'CONNELL P.GEO., M.SC. (GEOPHYSICS)	V.2	16TH FEBRUARY 2010

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Drawing 9313a_02	2D Resistivity & Seismic Profiles

1. SUMMARY

- An integrated waste management facility is proposed to the Murphy Environmental Hollywood Landfill in Naul, Co. Dublin where the existing landfill is located in a disused rock quarry. A recent geological survey indicated a stratigraphic contact running E-W through the site. There is also a major NNE striking fault which passes through the east-centre of the quarry.

- Apex Geoservices Ltd. was requested by ARUP Consulting Engineers, on behalf of MEHL. to carry out a trial geophysical survey to demonstrate the effectiveness of a number of geophysical techniques in mapping the location of the geological contact and the fault in the area adjacent to the existing landfill.

- Electromagnetic Ground Conductivity (EM31) mapping surveying, VLF-Resistivity, 2D Resistivity profiling and Seismic Refraction profiling were carried out at locations selected to intersect the NNE-trending fault.

- The relatively low resistivities of the rocks present in the survey area and the complex nature of the geology and weathering variations make the VLF-R method unsuitable for mapping lateral changes in lithology and structure. Further use is not recommended.

- The EM31 readings have outlined lateral changes that correspond with known geological boundaries and with more detailed 2D Resistivity profiles. The method will give useful information on changes in the near surface geology quickly and at low cost, and further use is recommended. Its effectiveness will be limited in areas of thicker overburden but rock is relatively shallow throughout this area.

- 2D Resistivity profiles R1 and R3 have a depth range of 0-50m bgl and run across the strike of the main NNE-trending fault. They clearly show the change from higher resistivity older, more competent rock to the west to lower resistivity, younger and weaker rock to the east. A downthrow to the east of the order of 30-40m is indicated.

- There is a general decrease in resistivity from south to north in line with younging of the rock to the north and the corresponding increase in shale/mudstone content.

- The resistivity profiles have also outlined an upper weathered layer of the order of 5 – 10 m thick.

- Profile R2 was located at the original ground level has mapped the southerly extension of the fault in the more weathered rock material at this location.

- Two seismic refraction profiles were recorded, one on either side of the fault. Markedly higher velocities (20-30% higher) were recorded over the more competent rocks to the west of the fault. A highly weathered layer of the order of 10m thick was also confirmed by the seismic data.

- Additional surveying using 2D Resistivity together with EM31and Seismic Refraction is recommended. Locations for further E-W 2D Resistivity lines across the fault strike are limited. Two continuous N-S profiles, one within the quarry and west of the fault, and one east of the fault are recommended. EM31 should be carried out to outline lateral changes in the shallow bedrock. Seismic refraction spreads should be located at selected intervals along the 2D Resistivity profiles in order to confirm lithology and provide information on weathering thickness.

2. INTRODUCTION

An integrated waste management facility is proposed to the Murphy Environmental Hollywood Landfill in Naul, Co. Dublin. The existing landfill is located in a disused rock quarry. Geological mapping and a topographical survey have been recently carried out on the site. The geological data indicates that the stratigraphy changes from younger shale-sandstone bedrock in the north to older limestone/shale in the south. The report also indicates that there is a major NNE striking fault, which passes through the east-centre of the quarry.

Apex Geoservices Ltd. was requested by ARUP Consulting Engineers, on behalf of MEHL., to carry out a trial geophysical survey (Project AGL09313a) to demonstrate the effectiveness of a number of geophysical techniques in mapping the location of the lithological boundary and the fault in the area adjacent to the existing landfill.

2.1 Site Background & Geological Setting

Naul Landfill is located in a disused rock quarry situated at Hollywood approximately 4 km south-east of Naul. The site is bounded by local roads to the south and west and by a stream in the north. There are green fields adjacent to the site in the east. The site is located on a local topographic high with steep fall of in topography to the east.

The Geological Survey of Ireland (GSI) 1:100,000 Bedrock Series Map for the area indicates that the site is predominantly underlain by Loughshinny Formation dark micrite and calcarenite interbedded with shale. The GSI Bedrock Series map also indicates Balrickard Formation coarse sandstone, shale and Walshestown Formation shale, sandstone and limestone in the north of the site.

The GSI Soils Map indicates that overburden across the site comprises shale and sandstone till (Namurian). The GSI Soils Map indicates rock outcrop/subcrop in the south and west of the site.

The recent geological survey of the site by Jones (2009) described a sequence of lithologies with limestones and shales of the Loughshinny Formation at lower levels in the south-western part of the quarry overlain by shales, limestones and sandstones of the Donore Formation overlain by sandstones, shales and rare micrites of the Balrickard Formation and then by Walshstown Formation black shales, siltstones and sandstones in the northern portion of the site. This report also noted a major fault with vein/breccias trending NNE, with beds of the Balrickard Formation exposed to the east of the fault and the Donore Formation and underlying Loughshinny Formation exposed to the west, with probable downthrow to the east of some tens of metres.

The report by Jones indicates that the Loughshinny Formation outcrop is restricted to an area further south than indicated on the GSI Bedrock map.

Much of the exposed rock is highly weathered with accurate identification difficult.

The majority of quarried material in the quarry has come from the more competent rock on the west side of the quarry with extraction terminating close to or at the NNE-trending fault.

Some other outcrops were examined during the present survey. The position of the NNE-trending fault where exposed in the southern portion of the quarry was recorded. Locations were recorded using DGPS and are shown on Drawing 9313a_01, Figure 1, with details in the following table:

Locality number	Location	Lithological description	Strike (degrees)	Dip (degrees)
1	West-centre of quarry	Thinly interbedded black shales and yellow sandstones	105	20N
2	NW corner of quarry	Thinly to very thinly bedded black shales and mid yellow-grey sandstones, moderately to highly weathtered	108	14N
3	Near NW corner	Black shale with thick (c.5m) sandstone bed	126	21N
4	Near centre of quarry	Thinly bedded yellow sandstones and medium-thick black shale interbeds. Gentle open folding	168	24N
5	East-centre of quarry	As Locality 4 but little or no folding		

Figure 1: **North-west corner of proposed north-east cell showing thinly interbedded black shales and yellow-grey sandstones of the Walshestown Formation dipping to NNE. Height of face in right of picture approx. 13m.**

Figure 2 **Looking to south-west in southern part of quarry along major fault at margin of yellow weathered area to the east.**

2.2 Survey Objectives

The objectives of the survey were:

1. To establish if a geophysical contrast exists between the shale-rich and limestone-rich formations.

2. To establish if the location of the NNE-trending fault can be mapped using geophysical methods.

2.3 Survey Methodology

The following program of geophysical surveying was carried out:

- VLF Resistivity (VLF-R) to outline variations in regional bedrock structure and lithology and to assist in locating the 2D-Resistivity Profiles;

- Electromagnetic Ground Conductivity (EM31) was carried out to establish if the method could map differences in bedrock type in areas of thin overburden.

- 2D-Resistivity Profiling to investigate the nature of lithological variations and map any fault zones, and to provide information on overburden and weathered rock thickness.

- Seismic Refraction Profiling to confirm overburden and weathered rock thickness, and provide information on the nature of the underlying fresh bedrock.

3. RESULTS

3.1 VLF-Resistivity

VLF-Resistivity was recorded along two profiles with one profile running from north-west to south-east across the NNE-trending fault and the second profile running from south-west to north-east to the south-east of the quarry. These profiles are shown in Drawing 9301a_01, Figure 2. The VLF-R apparent resistivity values ranged from 40 to 220 Ohm.m with phase angles of 24-57 degrees.

The VLF-R apparent resistivity values show a broad decrease from west to east but there is much local variation in the readings. This is associated with the variations in the lithology and weathering of the underlying geology which can be seen on the later 2D Resistivity profiles.

As the VLF-R method is best suited to mapping contacts between largely homogenous formations with a strong resistivity contrast and little internal lithological variation its effectiveness will be limited on this site and further use is not recommended.

3.2 EM31 Conductivity

The EM31 conductivity survey locations are shown on Drawing 9313a_01: Figure 1. The recorded EM31 conductivity values are shown as profiles on Drawing 9313a_01: Figure 3. The conductivity values change from around 15 mS/m to 20 mS/m from W-E across the fault zone corresponding to the broad change in the VLF resistivity and to the later change in 2D resistivity in the same location.

The S-N line also shows variation of similar amplitude and the lower values at the southern part of the profile may be associated with the change to limestone rich Loughshinny formation to the south.

The EM31 shows variations in line with the known changes in geology and corresponding to the 2D resistivity profiles. It gives information on changes in the underlying lithology where rock is within 6m of the surface. Given the dense station spacing and high speed of acquisition it provides useful information at low cost in certain areas and its future use is recommended.

3.3 2D-Resistivity Profiling

Three 2D Resistivity profiles were recorded as indicated on Drawing 9313a_01: Figure 1. The locations were selected to intersect the NNE-trending fault. Interpreted cross sections were compiled for the 2D-Resistivity profiles and are presented on Drawing 9313a_02. Due to the variation in resistivity from south to north each profile has been plotted using a unique scale in order to fully emphasis the resistivity contrasts. The three profiles are plotted at the same scale and spatially located in Drawing 9313a_01: Figure 4.

The resistivity values have been interpreted as follows:

Profile No.	**Resistivity (Ohm-m)**	**Interpretation**
R1	47-1049	Highly to Completely Weathered Limestone/Thin Shales (probable Loughshinny Formation)
	47-1049	Highly to Completely Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard/Walshestown Formations)
	130-625	Moderately to Highly Weathered Limestone/Thin Shales (probable Loughshinny Formation)
	70-500	Moderately to Highly Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard Formations)
	220-2200	Slightly to Moderately Weathered Limestone/Thin Shales (probable Loughshinny Formation)

Profile No.	**Resistivity (Ohm-m)**	**Interpretation**
R2	165-450	Highly to Completely Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard/Walshestown Formations)
	130-280	Moderately to Highly Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard Formations)
	280-1500	Slightly to Moderately Weathered Limestone/Thin Shales (probable Loughshinny Formation)
	315-825	Slightly to Moderately Weathered Shale/Sandstone/Argillaceous Limestone (probableDonore/Balrickard/Walshestown Formations)

Profile No.	**Resistivity (Ohm-m)**	**Interpretation**
R3	10-100	Highly to Completely Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard/Walshestown Formations)
	50-260	Moderately to Highly Weathered Shale/Sandstone/Argillaceous Limestone (probable Donore/Balrickard Formations)
	260-600	Fresh to Slightly Weathered Shale/Sandstone (probable Walshestown Formation)

Profile R1 (depth range 0-50m bgl) show the NNE-trending fault corresponding to its location recorded during geological mapping at 155m on R1. The high resistivity values to the west of the fault have been interpreted as probable limestones and thin shales of the Loughshinny Formation with downthrown weathered shales, sandstones and probable argillaceous limestones of the Balrickard or Donore Fomations to the east.

There is an increase in resistivity at depth on the eastern part of R1 which may correspond to the top of the underlying downthrown Loughshinny formation. This suggests a throw of the order of 30-40 m.

Resistivity **Profile R2** has been interpreted to indicate the fault at 105m on the profile, which corresponds with the position of the fault from examination of exposures at 115m. High resistivity values towards the north-western end of this profile have been interpreted as indicating limestones and thin shales of the Loughshinny Formation, whilst low resistivities around the centre of the profile and extending south-eastward to the fault have been interpreted as weathered shales, sandstones and possible argillaceous limestones of the Balrickard or Donore Formations. West of the fault the resistivity data has been interpreted to indicate slightly to moderately weathered possible Balrickard or Donore Formation shales, sandstones and argillaceous limestones.

The resistivity data clearly shows the NNE-trending fault at 180m on **Profile R3**. The fault here appears to be nearly vertically dipping. Higher resistivities below 100mOD to the west of the fault have been interpreted as indicating fresh to slightly weathered shale/sandstone of the Walshestown Formation which has been mapped by Jones (2009) in this area. The material overlying this and also occurring to the east of the fault has been interpreted as highly to completely and moderately to highly weathered shales and sandstones of the Walshestown Formation. The downthrow to the east on R3 is similar to that on R1 (30-40m)

Resistivity profiles R1 and R2 indicate a steep dip to the west for the fault, while R3 indicates a steep dip to the east.

Plates showing the three resistivity profiles plotted with the same contour levels have been overlaid on the summary map (Drawing 9313a_01, Figure 4) to illustrate how the resistivity progressively decreases going northward through Profile R2 to Profile R3.

This reflects the increasing argillaceous/shale content coming up the geological succession going from the Loughshinny Formation northwards through the overlying Donore and Balrickard Formations into the Walshestown Formation. Such a decrease in resistivity with younging of the Carboniferous sucession and increasing shale/mudstone content has been widely observed elsewhere throughout the Irish Carboniferous.

3.4 Seismic Refraction Profiling

Two seismic refraction profiles (**S1 and S2**) were recorded along 2D Resistivity Profile R1. S1 was located east of the fault and S2 west of the fault. The locations are indicated on Drawing 9313a_01: Figure 1 and the results are included on the interpreted cross sections in Drawing 9313a_02.

The seismic velocities have been interpreted as follows:

Layer	**Velocity (m/s)**	**Interpretation**
1	300-850	Soft-Firm/Loose-Medium Dense Overburden/Completely Weathered Rock.
2	750-1250	Highly Weathered Rock
3	1500-2200	Moderately Weathered Rock

There is a marked change in the seismic velocities of the above three layers across the fault with higher velocities occurring over the more competent rocks on the western side (see R1 on Drawing 9313a_02.) Similar changes in velocity between stronger/medium bedded and weaker/thinly bedded rocks are commonly observed on other sites.

4. REFERENCES

Geonics, 1980, EM16/16R Users Manual.

Campus Geophysical Instruments, 2000;
‘RES2DINV ver. 3.4 Users Manual’, Birmingham, England.

Golden Software, 2001;
‘Surfer 7 Surface Mapping System Users Manual’, Golden Software, CO., USA.

Geological Survey of Ireland, Sheet 13. The Geology of Meath.

Jones, G.l., 2009, Report on the Geology of the Landfill Site, Hollywood, Naul, Co. Fingal. Company report for Murphy Environmental Hollywood Ltd.

APPENDIX I GEOPHYSICAL METHODOLOGY

M1. Methods Used

1.1 VLF – Resistivity Surveying

The VLF-R method determines subsurface resistivity values by measuring the horizontal magnetic and vertical electrical components of waves transmitted by high-power military communications transmitters which operate in the 15-25 kHz frequency band.

1.2 Electromagnetic Conductivity Mapping

This method operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/metre (mS/m). As the effective penetration of this method is around 6m below ground level the measured conductivity is a function of the different overburden layers and/or rock from 0 to 6m below ground level.

1.3 2D-Resistivity Profiling

The resistivity surveying technique used for the survey makes use of the Wenner resistivity array whereby four electrodes are placed in a line in the ground and a current is passed through the two outer electrodes. The potential difference is measured across the two inner electrodes. The measured potential is divided by the current value to obtain the resistance. The resistivity is determined from the resistance using the following formula:

Resistivity = Resistance* 2 * Pi * Spacing

The 2D-resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types. The 2D-resistivity profiling method involves the use of 32 to 64 electrodes connected to a resistivity meter, using computer software to control the process of data collection and storage.

1.4 Seismic Refraction Profiling

This method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

M2. Equipment Used

2.1 VLF – Resistivity Surveying

The VLF-R survey was carried out using a Geonics EM-16R VLF meter and a 10m shielded cable. All readings were surveyed to give Irish National Grid Co-ordinates using a handheld Garmin 12XL.

2.2 Electromagnetic Conductivity Mapping

The equipment used was a GF CM31 Conductivity meter equipped with data logger. This instrument features a real time graphic display of the previous 20 measurement points to monitor data quality and results.

2.3 2D-Resistivity Profiling

The profiles were recorded using a Campus Tigre resistivity meter, imaging software, two 32 takeout multicore cables and up to 64 stainless steel electrodes. The recorded data were processed and viewed immediately after the survey.

2.4 Seismic Refraction Profiling

A Geode high resolution 24 channel digital seismograph, 12 10HZ vertical geophones and a 10 kg hammer were used to provide first break information, with two 12 take-out cables (3m spacing) and a trigger geophone. Equipment was carried in a 4WD vehicle with a three-person crew.

M3. Field Procedure

3.1 VLF – Resistivity Surveying

15 readings were taken on the 13th of January 2010. 12 readings were taken along a W-E profile with approximate 50m spacing between stations and 3 readings were taken along a N-S profile with approximate 100m spacing between stations.

To obtain the readings the 10m shielded cable is attached to the VLF-R meter and aligned towards the transmitter (Cumbria). A ‘null’ is obtained by adjusting controls to determine the subsurface resistivity and phase shift. Local conditions and variations were noted.

3.2 Electromagnetic Conductivity Mapping

367 conductivity readings were recorded on the 12th of January 2010. Conductivity and in-phase values were recorded along two profiles, a 580m South-North profile and a 380m East-West profile. Local conditions and variations were recorded.

3.3 2D-Resistivity Profiling

Three 2D resistivity profiles were recorded at locations crossing the estimated location of the main N-S fault. The resistivity data was acquired on the 12th and 13th of January 2010.

3.4 Seismic Refraction Profiling

Two spreads were recorded on the 13th of January 2010. Each seismic spread consisted of 24 collinear geophones at spacing of 3m, and was 69m in length. Records from five different positions were taken on each spread (2 x off-end, 2 x end, 1 x middle) to ensure optimum coverage of all refractors.

M4. Data Processing

4.1 VLF – Resistivity Surveying

The field readings of apparent resistivities and phase angles were plotted on Drawing 9313_01, figure 2.

4.2 Electromagnetic Conductivity Mapping

The data were downloaded and plotted. Assignation of material types and possible anomaly sources was carried out, with cross-reference to other data. Scaled plots of conductivity against distance were prepared (Drawing 9313_01a, figure 3a and figure 3b).

4.3 2D-Resistivity Profiling

The field readings were stored in computer files and inverted using the RES2DINV package (Campus Geophysical Instruments, 1997) with up to 5 iterations of the measured data carried out for each profile to obtain a 2D-Depth model of the resistivities.

The inverted 2D-Resistivity models and corresponding interpreted geology are displayed on Profiles R1 to R3. The chainage is indicated along the horizontal axis of the profile and the elevation to mOD is indicated on the vertical axis.

Please note that profiles have not been contoured using the same contour intervals and colour codes in the interpreted sections 9313_02 due to the large differences in interpreted resistivity, but are displayed using the same contour intervals and colour codes in the summary map (Drawing 9313_01, figure 5).

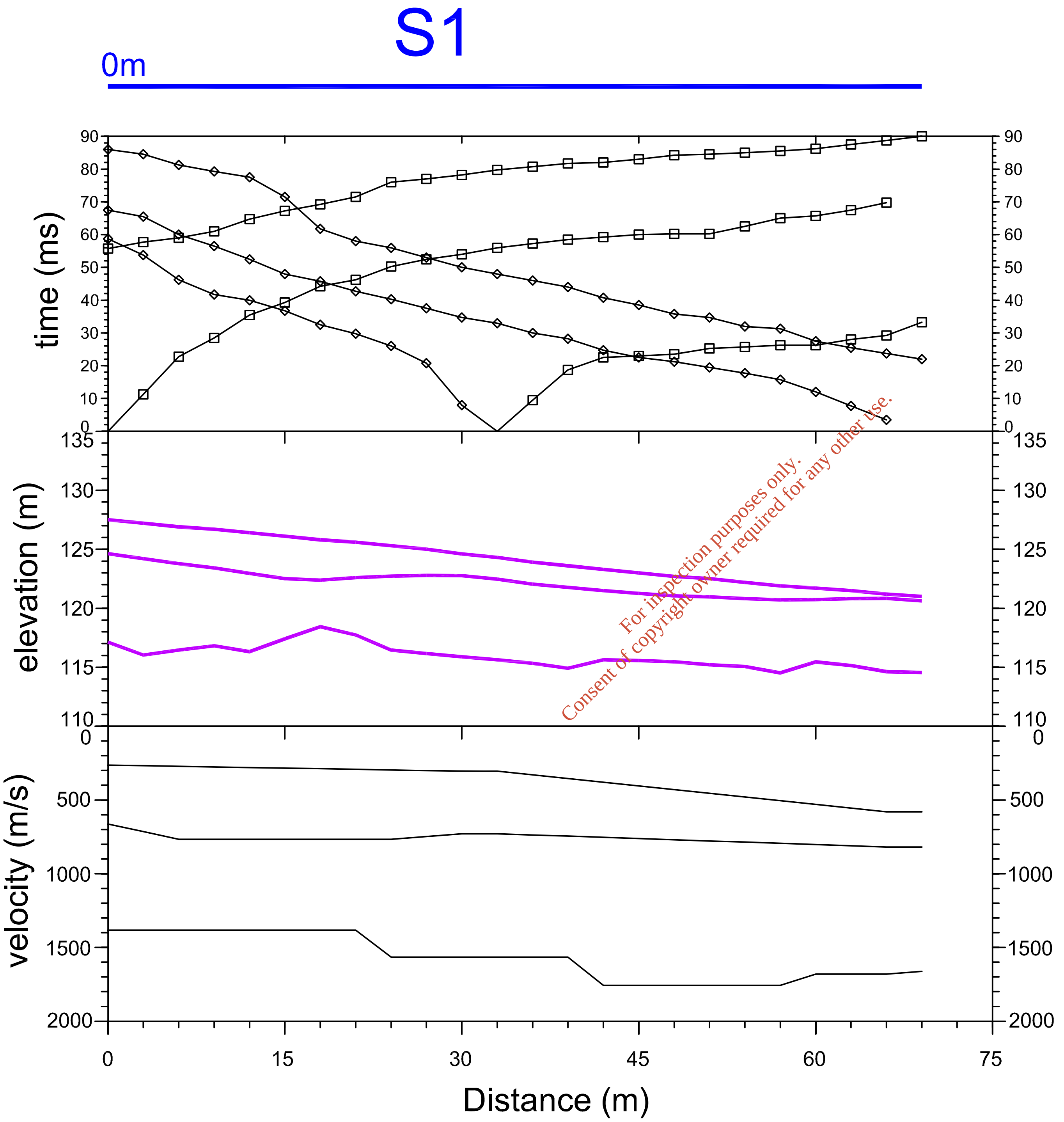
It is important to note that the data displayed on the 2D-Resistivity profiles is real physical data however interpretation of the geophysical results is required to transform the resistivities directly into geological layers.

4.4 Seismic Refraction Profiling

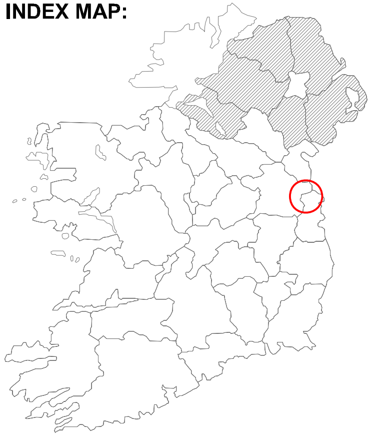
First break picking in digital format was carried out using the FIRSTPIX software program to construct traveltime plots for each spread. Velocity phases were selected from these plots using the GREMIX software program and were used to calculate the thickness of individual velocity units. Topographic data were input. Material types were assigned and estimation made of material properties, cross-referenced to the 2D Resistivity data. The processed seismic data are displayed in Appendix II and on Drawing 9313_02a and are annotated onto the R1 interpretation.

Approximate errors for velocities are estimated to be +/- 10%. Errors for the calculated layer thicknesses are of the order of +/-20%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

APPENDIX II SEISMIC REFRACTION PROFILES



INDEX MAP:



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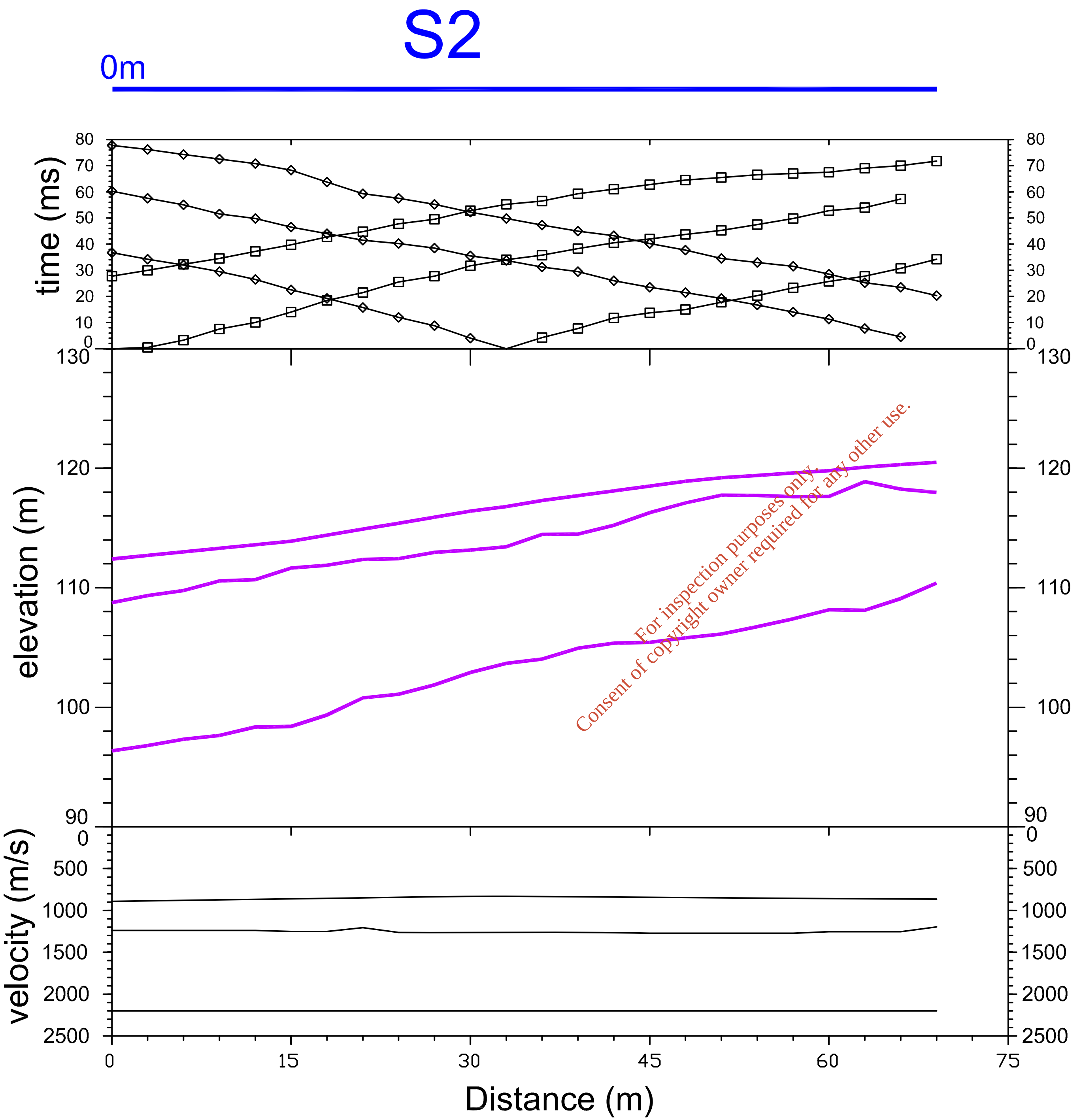
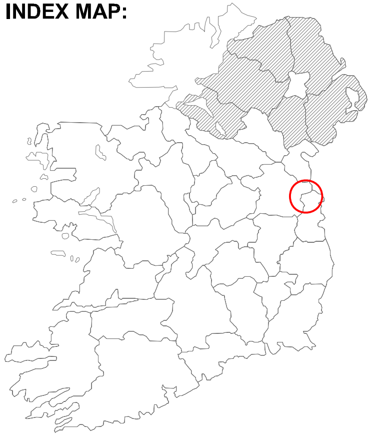
PROJECT: NAUL LANDFILL
DRAWING No: 9313 APPENDIX II
DATE: 15th JANUARY 2010
CLIENT: ARUP
SCALE: 1:1000 @A4

Version:	Date:	Drawn By:	Checked:
001	150110	FW	MN



INDEX MAP:



LEGEND:

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PROJECT: NAUL LANDFILL
DRAWING No: 9313 APPENDIX II
DATE: 15th JANUARY 2010
CLIENT: ARUP
SCALE: 1:1000 @A4

Version:	Date:	Drawn By:	Checked:
001	150110	FW	MN

FIGURE 1: Geophysical Survey Layout & Geological Observations, Scale 1:2000 @ A1

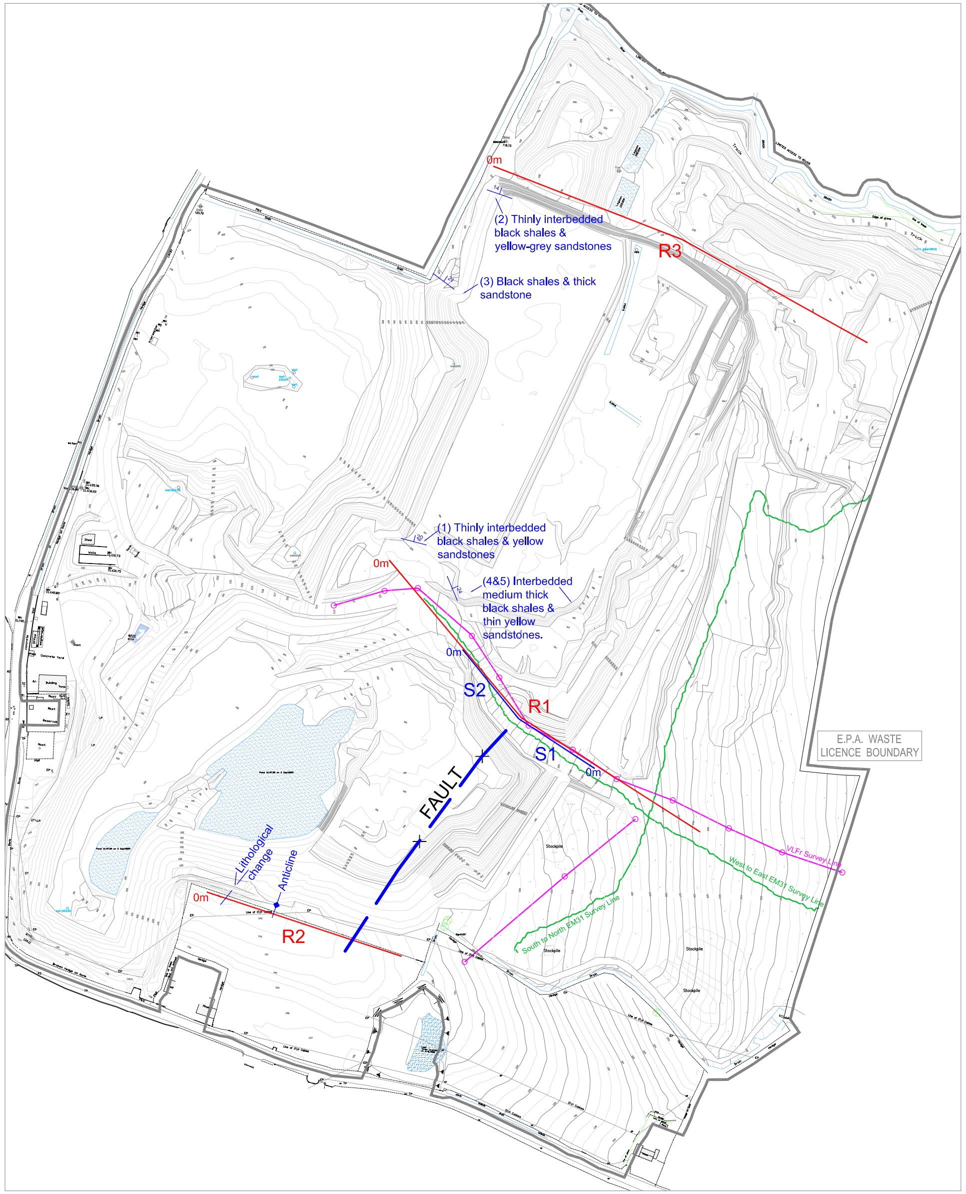


FIGURE 4: Geophysical Interpretation Summary Map, Scale 1:2000 @ A1

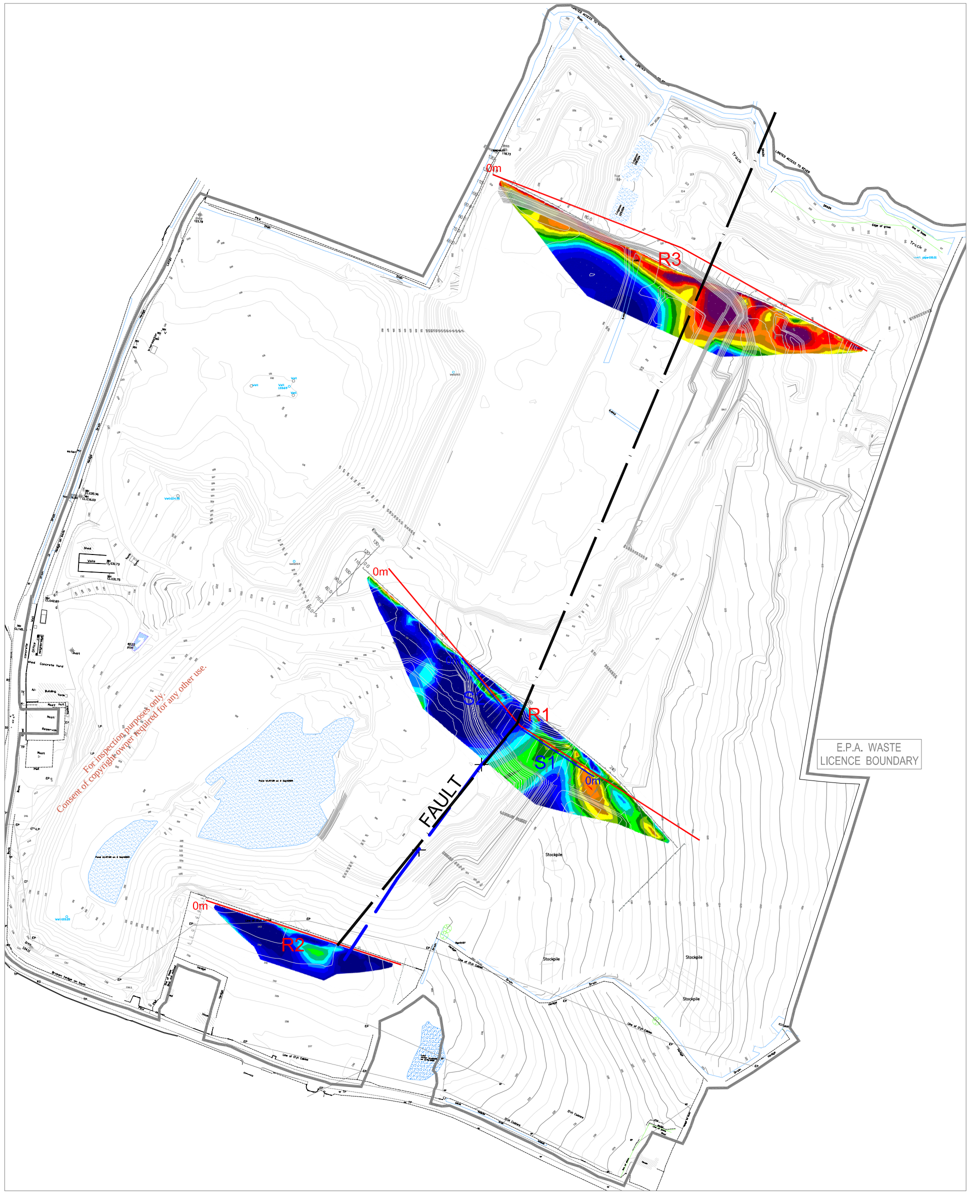


FIGURE 2: VLF-Resistivity Profile

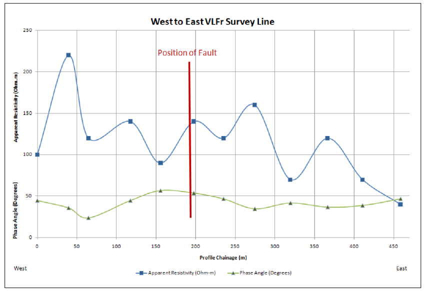
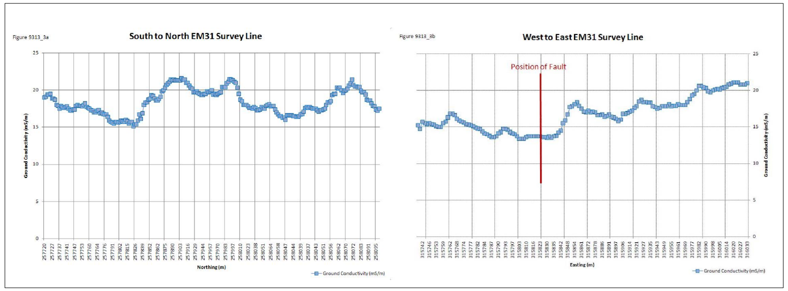
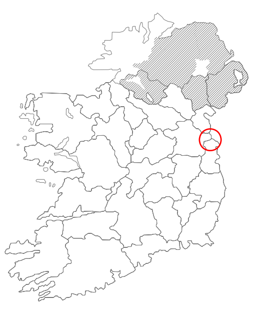


FIGURE 3: EM31 Ground Conductivity Profiles



INDEX MAP:



LEGEND:

2D Resitivity Profile

Seismic Refraction Profile

EM31 Conductivity Profile

VLF-Resistivity Profile

Dip/strike (degrees) of bedding

Fault mapped from outcrop

Fault interpreted from geophysics

2D Resitivity Scale

30.0 43.2 62.2 89.6 129 186 267 385

Resistivity in ohm.m

NOTES:

TITLE:
HOLLYWOOD LANDFILL GEOPHYSICAL SURVEY

PROJECT:
AGL09313a

CLIENT:
MEHL.

DRAWING:
MAP & SECTION

DRAWING NUMBER:
9313a_01

SCALE:
As shown

DATE:
15th JANUARY 2010

DRAWN: MF

CHECKED: POC

REVISION:	DATE:	DRAWN:	CHECKED:

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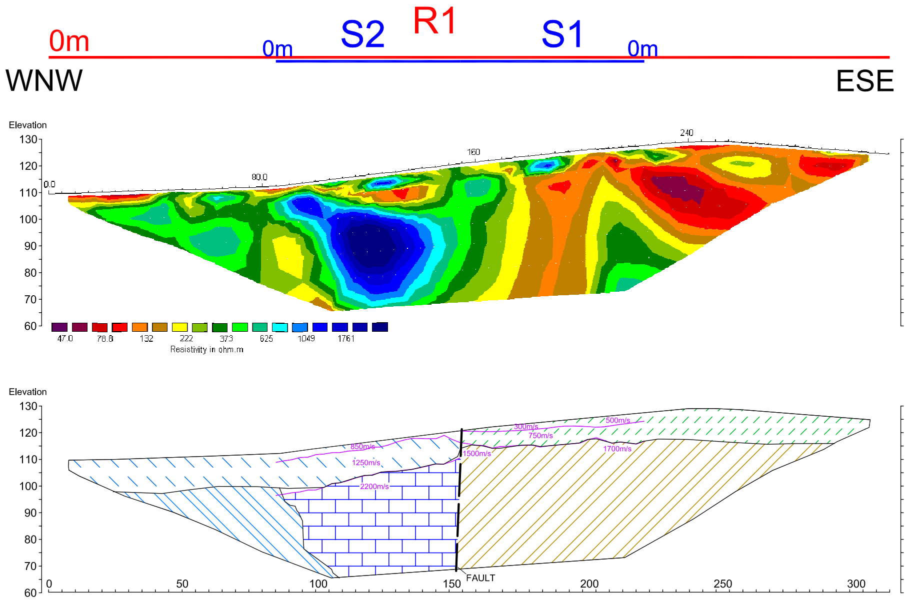
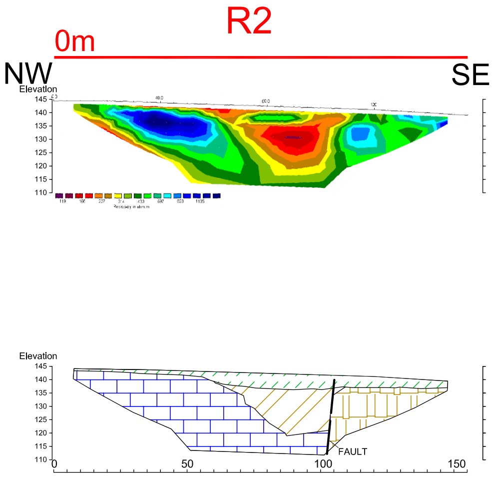
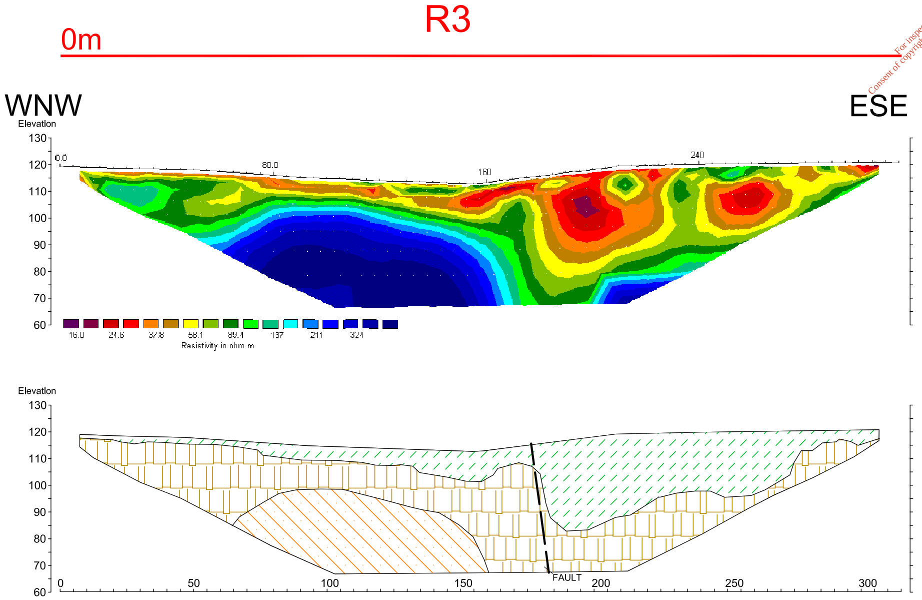
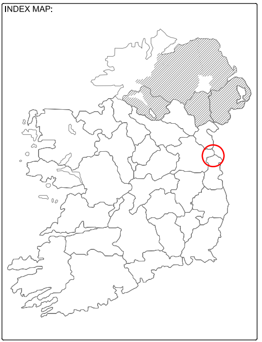
Rersistivity & Seismic Sections, Scale 1:1000 @ A1







INDEX MAP:



LEGEND:

▨	Highly to Completely Weathered Limestone/Thin Shales (Possible Loughshinny Formation)
▨	Highly to Completely Weathered Shale/Sandstone/Argillaceous Limestone (Donore/Balrickard/Walshestown Formations)
▨	Moderately to Highly Weathered Limestone/Thin Shales (Possible Loughshinny Formation)
▨	Moderately to Highly Weathered Shale/Sandstone/Argillaceous Limestone (Donore/Balrickard Formations)
▦	Slightly to Moderately Weathered Limestone/Thin Shales (Possible Loughshinny Formation)
▦	Slightly to Moderately Weathered Shale/Sandstone/Argillaceous Limestone (Donore/Balrickard/Walshestown Formations)
▨	Fresh to Slightly Weathered Shale/Sandstone (Walshestown Formation)

NOTES:

TITLE:
HOLLYWOOD LANDFILL GEOPHYSICAL SURVEY

PROJECT:
AGL09313a

CLIENT:
MEHL.

DRAWING:
RESISTIVITY & SEISMIC SECTIONS

DRAWING NUMBER:
9313a_02

SCALE:
As shown

DATE:
15th JANUARY 2010

DRAWN: MF
CHECKED: POC

REVISION:	DATE:	DRAWN:	CHECKED:

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Appendix E

Borehole Information

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH21**
		SHEET	Sheet 1 of 2
CO-ORDINATES	316,074.94 E 258,199.63 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	120.70	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	20.00
DATE DRILLED	14/04/2010	**DATE LOGGED**	14/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	MADE GROUND (Stockpile - Comprised of dark grey sandy gravelly clay)	▩			R2005	B	0.50-0.50			
1					R2006 R2007	B U	1.00-1.00 1.00-1.45	50%rec 12 blows		
					R2008	D	1.45-1.60			
2					R2009	B	2.00-2.00			
					R2010	D	2.50-2.50			
3					R2011	U	3.00-3.45	50%rec 9 blows		
					R2012	D	3.45-3.60			
4					R2013	B	4.00-4.00			
					R2014	D	4.50-4.50			
5					R2015	U	5.00-5.45	60%rec 12 blows		
					R2016	D	5.45-5.60			
6					R2017	B	6.00-6.00			
			114.00	6.70	R2018	D	6.50-6.50			
	Light brown sandy gravelly CLAY with some cobbles (occasionally grading to clayey gravel)	⊖			R2019	B	6.70-6.70			
7					R2020	U	7.00-7.45	80%rec 29 blows		
					R2021	D	7.45-7.60			
8					R2022	B	8.00-8.00			
					R2023	D	8.50-8.50			
9			111.40	9.30	R2024	U	9.00-9.45	60%rec 42 blows		
	Black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone	⊖			R2025	D	9.45-9.60			

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
7.7	7.8	0.75	
11	11.05	0.5	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Hole located on top of clay stockpile

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER	14695		
CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH21**
		SHEET	Sheet 2 of 2
CO-ORDINATES	316,074.94 E 258,199.63 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	120.70	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	20.00
DATE DRILLED	14/04/2010	**DATE LOGGED**	14/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
10	Black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone *(continued)*				R2026	B	10.00-10.00			
			110.00	10.70	R2027	D	10.50-10.50			
11	Angular cobbly gravel of moderately weathered SILTSTONE/MUDSTONE		109.60	11.10	R2028	B	11.00-11.00			
	Black/orange sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2029	D	11.50-11.50			
12					R2030	U	12.00-12.45	80%rec 39 blows		
			108.00	12.70	R2031	D	12.45-12.60			
13	Dark brown/orange sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2032	B	13.00-13.00			
					R2033	D	13.50-13.50			
14					R2034	U	14.00-14.60	0%rec 43 blows		
					R2035	D	14.50-14.50			
15					R2036	B	15.00-15.00			
					R2037	D	15.50-15.50			
16					R2038	U	16.00-16.45	60%rec 44 blows		
					R2039	D	16.45-16.60			
17					R2040	B	17.00-17.00			
					R2041	D	17.50-17.50			
18			102.30	18.40	R2042	U	18.00-18.45	15%rec 72 blows		
	Grey brown / green sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2043	D	18.45-18.60			
19					R2044	B	19.00-19.00			
			101.10	19.60	R2045	U	19.40-19.85	100%rec 52 blows		
	Very stiff dark grey/grey sandy gravelly CLAY		100.70	20.00	R2046	D	19.85-20.00			

End of Borehole at 20.00m

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
7.7	7.8	0.75	
11	11.05	0.5	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Hole located on top of clay stockpile

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH22**
		SHEET	Sheet 1 of 1
CO-ORDINATES	315,961.50 E 258,091.66 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	123.83	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	5.90
DATE DRILLED	09/04/2010	**DATE LOGGED**	12/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	MADE GROUND (Comprised of brown sandy gravelly clay with cobbles)	▩	122.83	1.00	AJ6563	B	0.50-0.95		N = 12 (1, 3, 3, 3, 3, 3)	
1	Firm, dark brown slightly sandy gravelly SILT with angular cobbles of weathered siltstone / mudstone	×o	117.93	5.90	AJ6564	D	1.00-1.00			
					AJ6565	U	1.50-2.10	0%rec		
2					AJ6566	D	2.00-2.00			
					AJ6567	D	2.50-2.50			
3					AJ6568	B	3.00-3.45		N = 14 (2, 3, 5, 3, 3, 3)	
					AJ6569	D	3.50-3.50			
4					AJ6570	U	4.50-4.95	60%rec 19 blows		
5					AJ6571	D	4.95-5.10			
					AJ6572	B	5.50-5.50			
6	Obstruction End of Borehole at 5.90 m				AJ6573	B	5.90-5.90			
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.7	2.75	0.75	
5.1	5.2	0.75	
5.8	5.9	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Obstruction at 5.90m . Moved 1m to BH22A and rebored

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER	14695
CONTRACT	MEHL Integrated Waste Management Facility
BOREHOLE NO.	**BH22A**
SHEET	Sheet 1 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N
GROUND LEVEL (m AOD)	123.73
RIG TYPE	Dando
BOREHOLE DIAMETER (mm)	200
BOREHOLE DEPTH (m)	20.60
DATE DRILLED	12/04/2010
DATE LOGGED	13/04/2010
CLIENT	MEHL
ENGINEER	WYG
SPT HAMMER REF. NO.	
ENERGY RATIO (%)	
BORED BY	J.Edwards
PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	MADE GROUND (Comprised of brown sandy gravelly clay with cobbles)		122.73	1.00						
1 2 3 4 5 6	Dark brown sandy very gravelly CLAY with occasional cobbles of weathered mudstone / siltstone		117.23	6.50						
	Dark brown slightly sandy gravelly CLAY with angular cobbles of weathered siltstone / mudstone.		116.63	7.10	AJ6574	D	6.50-6.50			
7					AJ6575	B	7.00-7.00			
	Firm to stiff, black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				AJ6576	U	7.50-7.95			
8					AJ6577 AJ6578	D B	7.95-8.10 8.00-8.00			
					AJ6579	D	8.50-8.50			
9					AJ6580 AJ6581	D B	9.00-9.45 9.00-9.50		N = 22 (1, 2, 4, 4, 6, 8)	

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH22A**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	123.73	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	20.60
DATE DRILLED	12/04/2010	**DATE LOGGED**	13/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
10	Firm to stiff, black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone *(continued)*				AJ6582	B	10.00-10.00			
					AJ6583	U	10.50-10.95	40%rec 20 blows		
			112.73	11.00	AJ6584	D	10.95-11.10			
11	Firm to stiff dark brown/orange slightly sandy gravelly SILT with occasional cobbles of weathered mudstone / siltstone.				AJ6585	B	11.00-11.00			
					AJ6586	D	11.50-11.50			
12					AJ6587	D	12.00-12.45		N = 15 (1, 2, 3, 3, 4, 5)	
					AJ6588	B	12.00-12.50			
			110.73	13.00						
13	Firm to stiff black /orange sandy gravelly CLAYSILT with occasional cobbles of weathered mudstone / siltstone				AJ6589	B	13.00-13.00			
					AJ6590	U	13.50-13.95	50%rec 20 blows		
14					AJ6591	D	13.95-14.10			
					AJ6592	B	14.00-14.00			
					AJ6593	D	14.50-14.50			
15					AJ6594	B	15.00-15.45		N = 50/75 mm (2, 11, 50)	
					AJ6595	D	15.50-15.50			
16										
					AJ6596	B	16.50-16.95		N = 23 (3, 4, 6, 5, 5, 7)	
			106.83	16.90						
17	Grey/green sandy very gravelly CLAY				AJ6597	D	17.00-17.00			
			106.33	17.40						
	Very stiff grey/brown/green slightly sandy slightly gravelly CLAY with occasional cobbles of weathered mudstone / siltstone				AJ6598	B	17.50-17.50			
18					AJ6599	B	18.00-18.45		N = 49 (5, 7, 13, 12, 12, 12)	
			105.13	18.60	AJ6600	D	18.50-18.50			
	Dark grey/green sandy very gravelly CLAY									
19					AJ6601	B	19.00-19.00			
			104.23	19.50	AJ6602	U	19.50-19.95	90%rec 67 blows		
	Black dense clayey GRAVEL									

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER	14695
CONTRACT	MEHL Integrated Waste Management Facility
BOREHOLE NO.	BH22A
SHEET	Sheet 3 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N
GROUND LEVEL (m AOD)	123.73
RIG TYPE	Dando
BOREHOLE DIAMETER (mm)	200
BOREHOLE DEPTH (m)	20.60
DATE DRILLED	12/04/2010
DATE LOGGED	13/04/2010
CLIENT	MEHL
ENGINEER	WYG
SPT HAMMER REF. NO.	
ENERGY RATIO (%)	
BORED BY	J.Edwards
PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples				Field Test Results	Standpipe Details
					Ref. Number	Sample Type	Depth (m)	Recovery		
20	Black dense clayey GRAVEL *(continued)*		103.13	20.60	AJ6603 AJ6604	D B	19.95-20.10 20.10-20.55		N = 50/225 mm (6, 11, 16, 17, 17)	
	End of Borehole at 20.60 m									
21										
22										
23										
24										
25										
26										
27										
28										
29										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH23**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	125.08	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	22.70
		DATE DRILLED	07/04/2010
		DATE LOGGED	08/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	Firm to stiff brown sandy gravelly CLAY with occasional cobbles									
					AJ6528	B	0.50-0.50			
1					AJ6529 AJ6530	D B	1.00-1.45 1.00-1.50		N = 15 (1, 2, 5, 4, 3, 3)	
2					AJ6531	U	2.00-2.45	70%rec 50 blows		
					AJ6532	D	2.45-2.60			
3					AJ6533 AJ6534	D B	3.00-3.45 3.00-3.50		N = 18 (2, 4, 4, 3, 5, 6)	
4			120.98	4.10	AJ6535	D	4.00-4.00			
	Dark brown sandy very gravelly CLAY with some cobbles of weathered mudstone / siltstone		120.28	4.80						
5	Firm to stiff dark brown slightly sandy gravelly CLAY with some cobbles and some bands of yellow/brown sand (grading in places to a clayey sandy gravel)				AJ6536 AJ6537	D B	5.00-5.45 5.00-5.50		N = 14 (2, 3, 5, 3, 3, 3)	
6					AJ6538	U	6.00-6.45	80%rec 28 blows		
					AJ6539	D	6.45-6.60			
7					AJ6540 AJ6541	D B	7.00-7.45 7.00-7.50		N = 12 (1, 2, 3, 3, 3, 3)	
8					AJ6542	U	8.00-8.60	0%rec 57 blows		
9					AJ6543	B	9.00-9.45		N = 23 (2, 5, 6, 6, 5, 6)	
			115.08	10.00						

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Backfill with bentonite GL - 23.00m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER	14695
CONTRACT	MEHL Integrated Waste Management Facility
BOREHOLE NO.	**BH23**
SHEET	Sheet 2 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N
GROUND LEVEL (m AOD)	125.08
RIG TYPE	Dando
BOREHOLE DIAMETER (mm)	200
BOREHOLE DEPTH (m)	22.70
DATE DRILLED	07/04/2010
DATE LOGGED	08/04/2010
CLIENT	MEHL
ENGINEER	WYG
SPT HAMMER REF. NO.	
ENERGY RATIO (%)	
BORED BY	J.Edwards
PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
10	Purplish brown / grey brown sightly sandy gravelly SILT/CLAY				AJ6544	D	10.00-10.00			
11					AJ6545 AJ6546	D B	11.00-11.45 11.00-11.50		N = 12 (1, 2, 4, 3, 2, 3)	
12					AJ6547	B	12.00-12.45		N = 29 (2, 5, 7, 7, 7, 8)	
13					AJ6548	D	13.00-13.00			
14					AJ6549 AJ6550	D B	14.00-14.45 14.00-14.50		N = 13 (1, 3, 3, 4, 3, 3)	
15					AJ6551	D	15.00-15.00			
16					AJ6552 AJ6553	D B	16.00-16.45 16.00-16.50		N = 48/225 mm (2, 2, 16, 16, 16)	
17					AJ6554	B	17.50-17.95		N = 24 (2, 3, 9, 7, 3, 5)	
			107.08	18.00						
18	Grey green very gravelly CLAY		106.58	18.50	AJ6555	D	18.00-18.00			
	Yellow brown clayey GRAVEL / gravelly CLAY		105.68	19.40						
19	Medium dense clayey GRAVEL / stiff very gravelly CLAY		105.18	19.90	AJ6556 AJ6557	B U	19.40-19.40 19.50-19.95	80%rec 32 blows		

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Backfill with bentonite GL - 23.00m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH23**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N	**RIG TYPE**	Dando
		BOREHOLE DIAMETER (mm)	200
GROUND LEVEL (m AOD)	125.08	**BOREHOLE DEPTH (m)**	22.70
		DATE DRILLED	07/04/2010
		DATE LOGGED	08/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
20	Dark grey/ black slightly sandy slightly gravelly CLAY *(continued)*				AJ6558	D	19.95-20.10			
					AJ6559	B	20.50-20.50			
21					AJ6560	U	21.00-21.45	70%rec 61 blows		
					AJ6561	D	21.45-21.60			
22										
			102.38	22.70	AJ6562	B	22.50-22.70			
	End of Borehole at 22.70 m									
23										
24										
25										
26										
27										
28										
29										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Backfill with bentonite GL - 23.00m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

Appendix 2

Corehole Records

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT MEHL Integrated Waste Management Facility

DRILLHOLE NO BH15
SHEET Sheet 1 of 4

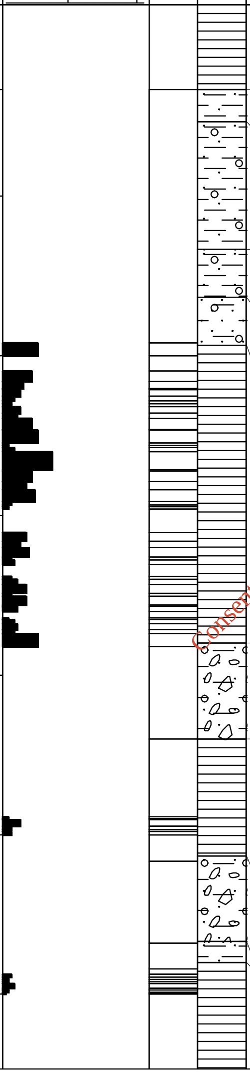
CO-ORDINATES 315,786.30 E
257,849.63 N
GROUND LEVEL (mOD) 105.89

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

DATE DRILLED 06/04/2010
DATE LOGGED 12/04/2010

CLIENT MEHL
ENGINEER ARUP

DRILLED BY Petersen
LOGGED BY D.O'Shea



Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
0.80	0	0	0
1.80	100	0	12
3.30	87	13	9
4.80	100	80	0
6.30	100	39	0
7.80	80	9	0
9.30	100	3	0
	67	33	0

Description	Depth (m)	Elevation
SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered mudstone	0.80	105.09
Highly weathered rock recovered as soft, orange/brown, sandy CLAY/SILT	1.10	104.79
Highly weathered rock recovered as stiff, dark brown, slightly sandy, slightly gravelly CLAY/SILT. Gravel is angular, fine to coarse of sandstone.	2.30	103.59
Highly weathered rock recovered as stiff, orange/brown, slightly sandy, slightly gravelly CLAY/SILT. Gravel is angular, fine to coarse of sandstone.	2.75	103.14
Highly weathered rock recovered as medium dense, orange/brown, clayey, gravelly SAND. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone.	3.20	102.69
Moderately strong to moderately weak, thickly laminated to thinly bedded (to structureless where clay-filled), interbedded fine-grained SANDSTONE and MUDSTONE with large amounts of orange/yellow/brown clay infill (Balrickard Formation), moderately to locally slightly weathered. Discontinuities are smooth, planar. Apertures are tight to open, commonly clay-filled (especially at 4.74-4.96m & 5.70-5.76m), commonly penetrative iron-oxide stained. Dips are sub-horizontal & locally sub-vertical.	6.00	99.89
Highly weathered rock recovered as brown clayey sandy GRAVEL. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone with pennetrative iron-oxide staining - Loss of recovery.	6.90	98.99
Weak, thinly bedded (to structureless where clay-filled), grey/dark grey/orange/brown, interbedded fine-grained SANDSTONE and SILTSTONE, moderately weathered. Discontinuities are smooth to rough, irregular. Apertures are tight to open, commonly clay-filled (especially at 7.20-7.40m & 7.80-8.05m). Dips are irregular.	8.00	97.89
Highly weathered rock recovered as brown clayey sandy GRAVEL. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone with pennetrative iron-oxide staining - Loss of recovery.	8.80 9.00	97.09 96.89
Highly weathered rock recovered as stiff, orange, slightly sandy CLAY.		

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

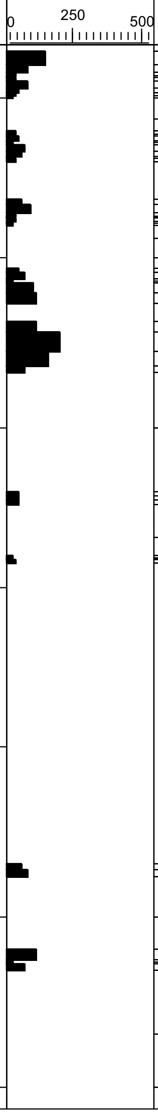
INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 2 of 4
CO-ORDINATES	315,786.30 E 257,849.63 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
RIG TYPE		**DRILLED BY**	Petersen
FLUSH	Air/Mist	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		
CLIENT	MEHL		
ENGINEER	ARUP		



Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
10	10.50				Strong to moderately strong/weak, medium to thinly bedded (to structureless where clay-filled), grey/dark grey, interbedded fine-grained SANDSTONE and SILTSTONE with large amounts of brown clay infill (Donore Formation), slightly to moderately weathered. Core loss due to probable sandy clay-filled fracture at 9.3-9.9m & 13.6-14.1m). Discontinuities are smooth, planar. Apertures are tight to open, commonly clay-filled (especially at 10.70-10.81m, 11.10-11.45m, 11.70-11.82m, 12.00-12.10m, 12.43-12.60m, 13.08-13.60m, 14.32-14.63m), locally slightly iron-oxide stained. Dips are sub-horizontal & sub-vertical. *(continued)*				
11	12.00	93	14	0					
12, 13	13.60	100	51	0					
14	15.10	67	11	0		15.10	90.79		
15, 16	16.60	100	0	0	Highly weathered rock recovered as dense, dark brown/orange mottled, clayey gravelly SAND with occasional cobbles. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse of sandstone. Cobbles are sub-angular to sub-rounded of sandstone.				
17	18.20	100	9	0		17.65	88.24		
18, 19	19.80	81	14	0					

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

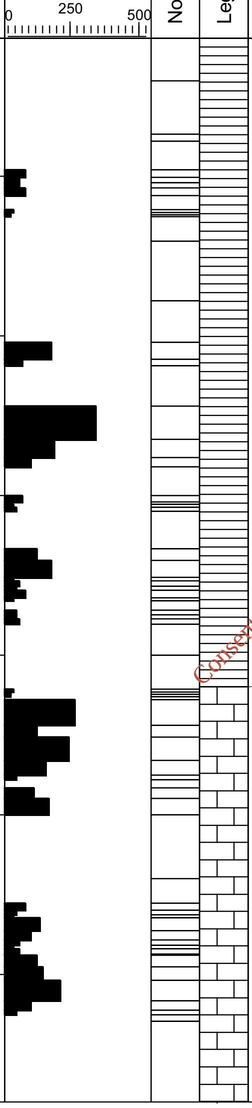
REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 3 of 4
CO-ORDINATES	315,786.30 E 257,849.63 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE	
FLUSH	Air/Mist
INCLINATION (deg)	-90
CORE DIAMETER (mm)	102

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation
20		73	13	0	Strong to moderately strong/weak, medium to thinly bedded (to structureless where clay-filled), grey/dark grey (becoming brown 22.8-25.5m), interbedded fine-grained SANDSTONE and SILTSTONE with large amounts of brown clay infill (Donore Formation), slightly to moderately weathered. Core loss due to probable sandy gravel-filled fracture at 19.4-20.9m & 25.50-25.80m). Discontinuities are smooth to rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 18.20-18.50m, 19.30-19.80m, 20.90-20.97m, 21.91-22.47m, 23.08-23.46m, 24.03-24.30m, 24.45-24.80m), locally slightly iron-oxide stained. Dips are sub-horizontal & locally sub-vertical. *(continued)*		
21	21.30	100	19	0			
22	22.80	100	59	34			
23							
24	24.30	100	38	10			
25	25.80				25.0-25.5m - Substantial flush loss through large sub vertical fracture		
26		100	71	55	Strong to very strong (to locally weak at 27.3-29.1m), thickly to thinly bedded, grey/dark grey/black, interbedded fine-grained LIMESTONE and MUDSTONE (Loughshinny Formation), slightly to locally moderately/highly weathered. Core loss due to probable highly weathered layer at 27.30-29.10m). Discontinuities are smooth to rough, planar. Apertures are tight to open, commonly clay-filled (especially at 26.97-27.05m, 27.30-27.9m, 29.18-29.24m), locally calcite veined (1-30mm thick), locally slightly iron-oxide stained. Dips are sub-horizontal & locally sub-vertical.	26.10	79.79
27	27.30	60	5	0			
28	28.80						
29		100	76	36			

Fracture Spacing Log (mm)



Non-intact Zone | Legend | Standpipe Details | Backfill Elevation (mOD)

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT MEHL Integrated Waste Management Facility

DRILLHOLE NO **BH15**
SHEET Sheet 4 of 4

CO-ORDINATES 315,786.30 E
257,849.63 N
GROUND LEVEL (mOD) 105.89

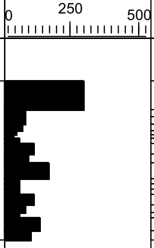
RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

DATE DRILLED 06/04/2010
DATE LOGGED 12/04/2010

CLIENT MEHL
ENGINEER ARUP

DRILLED BY Petersen
LOGGED BY D.O'Shea

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm)	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
30	30.40											
31		100	70	35				30.5-31.0m - Substantial flush loss through large sub vertical, partially calcite-filled fracture.				
	31.90								31.90	73.99		73.99
32								End of Borehole at 31.90 m				
33												
34												
35												
36												
37												
38												
39												



REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
12-04-10	31.90	31.90	5.70	Start of shift

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15A**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,786.30 E 257,849.63 N	**DATE DRILLED**	16/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE

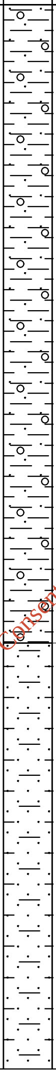
FLUSH Air/Mist

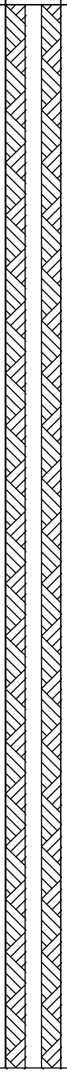
INCLINATION (deg) -90

CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
0								Orange/brown mottled sandy slightly gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone.				
6								Mid brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone.	6.00	99.89		

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9





REMARKS

Hole drilled by Briody 4 metres from IGSL Geobor Hole.
Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15A**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,786.30 E 257,849.63 N	**DATE DRILLED**	16/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	22/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)			

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
10								Mid brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone. *(continued)*	14.00	91.89		
14								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone.	19.00	86.89		
19								Wet, dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone.				

REMARKS

Hole drilled by Briody 4 metres from IGSL Geobor Hole.
Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

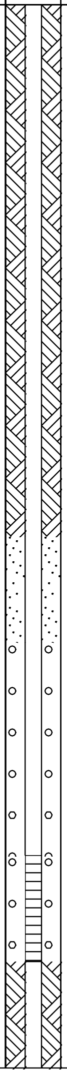
REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15A**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,786.30 E 257,849.63 N	**DATE DRILLED**	16/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
20								Wet, dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone. *(continued)*				
24								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, sandstone & limestone with calcite veining.	24.00	81.89		
25												80.89
26												79.89
28												77.89
29												76.89
									30.00	75.89		75.89

Downhole depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29



End of Borehole at 30.00 m

REMARKS
Hole drilled by Briody 4 metres from IGSL Geobor Hole.
Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 1 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
0.80			
1.60	100	0	0
3.10	93	0	0
4.70	100	0	0
6.20	100	0	0
7.60	71	13	0
9.10	100	7	0
	80	0	0

Description	Depth (m)	Elevation
SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered shaley mudstone/sandstone with sandy gravelly clay layers.	0.80	103.99
Weak, structureless, black, highly weathered fine-grained MUDSTONE - recovered as angular gravel with bands of black sandy gravelly clay.	4.20	100.59
Weak, structureless, black, highly weathered fine-grained MUDSTONE - recovered as angular gravel with occasional bands of black sandy gravelly clay.	6.85	97.94
Moderately weak to moderately strong, thinly bedded to thinly laminated, dark grey/black, interbedded fine-grained SANDSTONE & SILTSTONE/MUDSTONE with large amounts of black clay infill (Walshestown Formation), moderately/highly to very locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 10.72-10.90m & 11.50-12.0m). Dips are 20-30° & sub-vertical.		

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 2 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
10.60			
12.10	100	0	0
13.60	73	0	0
15.10	67	12	0
16.60	67	7	0
17.50	100	0	0
18.00	0	0	0
19.00	55	0	0
19.60	100	0	0

Description	Depth (m)	Elevation
Moderately weak to moderately strong, thinly bedded to thinly laminated, dark grey/black, interbedded fine-grained SANDSTONE & SILTSTONE/MUDSTONE with large amounts of black clay infill (Walshestown Formation), moderately/highly to very locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 10.72-10.90m & 11.50-12.0m). Dips are 20-30° & sub-vertical. *(continued)*	12.00	92.79
Weak, structureless, orange/brown/black, highly weathered interbedded fine-grained SANDSTONE & MUDSTONE - recovered as angular gravel with bands of black sandy gravelly clay. Gravel is angular, fine to coarse with orange/brown, iron-oxide staining.	14.40	90.39
Weak, structureless, orange/brown/black/grey, highly weathered fine-grained interbedded SANDSTONE & MUDSTONE - recovered as sandy angular gravel. 17.5-18.0m - No recovery - probable highly weathered rock.	19.70	85.09

Backfill Elevation (mOD): 86.79, 85.79, 84.79

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 3 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
20.70	100	16	15
21.10	100	0	0
22.60	33	0	0
23.80	88	4	0
24.60	94	6	0
25.50	89	19	0
27.00	100	18	0
28.50	7	0	0
30.00	33	12	0

Description	Depth (m)	Elevation
Moderately weak to moderately strong, thinly bedded to thinly laminated, grey/orange/brown, fine-grained SANDSTONE (Walshestown Formation), moderately weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-smeared, commonly moderately iron-oxide stained. Dips are 20-30° & sub-vertical. *(continued)*	25.00	79.79
Moderately strong, medium to thinly bedded, black, fine-grained MUDSTONE (Walshestown Formation), slightly weathered. Discontinuities are smooth, planar. Apertures are tight to moderately open, locally clay-smeared. Dips are 20-30° & sub-vertical.	25.50	79.29
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black/brown, interbedded fine-grained SILTSTONE & MUDSTONE with large amounts of black clay infill (Walshestown Formation), slightly to locally moderately/highly weathered. Discontinuities are smooth to locally rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 26.0-26.15m, 26.42-26.47m, 30.98-31.18m, 31.33-31.41m). Dips are 20-30° & sub-vertical. 27.0-27.5m - No recovery - probable highly weathered rock.		

Backfill Elevation (mOD): 82.79, 81.79, 80.79

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 4 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
RIG TYPE			
FLUSH	Air/Mist	**DRILLED BY**	Petersen
INCLINATION (deg)	-90	**LOGGED BY**	D.O'Shea
CORE DIAMETER (mm)	102		
CLIENT	MEHL		
ENGINEER	ARUP		

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
31.50	60	5	0
33.00	80	18	14
34.50	80	22	0
36.00	100	19	0
37.00	100	10	0
37.50	100	10	0
38.30	88	18	0
39.00	100	10	0
	100	23	0

Fracture Spacing Log (mm): 0 250 500

Description	Depth (m)	Elevation
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black/brown, interbedded fine-grained SILTSTONE & MUDSTONE with large amounts of black clay infill (Walshestown Formation), slightly to locally moderately/highly weathered. Discontinuities are smooth to locally rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 26.0-26.15m, 26.42-26.47m, 30.98-31.18m, 31.33-31.41m). Dips are 20-30° & sub-vertical. *(continued)*	32.40	72.39
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical.		

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

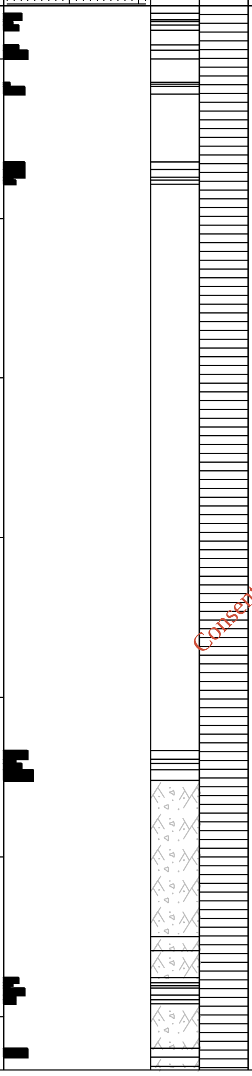
REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 5 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
40.00–40.50			
40.50–42.00	100	7	0
42.00–43.50	87	3	0
43.50–45.00	100	5	0
45.00–46.50	100	0	0
46.50–48.00	100	7	0
48.00–49.50	100	7	0
49.50–			

Downhole Depth (m): 40, 41, 42, 43, 44, 45, 46, 47, 48, 49



Description

Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered.

Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical. *(continued)*

Depth (m) | Elevation | Standpipe Details | Backfill Elevation (mOD)

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

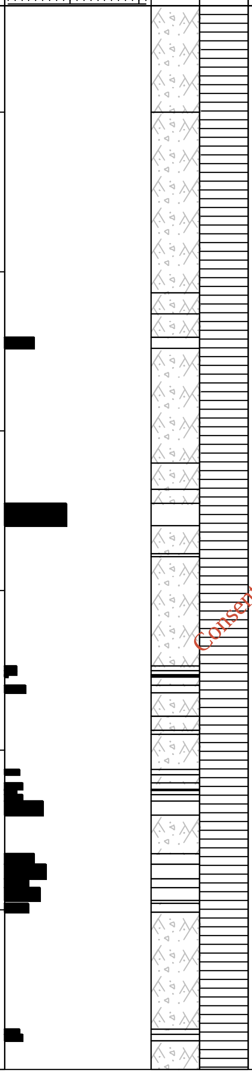
GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER	14695
CONTRACT	MEHL Integrated Waste Management Facility
DRILLHOLE NO	**BH16**
SHEET	Sheet 6 of 6
CO-ORDINATES	315,861.92 E 258,218.23 N
GROUND LEVEL (mOD)	104.79
CLIENT	MEHL
ENGINEER	ARUP
RIG TYPE	
FLUSH	Air/Mist
INCLINATION (deg)	-90
CORE DIAMETER (mm)	102
DATE DRILLED	12/04/2010
DATE LOGGED	20/04/2010
DRILLED BY	Petersen
LOGGED BY	D.O'Shea

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
50		100	16	0
51	51.00	100	2	0
52	52.50	100	4	0
53–54	54.00	100	15	0
55	55.50	100	7	0
56–57	57.00	100	31	9
58–59	58.50	87	8	0
	60.00			



Description

Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered.

Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical. *(continued)*

58.07-58.20m - Limestone layer

Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
60.00	44.79		44.79

End of Borehole at 60.00 m

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
19-04-10	60.00	60.00	2.50	Start of shift

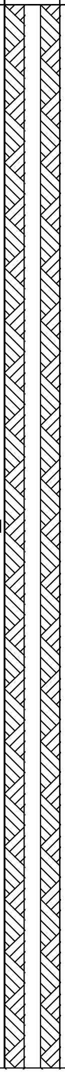
GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 1 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
0								Orange/brown mottled slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with iron-oxide staining.				
1												
2												
3												
4												
5								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with slight iron-oxide staining.	5.00	100.41		
6												
7												
8												
9												



REMARKS

Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 2 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
RIG TYPE			
FLUSH	Air/Mist	**DRILLED BY**	Briody
INCLINATION (deg)	-90	**LOGGED BY**	D.O'Shea
CLIENT	MEHL		
ENGINEER	ARUP		
CORE DIAMETER (mm)			

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
10								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with slight iron-oxide staining. *(continued)*	11.00	94.41		
11								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of shaley siltstone/mudstone.				
12												
13												
14												
15												
16												
17												
18												
19												

REMARKS

Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 3 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
20								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of shaley siltstone/mudstone. *(continued)*				
21												
22								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with slight iron-oxide staining.	22.00	83.41		83.41
23												82.41
24												
25												79.98
26												
27												78.12
28												
29												

REMARKS

Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

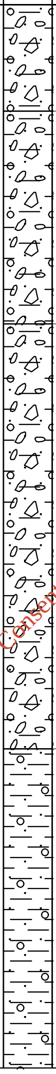
GROUNDWATER DETAILS

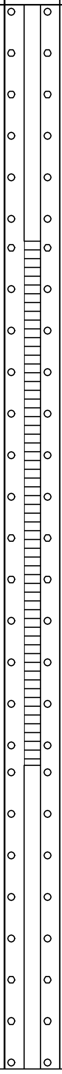
Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 4 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)			
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea





Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
30								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with slight iron-oxide staining. *(continued)*	31.00	74.41		
31								Black/grey/brown slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone with slight iron-oxide staining.				
32									33.00	72.41		73.19
33								Black slightly clayey, sandy GRAVEL - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone/mudstone.				
34												
35												
36									37.00	68.41		
37								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, sandstone & limestone.				68.26
38												
39												

REMARKS

Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 5 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)			

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
40								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, sandstone & limestone. *(continued)*				
41												
42												63.33
43												
44												
45												
46												
47												57.47
48												
49												

REMARKS

Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

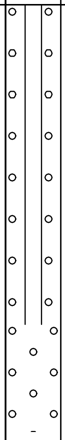
GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH17**
		SHEET	Sheet 6 of 6
CO-ORDINATES	315,794.71 E 258,003.06 N	**DATE DRILLED**	05/05/2010
GROUND LEVEL (mOD)	105.41	**DATE LOGGED**	13/05/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
50								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, sandstone & limestone. *(continued)*				
51												
52												52.41
53												
54								End of Borehole at 54.00 m	54.00	51.41		51.41
55												
56												
57												
58												
59												



REMARKS
Pump Well. Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
	54.00	22.00	54.00	125mm well screen

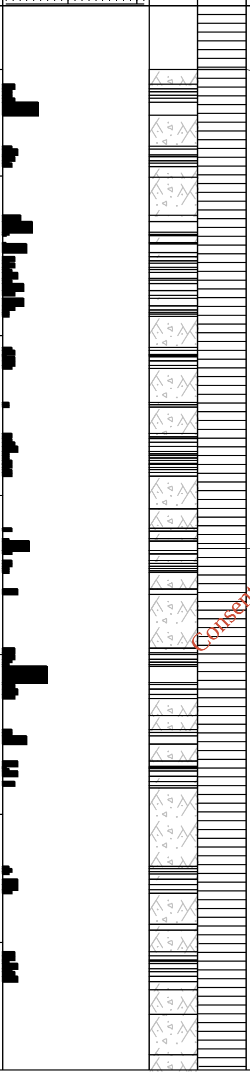
GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,710.96 E 257,996.35 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
RIG TYPE		**DRILLED BY**	Petersen
FLUSH	Air/Mist	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		
CLIENT	MEHL		
ENGINEER	ARUP		



Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation
0.60				SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered shaley mudstone/sandstone with clay layers.	0.60	109.90
1.60	100	14	0	Moderately strong to moderately weak, thickly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey/brown interbedded fine-grained SANDSTONE and MUDSTONE with large amounts of orange/yellow/brown clay infill (Possible Balrickard Formation), moderately to locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 1.61-1.97m, 2.72-2.75m, 3.41-3.73m, 4.73-4.91m & 4.94-5.01m), strongly iron-oxide stained. Dips are 20-30° & 70° to sub-vertical.	5.10	105.40
3.10	100	12	0			
4.60	100	19	0			
6.10	100	24	0	Moderately strong to moderately weak, thinly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey interbedded fine-grained SANDSTONE and MUDSTONE (Possible Donore Formation), slightly to locally moderately weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 5.53-6.04m, 7.35-8.09m, 9.25-9.48m, 9.86-10.11m, 10.29-10.4m, 11.14-11.31m, 11.66-12.0m, 12.08-12.11m, 12.51-13.0m, 13.21-13.44m, 13.79-13.93m, 14.23-14.51m, 14.86-15.2m), strongly iron-oxide stained. Dips are 30-50° & locally sub-vertical. 7.5-8.05m -poor recovery - probable highly weathered rock.		
7.60	100	39	0			
8.80	100	13	0			
	100	17	0			

REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

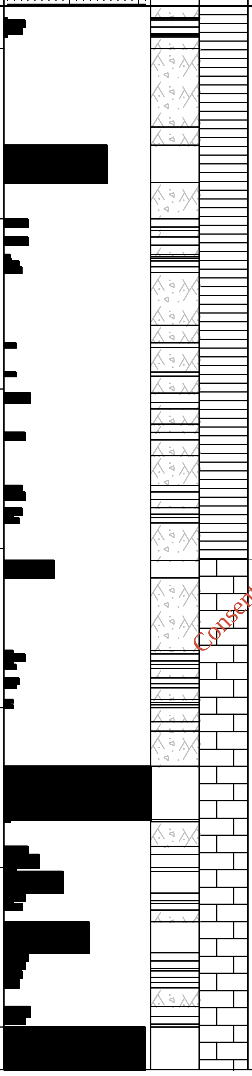
Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	20.00	15.00	21.20	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,710.96 E 257,996.35 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
10.40			
12.00	100	5	0
13.60	100	19	0
15.10	100	8	0
16.60	100	22	11
18.10	100	59	36
19.60	100	81	29



Description

Moderately strong to moderately weak, thinly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey interbedded fine-grained SANDSTONE and MUDSTONE (Possible Donore Formation), slightly to locally moderately weathered.

Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 5.53-6.04m, 7.35-8.09m, 9.25-9.48m, 9.86-10.11m, 10.29-10.4m, 11.14-11.31m, 11.66-12.0m, 12.08-12.11m, 12.51-13.0m, 13.21-13.44m, 13.79-13.93m, 14.23-14.51m, 14.86-15.2m), strongly iron-oxide stained. Dips are 30-50° & locally sub-vertical. *(continued)*

12.7-12.85m -clay layer with angular and linear white mineralisation

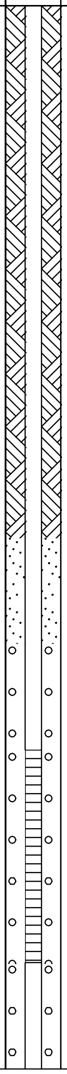
14.80m - Substantial flush loss (100%)

Depth (m): 15.20 — Elevation: 95.30

Strong to very strong (to locally weak where shale), thickly bedded to thinly laminated, grey/dark grey/black, interbedded fine-grained LIMESTONE and MUDSTONE (Shale) (Loughshinny Formation), slightly to locally moderately/highly weathered.

Discontinuities are smooth to locally rough, planar to locally stepped. Apertures are tight to open, locally clay-filled (especially at 15.38-16.06m), strongly iron-oxide stained, locally calcite-veined (2-8mm thick). Dips are 10-20° & locally 70-80°.

18.6-19.0m - Large sub vertical fracture



Backfill Elevation (mOD): 95.50, 94.50, 93.50, 91.50, 90.50

Downhole Depth (m): 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	20.00	15.00	21.20	50mm SP

GROUNDWATER DETAILS

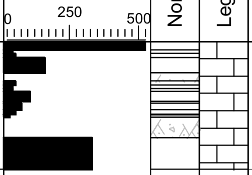
Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,710.96 E 257,996.35 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm)	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
20		100	81	51								
21	21.20								21.20	89.30		89.30
								End of Borehole at 21.20 m				
22												
23												
24												
25												
26												
27												
28												
29												



REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	20.00	15.00	21.20	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
22-04-10	21.20	0.60	9.00	Start of shift

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH19**
		SHEET	Sheet 1 of 2
CO-ORDINATES	315,887.13 E 258,059.09 N	**DATE DRILLED**	21/04/2010
GROUND LEVEL (mOD)	105.08	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
RIG TYPE			
FLUSH	Air/Mist		
INCLINATION (deg)	-90		
CORE DIAMETER (mm)			

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
0								No recovery				
1												
2												
3												
4												
5								Orange/brown mottled sandy slightly gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone.	5.00	100.08		
6												
7												
8												
9												

REMARKS

Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	17.00	13.00	18.00	50mm SP

IGSL RC PHOENIX 14695.GPJ IGSL.GDT 7/9/10

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**DRILLHOLE NO**	**BH19**
		SHEET	Sheet 2 of 2
CO-ORDINATES	315,887.13 E 258,059.09 N	**DATE DRILLED**	21/04/2010
GROUND LEVEL (mOD)	105.08	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Briody
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm)

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm) 0 250 500	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
10								Orange/brown mottled sandy slightly gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of siltstone, mudstone & sandstone. *(continued)*	11.00	94.08		
11								Dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, siltstone & sandstone.	14.00	91.08		92.08 91.08
14								Slightly wet dark brown, slightly sandy gravelly CLAY - highly weathered rock. Gravel is angular to sub-angular, fine to coarse, of mudstone, siltstone & sandstone.	18.00	87.08		89.08 88.08 87.08
18								End of Borehole at 18.00 m				
19												

REMARKS

Descriptions based on chipped returns from open hole drilling

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
21-04-10	18.00	16.00	1.45	Start of shift

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	17.00	13.00	18.00	50mm SP

Appendix F

Monitoring Dataset

Manual Groundwater Level Measurements

BH05			BH08			BH08A			BH09			BH10A	
BH05			BH08			BH08A			BH09			BH10A	
118.615	**Datum**		**136.748**	**Datum**		**136.687**	**Datum**		**128.759**	**Datum**		**136.985**	**Datum**
Nam	**Unit**		**Overburden & Shallow Nam**	**Unit**		**Nam**	**Unit**		**Nam**	**Unit**		**LF**	**Unit**
Date/Time	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**
19/02/2018	16.62	102.00	24/08/2018 12:00	3.43	133.32	16/11/2018 15:11	33.04	103.65	24/08/2018	24.25	104.51	22/02/2018	37.67
20/02/2018	16.62	102.00	27/08/2018 12:00	3.47	133.28	20/11/2018 09:37	33.05	103.64	27/08/2018	24.26	104.50	23/02/2018	37.69
21/02/2018	16.63	101.99	05/09/2018 12:00	3.50	133.25	20/11/2018 10:13	33.05	103.64	05/09/2018	24.50	104.26	26/02/2018	37.70
22/02/2018	16.59	102.03	13/09/2018 12:00	3.80	132.95	20/11/2018 10:39	33.05	103.64	13/09/2018	24.55	104.21	05/03/2018	37.59
23/02/2018	16.58	102.04	20/09/2018 15:26	3.53	133.22	20/11/2018 11:22	33.05	103.64	20/09/2018 15:35	24.60	104.16	06/03/2018	37.58
26/02/2018	16.58	102.04	27/09/2018 15:32	3.62	133.13	20/11/2018 11:52	33.06	103.63	27/09/2018 15:27	24.56	104.20	08/03/2018	37.58
05/03/2018	16.44	102.18	03/10/2018 14:17	3.55	133.20	20/11/2018 13:02	33.04	103.65	03/10/2018 14:22	24.64	104.12	13/03/2018	37.57
06/03/2018	16.46	102.16	10/10/2018 14:26	3.57	133.18	20/11/2018 13:05	33.05	103.64	10/10/2018 14:39	24.66	104.10	27/03/2018	37.60
08/03/2018	16.41	102.21	18/10/2018 14:34	3.19	133.56	20/11/2018 14:27	33.04	103.64	18/10/2018 14:40	24.85	103.91	06/04/2018	37.62
13/03/2018	16.39	102.23	31/10/2018 12:15	3.27	133.48	20/11/2018 14:59	33.05	103.64	31/10/2018 10:25	25.04	103.72	13/04/2018	37.65
27/03/2018	16.40	102.22	08/11/2018 13:40	3.08	133.67	21/11/2018 09:30	33.05	103.64	08/11/2018 10:02	25.07	103.69	20/04/2018	37.72
06/04/2018	16.48	102.14	16/11/2018 15:11	3.25	133.50	21/11/2018 12:26	33.06	103.63	16/11/2018 12:30	25.30	103.46	27/04/2018	37.56
13/04/2018	16.55	102.07	20/11/2018 10:41	3.31	133.44	21/11/2018 15:57	33.06	103.63	20/11/2018 09:42	25.31	103.45	04/05/2018	37.52
20/04/2018	16.53	102.09	20/11/2018 11:54	3.30	133.45	22/11/2018 10:20	33.07	103.62	20/11/2018 10:17	25.31	103.45	18/05/2018	37.60
27/04/2018	16.62	102.00	20/11/2018 14:29	3.30	133.45	22/11/2018 14:39	33.07	103.62	20/11/2018 10:45	25.31	103.45	25/05/2018	37.67
04/05/2018	16.76	101.86	20/11/2018 11:23	3.30	133.45	23/11/2018 08:49	33.07	103.62	20/11/2018 11:27	25.31	103.45	01/06/2018	37.57
18/05/2018	17.00	101.62	20/11/2018 09:39	3.30	133.45	23/11/2018 16:18	33.07	103.62	20/11/2018 11:58	25.30	103.46	08/06/2018	37.20
25/05/2018	17.03	101.59	20/11/2018 10:15	3.30	133.45	24/11/2018 09:05	33.07	103.62	20/11/2018 13:26	25.30	103.46	15/06/2018	37.39
01/06/2018	17.16	101.46	20/11/2018 13:21	3.30	133.45	24/11/2018 14:15	33.07	103.62	20/11/2018 14:33	25.32	103.44	22/06/2018	37.44
08/06/2018	17.20	101.42	20/11/2018 14:58	3.30	133.45	24/11/2018 16:04	33.07	103.62	20/11/2018 15:02	25.30	103.46	29/06/2018	37.89
15/06/2018	17.22	101.40	20/11/2018 13:53	3.30	133.45	25/11/2018 10:20	33.08	103.61	21/11/2018 09:32	25.31	103.45	06/07/2018	37.83
22/06/2018	17.25	101.37	21/11/2018 12:27	3.02	133.73	25/11/2018 16:26	33.08	103.61	21/11/2018 12:30	25.30	103.46	13/07/2018	37.75
29/06/2018	17.15	101.47	21/11/2018 09:31	3.01	133.74	26/11/2018 08:48	33.10	103.59	21/11/2018 16:03	25.31	103.45	20/07/2018	37.82
06/07/2018	17.04	101.58	21/11/2018 15:58	3.01	133.74	26/11/2018 15:16	33.10	103.59	22/11/2018 10:23	25.31	103.45	27/07/2018	37.81
13/07/2018	17.06	101.56	22/11/2018 10:21	2.98	133.77	27/11/2018 09:42	33.07	103.62	22/11/2018 14:42	25.31	103.45	01/08/2018	37.77
20/07/2018	17.10	101.52	22/11/2018 14:38	2.97	133.78	27/11/2018 15:45	33.07	103.62	23/11/2018 08:54	25.31	103.45	09/08/2018	37.82
27/07/2018	17.16	101.46	23/11/2018 16:20	3.01	133.74	28/11/2018 09:46	33.04	103.65	23/11/2018 16:21	25.30	103.46	17/08/2018	37.80
01/08/2018	17.24	101.38	23/11/2018 08:50	3.00	133.75	28/11/2018 15:52	33.05	103.64	24/11/2018 09:09	25.32	103.44	24/08/2018	37.83
09/08/2018	17.21	101.41	24/11/2018 14:16	3.06	133.69	29/11/2018 09:37	33.03	103.66	24/11/2018 14:19	25.32	103.44	27/08/2018	37.87
17/08/2018	17.28	101.34	24/11/2018 16:03	3.06	133.69	29/11/2018 15:41	33.03	103.66	24/11/2018 16:06	25.32	103.44	05/09/2018	38.20
24/08/2018	17.36	101.26	24/11/2018 09:07	3.05	133.70	30/11/2018 09:16	33.04	103.65	25/11/2018 10:23	25.33	103.43	13/09/2018	38.26
27/08/2018	17.45	101.17	25/11/2018 10:19	3.09	133.66	30/11/2018 15:27	33.04	103.65	25/11/2018 16:29	25.33	103.43	20/09/2018 15:30	38.32
05/09/2018	17.71	100.91	25/11/2018 16:25	3.09	133.66	01/12/2018 09:22	33.00	103.69	26/11/2018 08:53	25.34	103.42	27/09/2018 17:00	38.33
13/09/2018	17.64	100.98	26/11/2018 08:50	3.10	133.65	01/12/2018 15:37	32.99	103.70	26/11/2018 15:18	25.35	103.41	03/10/2018 17:04	38.36
20/09/2018 15:19	17.78	100.84	26/11/2018 15:15	3.09	133.66	02/12/2018 10:45	32.97	103.72	27/11/2018 09:44	25.31	103.45	10/10/2018 17:00	38.39
27/09/2018 15:41	17.84	100.78	27/11/2018 09:40	3.05	133.70	02/12/2018 16:09	32.95	103.74	27/11/2018 15:47	25.32	103.44	18/10/2018 11:36	38.65
03/10/2018 14:10	17.86	100.76	27/11/2018 15:44	2.94	133.81	03/12/2018 09:11	32.96	103.73	28/11/2018 09:48	25.27	103.49	31/10/2018 11:20	38.60
10/10/2018 14:16	17.83	100.79	28/11/2018 09:44	2.83	133.92	03/12/2018 10:38	32.93	103.76	28/11/2018 15:54	25.29	103.47	06/11/2018 16:00	38.60
18/10/2018 14:47	17.98	100.64	28/11/2018 15:51	2.77	133.98	03/12/2018 11:01	32.93	103.76	29/11/2018 09:40	25.27	103.49	20/11/2018 08:01	38.56
31/10/2018 10:14	18.06	100.56	29/11/2018 09:38	2.85	133.90	03/12/2018 11:46	32.92	103.76	29/11/2018 15:42	25.27	103.49	20/11/2018 11:06	38.56
08/11/2018 10:05	18.78	99.84	29/11/2018 15:39	2.80	133.95	03/12/2018 12:10	32.93	103.76	30/11/2018 09:18	25.27	103.49	20/11/2018 11:50	38.57
15/11/2018 15:05	18.38	100.24	30/11/2018 09:15	2.81	133.94	03/12/2018 13:37	32.93	103.76	30/11/2018 15:29	25.27	103.49	20/11/2018 13:11	38.56
20/11/2018 09:44	18.33	100.29	30/11/2018 15:25	2.85	133.90	03/12/2018 14:03	32.93	103.76	01/12/2018 09:32	25.24	103.52	20/11/2018 13:45	38.56
20/11/2018 10:26	18.55	100.07	01/12/2018 09:20	2.93	133.82	03/12/2018 14:28	32.93	103.76	01/12/2018 15:40	25.23	103.53	20/11/2018 14:25	38.56
20/11/2018 10:49	18.73	99.89	01/12/2018 15:36	2.94	133.81	03/12/2018 15:02	32.93	103.76	02/12/2018 10:48	25.22	103.54	20/11/2018 15:07	38.56
20/11/2018 11:31	18.92	99.69	02/12/2018 10:44	2.97	133.78	03/12/2018 15:29	32.93	103.76	02/12/2018 16:10	25.20	103.56	21/11/2018 08:23	38.54
20/11/2018 12:02	19.02	99.60	02/12/2018 16:08	2.97	133.78	04/12/2018 07:19	32.97	103.72	03/12/2018 09:14	25.20	103.56	21/11/2018 10:00	38.54
20/11/2018 13:30	19.17	99.45	03/12/2018 09:05	2.98	133.77	05/12/2018 12:23	32.87	103.82	03/12/2018 10:42	25.19	103.57	21/11/2018 12:05	38.53
20/11/2018 14:04	19.21	99.41	03/12/2018 10:38	2.98	133.77	17/12/2018 12:05	32.41	104.28	03/12/2018 11:08	25.18	103.58	21/11/2018 15:24	38.52
20/11/2018 14:37	19.24	99.38	03/12/2018 11:04	2.98	133.77	23/01/2019 09:19	31.48	105.21	03/12/2018 11:50	25.18	103.58	22/11/2018 08:30	38.53
20/11/2018 15:07	19.26	99.36	03/12/2018 11:42	2.98	133.77	15/02/2019 15:00	31.60	105.09	03/12/2018 12:13	25.21	103.55	22/11/2018 11:21	38.58
21/11/2018 09:36	19.54	99.08	03/12/2018 12:09	2.99	133.76	08/03/2019 12:17	31.66	105.03	03/12/2018 13:44	25.18	103.58	22/11/2018 15:10	38.58
21/11/2018 12:35	19.56	99.06	03/12/2018 13:36	2.99	133.76	11/04/2019 11:32	30.91	105.78	03/12/2018 14:07	25.18	103.58	23/11/2018 08:32	38.56
21/11/2018 18:08	19.59	99.03	03/12/2018 14:02	2.99	133.76	10/05/2019 11:32	31.21	105.48	03/12/2018 14:33	25.18	103.58	23/11/2018 14:03	38.56
22/11/2018 10:27	19.73	98.89	03/12/2018 14:27	2.99	133.76				03/12/2018 15:06	25.18	103.58	23/11/2018 15:51	38.54
22/11/2018 14:46	19.73	98.89	03/12/2018 15:01	2.98	133.77				04/12/2018 00:00	25.29	103.47	24/11/2018 10:21	38.59
23/11/2018 08:59	19.80	98.82	03/12/2018 15:28	2.99	133.76				04/12/2018 07:23	25.21	103.55	24/11/2018 15:31	38.55
23/11/2018 16:25	19.82	98.80	04/12/2018 07:18	3.00	133.75				05/12/2018 12:29	24.99	103.77	25/11/2018 09:46	38.59
24/11/2018 09:13	19.94	98.68	05/12/2018 12:26	2.89	133.86				17/12/2018 12:05	24.51	104.25	25/11/2018 15:54	38.56
24/11/2018 14:22	19.96	98.66	17/12/2018 12:05	3.10	133.65				23/01/2019 09:19	23.61	105.15	26/11/2018 08:20	38.57
24/11/2018 16:09	19.96	98.66	23/01/2019 09:19	3.58	133.17				15/02/2019 09:40	23.77	104.99	26/11/2018 14:45	38.60
25/11/2018 10:27	20.03	98.59	15/02/2019 15:02	3.20	133.55				08/03/2019 12:25	23.93	104.83	27/11/2018 09:05	38.56
25/11/2018 16:33	20.03	98.59	08/03/2019 12:15	2.95	133.80				11/04/2019 11:36	23.18	105.58	27/11/2018 15:05	38.55
26/11/2018 08:37	20.10	98.52	11/04/2019 11:29	3.26	133.49				10/05/2019 10:47	23.49	105.27	28/11/2018 09:05	38.51
26/11/2018 15:21	20.14	98.48	10/05/2019 10:42	3.425	133.32							28/11/2018 15:16	38.54
27/11/2018 09:47	20.14	98.48										29/11/2018 08:55	38.50
27/11/2018 15:50	20.21	98.41										29/11/2018 14:56	38.53
28/11/2018 09:51	20.22	98.40										30/11/2018 08:33	38.54
28/11/2018 15:58	20.28	98.34										30/11/2018 14:52	38.56
29/11/2018 09:44	20.34	98.28										01/12/2018 10:11	38.52
29/11/2018 15:47	20.36	98.26										01/12/2018 15:02	38.53
30/11/2018 09:21	20.44	98.18										02/12/2018 10:09	38.51
30/11/2018 15:32	20.46	98.16										02/12/2018 15:39	38.52
01/12/2018 09:35	20.42	98.20										03/12/2018 08:28	38.54
01/12/2018 15:43	20.46	98.16										03/12/2018 11:38	38.54
02/12/2018 10:50	20.52	98.10										03/12/2018 12:28	38.54
02/12/2018 16:13	20.52	98.10										03/12/2018 13:45	38.50
03/12/2018 09:19	20.56	98.06										03/12/2018 14:25	38.50
03/12/2018 10:46	20.44	98.18										04/12/2018 08:27	38.57
03/12/2018 11:10	20.26	98.36										05/12/2018 13:27	38.44
03/12/2018 11:17	20.01	98.60										17/12/2018 09:30	38.39
03/12/2018 11:53	20.08	98.54										23/01/2019 08:44	38.25
03/12/2018 13:48	19.82	98.79										15/02/2019 08:05	38.24
03/12/2018 14:10	19.80	98.82										08/03/2019 15:35	38.27
03/12/2018 14:37	19.77	98.85										11/04/2019 12:55	39.09
03/12/2018 15:12	19.73	98.88										10/05/2019 13:48	40.42
04/12/2018 07:27	19.38	99.24											
05/12/2018 12:18	19.02	99.60											
17/12/2018 12:18	18.31	100.31											
15/02/2019 14:38	17.31	101.31											
08/03/2019 15:35	17.24	101.38											
11/04/2019 12:43	17.46	101.16											
10/05/2019 11:18	18.225	100.39											

🟩	**Background or Long-Term Monitoring**
🟦	**Constant Rate Test**

Manual Groundwater Level Measurements

	BH11A			**BH13**			**BH14**		
	BH11A						BH14		
	99.96	**Datum**			**Datum**		**125.064**	**Datum**	
	Nam	**Unit**			**Unit**		**LF**	**Unit**	
maOD	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**
99.32	24/08/2018	0.59	99.37	24/08/2018	31.87	-31.87	24/08/2018	26.97	98.09
99.30	27/08/2018	0.62	99.34	27/08/2018	31.91	-31.91	27/08/2018	27.02	98.04
99.29	05/09/2018	1.48	98.48	05/09/2018	32.88	-32.88	05/09/2018	27.10	97.96
99.40	13/09/2018	1.45	98.51	13/09/2018	32.75	-32.75	13/09/2018	26.96	98.10
99.41	20/09/2018 15:41	1.50	98.46	20/09/2018 15:53	32.66	-32.66	20/09/2018 16:07	27.01	98.05
99.41	27/09/2018 15:09	1.54	98.42	27/09/2018 14:57	32.94	-32.94	27/09/2018 14:47	27.03	98.03
99.42	03/10/2018 14:30	1.52	98.44	10/10/2018 14:59	32.92	-32.92	03/10/2018 14:45	26.98	98.08
99.39	10/10/2018 14:46	1.55	98.41	31/10/2018 11:00	33.10	-33.10	10/10/2018 15:07	27.02	98.04
99.37	18/10/2018 15:08	1.48	98.48	08/11/2018 14:00	33.03	-33.03	18/10/2018 15:48	27.14	97.92
99.34	31/10/2018 10:30	1.42	98.54	22/01/2019 09:01	34.13	-34.13	31/10/2018 10:18	27.14	97.92
99.27	08/11/2018 10:25	1.47	98.49	08/03/2019 12:06	34.15	-34.15	08/11/2018 11:00	27.24	97.82
99.43	16/11/2018 10:05	1.59	98.37	11/04/2019 11:22	33.45	-33.45	27/11/2018 15:10	27.33	97.74
99.47	20/11/2018 09:00	1.57	98.39	10/05/2019 10:35	33.76	-33.76	27/11/2018 09:10	27.24	97.82
99.39	20/11/2018 10:17	1.59	98.37				27/11/2018 15:21	27.28	97.78
99.32	20/11/2018 10:45	1.59	98.37				29/11/2018 09:00	27.27	97.79
99.42	20/11/2018 11:15	1.59	98.37				29/11/2018 15:05	27.29	97.77
99.79	20/11/2018 11:40	1.59	98.37				30/11/2018 08:39	27.35	97.71
99.60	20/11/2018 12:48	1.59	98.37				30/11/2018 14:58	27.34	97.73
99.55	20/11/2018 13:50	1.59	98.37				01/12/2018 10:18	27.25	97.81
99.10	20/11/2018 14:57	1.59	98.37				01/12/2018 15:08	27.26	97.80
99.16	20/11/2018 15:35	1.59	98.37				02/12/2018 10:12	27.26	97.80
99.24	21/11/2018 08:37	1.46	98.50				02/12/2018 15:44	27.24	97.82
99.17	21/11/2018 12:05	1.49	98.48				03/12/2018 08:33	27.29	97.78
99.18	21/11/2018 15:40	1.50	98.46				03/12/2018 11:54	27.29	97.77
99.22	22/11/2018 10:41	1.60	98.36				03/12/2018 12:34	27.30	97.76
99.17	22/11/2018 14:59	1.60	98.36				03/12/2018 13:52	27.30	97.76
99.19	23/11/2018 09:15	1.61	98.36				03/12/2018 14:43	27.30	97.76
99.16	23/11/2018 16:35	1.61	98.35				04/12/2018 08:31	27.33	97.73
99.12	24/11/2018 09:41	1.63	98.34				05/12/2018 11:00	27.17	97.89
98.79	24/11/2018 14:34	1.61	98.35				17/12/2018 10:12	27.07	98.00
98.73	24/11/2018 16:25	1.61	98.35				23/01/2019 11:19	26.96	98.10
98.67	25/11/2018 11:13	1.61	98.36				15/02/2019 08:31	26.93	98.13
98.66	25/11/2018 16:51	1.61	98.35				08/03/2019 08:45	27.10	97.96
98.63	26/11/2018 09:23	1.60	98.37				11/04/2019 13:01	27.30	97.76
98.60	26/11/2018 15:49	1.61	98.36				10/05/2019 14:04	28.06	97.00
98.34	27/11/2018 10:19	1.60	98.36						
98.39	27/11/2018 16:21	1.53	98.43						
98.39	28/11/2018 10:27	1.60	98.36						
98.43	28/11/2018 16:25	1.60	98.36						
98.43	29/11/2018 10:10	1.50	98.46						
98.42	29/11/2018 16:14	1.58	98.38						
98.43	30/11/2018 10:17	1.61	98.36						
98.43	30/11/2018 16:00	1.61	98.36						
98.43	01/12/2018 09:14	1.61	98.36						
98.43	01/12/2018 16:06	1.61	98.36						
98.45	02/12/2018 11:18	1.61	98.36						
98.45	02/12/2018 16:35	1.60	98.36						
98.46	03/12/2018 09:53	1.60	98.36						
98.47	03/12/2018 10:55	1.60	98.36						
98.46	03/12/2018 11:35	1.60	98.36						
98.41	03/12/2018 12:28	1.61	98.36						
98.41	03/12/2018 13:43	1.61	98.36						
98.43	03/12/2018 14:46	1.61	98.36						
98.43	03/12/2018 15:22	1.61	98.36						
98.45	03/12/2018 16:17	1.61	98.36						
98.40	04/12/2018 07:51	1.60	98.36						
98.44	05/12/2018 11:00	1.49	98.47						
98.40	17/12/2018 11:35	1.55	98.41						
98.43	23/01/2019 11:19	1.49	98.47						
98.42	15/02/2019 09:05	1.52	98.44						
98.39	08/03/2019 14:42	1.54	98.42						
98.43	11/04/2019 12:33	1.60	98.36						
98.44	10/05/2019 13:37	1.61	98.35						
98.48									
98.45									
98.49									
98.46									
98.45									
98.43									
98.47									
98.46									
98.48									
98.47									
98.45									
98.45									
98.45									
98.49									
98.49									
98.42									
98.55									
98.60									
98.74									
98.75									
98.72									
97.90									
96.57									

Manual Groundwater Level Measurements

BH15A			BH17			BH18			BH19			BH20			BH24
BH15A			BH17			BH18			BH19			BH20			BH24
106.134	**Datum**		**105.295**	**Datum**		**110.403**	**Datum**		**105.52**	**Datum**		**104.178**	**Datum**		**106.039**
LF	**Unit**		**LF & Nam**	**Unit**		**LF**	**Unit**		**Nam**	**Unit**		**Nam**	**Unit**		**Nam**
Date/Time	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**
19/02/2018	6.45	99.68	19/02/2018	4.90	100.40	16/11/2018 12:30	10.61	99.79	24/08/2018 12:00	4.30	101.22	18/10/2018 16:20	4.64	99.54	23/02/2018
20/02/2018	6.56	99.57	20/02/2018	4.91	100.39	20/11/2018 09:09	10.65	99.75	27/08/2018 12:00	4.35	101.17	31/10/2018 11:18	5.06	99.12	26/02/2018
21/02/2018	6.56	99.57	21/02/2018	4.92	100.38	20/11/2018 10:06	10.65	99.75	05/09/2018 12:00	4.48	101.04	08/11/2018 11:45	8.52	95.66	05/03/2018
22/02/2018	6.53	99.60	22/02/2018	4.92	100.38	20/11/2018 10:31	10.66	99.74	13/09/2018 12:00	4.59	100.93	15/11/2018 11:15	4.94	99.24	06/03/2018
23/02/2018	6.54	99.59	23/02/2018	4.91	100.39	20/11/2018 10:56	10.66	99.74	20/09/2018 16:38	4.59	100.93	19/11/2018 09:12	4.98	99.20	08/03/2018
26/02/2018	6.53	99.60	26/02/2018	4.89	100.41	20/11/2018 11:03	10.66	99.74	27/09/2018 14:16	4.64	100.88	20/11/2018 09:04	4.91	99.27	13/03/2018
05/03/2018	6.48	99.65	05/03/2018	4.75	100.55	20/11/2018 11:51	10.67	99.73	03/10/2018 15:11	4.60	100.92	20/11/2018 10:07	5.27	98.91	27/03/2018
06/03/2018	6.48	99.65	06/03/2018	4.73	100.57	20/11/2018 12:33	10.67	99.73	10/10/2018 15:35	4.56	100.96	20/11/2018 10:25	5.55	98.62	06/04/2018
08/03/2018	6.50	99.63	08/03/2018	4.73	100.57	20/11/2018 13:04	10.68	99.72	18/10/2018 16:23	4.80	100.72	20/11/2018 10:39	5.79	98.39	13/04/2018
13/03/2018	6.50	99.63	13/03/2018	4.70	100.60	20/11/2018 13:39	10.68	99.72	31/10/2018 11:20	4.98	100.54	20/11/2018 10:46	5.84	98.34	20/04/2018
27/03/2018	6.51	99.62	27/03/2018	4.82	100.48	20/11/2018 14:16	10.68	99.72	08/11/2018 11:35	5.54	99.98	20/11/2018 11:05	5.95	98.23	27/04/2018
06/04/2018	6.45	99.68	06/04/2018	4.75	100.55	20/11/2018 14:44	10.69	99.71	15/11/2018 11:59	4.79	100.73	20/11/2018 11:20	6.03	98.15	04/05/2018
13/04/2018	6.65	99.48	13/04/2018	4.65	100.65	20/11/2018 15:55	10.70	99.70	19/11/2018 09:22	4.79	100.73	20/11/2018 11:36	6.08	98.10	18/05/2018
20/04/2018	6.50	99.63	20/04/2018	4.72	100.58	21/11/2018 08:44	10.76	99.64	20/11/2018 09:07	4.84	100.68	20/11/2018 11:49	6.13	98.05	25/05/2018
27/04/2018	6.24	99.89	27/04/2018	4.67	100.63	21/11/2018 11:25	10.76	99.64	20/11/2018 10:11	4.84	100.68	20/11/2018 12:36	6.24	97.94	01/06/2018
04/05/2018	6.37	99.76	04/05/2018	4.71	100.59	21/11/2018 15:28	10.73	99.67	20/11/2018 10:29	4.86	100.66	20/11/2018 13:37	6.33	97.85	08/06/2018
18/05/2018	6.52	99.61	18/05/2018	4.56	100.74	22/11/2018 10:32	10.71	99.69	20/11/2018 10:39	4.88	100.65	20/11/2018 14:42	6.38	97.80	15/06/2018
25/05/2018	6.67	99.46	25/05/2018	4.70	100.60	22/11/2018 15:04	10.74	99.66	20/11/2018 10:46	4.89	100.63	20/11/2018 15:34	6.42	97.76	22/06/2018
01/06/2018	6.87	99.26	01/06/2018	4.43	100.87	23/11/2018 08:46	10.83	99.57	20/11/2018 11:04	4.92	100.60	20/11/2018 16:33	6.45	97.73	29/06/2018
08/06/2018	6.93	99.20	08/06/2018	4.40	100.90	23/11/2018 15:29	10.87	99.54	20/11/2018 11:23	4.96	100.56	20/11/2018 19:11	6.51	97.67	06/07/2018
15/06/2018	6.97	99.16	15/06/2018	4.60	100.70	24/11/2018 09:32	10.96	99.44	20/11/2018 11:38	4.99	100.54	21/11/2018 07:34	6.61	97.57	13/07/2018
22/06/2018	7.00	99.13	22/06/2018	4.72	100.58	24/11/2018 14:13	10.98	99.42	20/11/2018 11:52	5.01	100.51	21/11/2018 11:15	6.65	97.53	20/07/2018
29/06/2018	7.05	99.08	29/06/2018	4.78	100.52	24/11/2018 16:12	10.99	99.42	20/11/2018 12:38	5.08	100.44	21/11/2018 14:08	6.66	97.52	27/07/2018
06/07/2018	7.00	99.13	06/07/2018	4.64	100.66	25/11/2018 10:44	11.08	99.33	20/11/2018 13:39	5.15	100.37	21/11/2018 16:26	6.68	97.50	01/08/2018
13/07/2018	6.93	99.20	13/07/2018	4.60	100.70	25/11/2018 16:42	11.09	99.31	20/11/2018 14:48	5.21	100.32	21/11/2018 20:38	6.73	97.45	09/08/2018
20/07/2018	6.78	99.35	20/07/2018	4.52	100.78	26/11/2018 09:14	11.15	99.25	20/11/2018 15:37	5.24	100.28	22/11/2018 08:21	6.77	97.41	17/08/2018
27/07/2018	6.74	99.39	27/07/2018	4.47	100.83	26/11/2018 15:36	11.18	99.22	20/11/2018 16:35	5.27	100.25	22/11/2018 14:15	6.77	97.41	24/08/2018
01/08/2018	6.81	99.32	01/08/2018	4.52	100.78	27/11/2018 10:06	11.20	99.20	20/11/2018 19:14	5.35	100.18	22/11/2018 18:12	6.80	97.38	27/08/2018
09/08/2018	6.79	99.34	09/08/2018	4.54	100.76	27/11/2018 16:10	11.20	99.20	20/11/2018 21:54	5.40	100.12	23/11/2018 08:10	6.84	97.34	13/09/2018
17/08/2018	6.81	99.32	17/08/2018	4.54	100.76	28/11/2018 10:15	11.15	99.25	21/11/2018 07:37	5.42	100.10	23/11/2018 14:13	6.86	97.32	20/09/2018 16:47
24/08/2018	7.03	99.10	24/08/2018	4.58	100.72	28/11/2018 16:14	11.16	99.24	21/11/2018 11:18	5.47	100.05	23/11/2018 18:09	6.87	97.31	27/09/2018 14:05
27/08/2018	7.15	98.98	27/08/2018	4.64	100.66	29/11/2018 10:01	11.18	99.22	21/11/2018 14:12	5.49	100.03	24/11/2018 08:40	6.95	97.23	03/10/2018 15:21
05/09/2018	7.23	98.90	05/09/2018	5.75	99.55	29/11/2018 16:02	11.16	99.24	21/11/2018 16:28	5.52	100.00	24/11/2018 13:42	6.96	97.22	10/10/2018 15:46
13/09/2018	7.34	98.79	13/09/2018	5.69	99.61	30/11/2018 10:05	11.15	99.25	21/11/2018 20:41	5.58	99.95	24/11/2018 19:31	7.00	97.18	18/10/2018 15:46
20/09/2018 16:16	7.41	98.72	20/09/2018 16:23	5.76	99.54	30/11/2018 15:49	11.16	99.24	22/11/2018 08:25	5.62	99.91	25/11/2018 10:49	7.05	97.13	31/10/2018 11:35
27/09/2018 14:36	7.37	98.76	27/09/2018 14:25	5.71	99.59	01/12/2018 09:01	11.20	99.21	22/11/2018 14:17	5.63	99.90	25/11/2018 14:05	7.05	97.13	08/11/2018 12:00
03/10/2018 14:51	7.41	98.72	03/10/2018 15:07	5.70	99.60	01/12/2018 15:56	11.22	99.18	22/11/2018 18:16	5.64	99.89	25/11/2018 19:29	7.07	97.11	15/11/2018 10:20
10/10/2018 15:14	7.42	98.71	10/10/2018 15:20	6.67	98.63	02/12/2018 11:07	11.26	99.14	23/11/2018 08:12	5.66	99.86	26/11/2018 07:47	7.11	97.07	19/11/2018 09:36
18/10/2018 16:08	7.50	98.63	18/10/2018 16:16	5.94	99.36	02/12/2018 16:25	11.27	99.13	23/11/2018 14:17	5.68	99.84	26/11/2018 14:12	7.12	97.06	20/11/2018 09:01
31/10/2018 10:45	7.60	98.53	31/10/2018 11:10	6.03	99.27	03/12/2018 09:40	11.30	99.10	23/11/2018 18:12	5.70	99.83	26/11/2018 18:08	7.12	97.06	20/11/2018 10:03
08/11/2018 11:15	7.60	98.53	08/11/2018 11:30	6.60	98.70	03/12/2018 10:39	11.30	99.10	24/11/2018 08:42	5.77	99.76	27/11/2018 08:47	7.13	97.05	20/11/2018 10:21
15/11/2018 13:48	7.79	98.34	15/11/2018 12:15	6.02	99.28	03/12/2018 11:11	11.30	99.10	24/11/2018 13:44	5.79	99.73	27/11/2018 14:08	7.14	97.04	20/11/2018 10:32
20/11/2018 09:02	7.78	98.35	19/11/2018 09:26	6.04	99.26	03/12/2018 11:19	11.30	99.10	24/11/2018 19:33	5.81	99.71	27/11/2018 18:22	7.17	97.01	20/11/2018 10:52
20/11/2018 10:04	7.78	98.35	20/11/2018 09:11	6.07	99.23	03/12/2018 11:52	11.30	99.10	25/11/2018 10:47	5.86	99.67	28/11/2018 08:37	7.14	97.04	20/11/2018 11:09
20/11/2018 10:31	7.78	98.35	20/11/2018 10:14	6.10	99.20	03/12/2018 12:13	11.29	99.11	25/11/2018 14:07	5.86	99.67	28/11/2018 15:02	7.17	97.01	20/11/2018 11:26
20/11/2018 11:13	7.78	98.35	20/11/2018 10:31	6.14	99.15	03/12/2018 12:54	11.29	99.11	25/11/2018 19:31	5.88	99.64	28/11/2018 20:57	7.24	96.94	20/11/2018 11:42
20/11/2018 11:41	7.80	98.34	20/11/2018 10:41	6.16	99.13	03/12/2018 13:26	11.29	99.12	26/11/2018 07:49	5.92	99.61	29/11/2018 08:29	7.20	96.98	20/11/2018 12:02
20/11/2018 12:15	7.78	98.35	20/11/2018 10:49	6.18	99.11	03/12/2018 14:02	11.29	99.12	26/11/2018 14:14	5.92	99.60	29/11/2018 14:21	7.23	96.95	20/11/2018 12:33
20/11/2018 13:42	7.79	98.35	20/11/2018 11:56	6.24	99.05	03/12/2018 14:30	11.28	99.12	26/11/2018 18:11	5.93	99.59	29/11/2018 19:11	7.24	96.94	20/11/2018 13:44
20/11/2018 14:17	7.79	98.35	20/11/2018 12:07	6.27	99.02	03/12/2018 15:37	11.28	99.13	27/11/2018 08:49	5.89	99.64	30/11/2018 08:20	7.29	96.89	20/11/2018 14:42
20/11/2018 14:49	7.78	98.35	20/11/2018 13:36	6.32	98.98	03/12/2018 16:26	11.28	99.13	27/11/2018 14:10	5.87	99.65	30/11/2018 16:12	7.33	96.85	20/11/2018 15:58
20/11/2018 15:21	7.79	98.34	20/11/2018 14:11	6.33	98.96	04/12/2018 07:31	11.18	99.22	27/11/2018 18:25	5.93	99.59	30/11/2018 19:06	7.33	96.85	20/11/2018 19:17
21/11/2018 09:22	7.80	98.33	20/11/2018 14:43	6.35	98.95	05/12/2018 11:26	10.97	99.43	28/11/2018 08:39	5.88	99.64	01/12/2018 08:40	7.29	96.89	20/11/2018 21:37
21/11/2018 12:19	7.82	98.31	20/11/2018 15:16	6.36	98.94	17/12/2018 11:40	10.32	100.08	28/11/2018 15:04	5.91	99.62	01/12/2018 19:16	7.32	96.86	21/11/2018 07:41
21/11/2018 15:48	7.83	98.30	21/11/2018 11:20	6.46	98.84	23/01/2019 10:04	10.15	100.25	28/11/2018 20:59	6.01	99.51	02/12/2018 09:43	7.35	96.83	21/11/2018 11:21
22/11/2018 10:12	7.84	98.30	21/11/2018 14:14	6.46	98.84	15/02/2019 13:20	10.10	100.30	29/11/2018 08:32	5.92	99.60	02/12/2018 14:12	7.35	96.83	21/11/2018 14:20
22/11/2018 14:28	7.82	98.31	21/11/2018 16:30	6.46	98.84	08/03/2019 12:35	9.91	100.49	29/11/2018 14:23	5.98	99.54	02/12/2018 18:26	7.38	96.80	21/11/2018 16:24
23/11/2018 08:39	7.83	98.31	21/11/2018 20:43	6.48	98.82	11/04/2019 11:43	10.65	99.75	29/11/2018 19:15	6.01	99.51	03/12/2018 10:37	6.99	97.18	21/11/2018 20:50
23/11/2018 15:34	7.83	98.31	22/11/2018 08:27	6.49	98.81	10/05/2019 11:50	11.65	98.75	30/11/2018 08:22	6.08	99.45	03/12/2018 10:50	6.81	97.37	22/11/2018 09:30
24/11/2018 09:26	7.85	98.28	22/11/2018 14:23	6.50	98.80				30/11/2018 16:09	6.10	99.42	03/12/2018 11:00	6.69	97.48	22/11/2018 14:12
24/11/2018 14:07	7.85	98.28	22/11/2018 18:20	6.52	98.78				30/11/2018 19:08	6.11	99.42	03/12/2018 11:13	6.60	97.58	22/11/2018 18:07
24/11/2018 16:15	7.85	98.28	23/11/2018 08:21	6.56	98.74				01/12/2018 08:42	6.04	99.49	03/12/2018 11:22	6.54	97.64	23/11/2018 08:05
25/11/2018 16:38	7.87	98.27	23/11/2018 14:19	6.58	98.72				01/12/2018 19:19	6.07	99.45	03/12/2018 11:35	6.56	97.62	23/11/2018 14:08
25/11/2018 22:38	7.87	98.27	23/11/2018 18:14	6.60	98.70				02/12/2018 09:45	6.09	99.43	03/12/2018 11:50	6.49	97.69	23/11/2018 18:04
26/11/2018 09:08	7.81	98.32	24/11/2018 08:44	6.67	98.63				02/12/2018 14:14	6.10	99.43	03/12/2018 12:11	6.42	97.76	24/11/2018 08:37
26/11/2018 15:32	7.82	98.31	24/11/2018 13:46	6.66	98.64				02/12/2018 18:28	6.11	99.42	03/12/2018 12:24	6.39	97.79	24/11/2018 13:38
27/11/2018 09:57	7.76	98.37	24/11/2018 19:37	6.68	98.62				03/12/2018 10:43	6.21	99.32	03/12/2018 12:49	6.33	97.85	24/11/2018 19:27
27/11/2018 16:04	7.80	98.33	25/11/2018 10:46	6.72	98.58				03/12/2018 10:53	6.19	99.33	03/12/2018 13:25	6.27	97.91	25/11/2018 10:54
28/11/2018 10:10	7.74	98.40	25/11/2018 14:08	6.73	98.57				03/12/2018 11:04	6.18	99.34	03/12/2018 13:48	6.24	97.94	25/11/2018 14:01
28/11/2018 16:09	7.79	98.34	25/11/2018 19:34	6.74	98.56				03/12/2018 11:14	6.15	99.37	03/12/2018 14:32	6.19	97.99	25/11/2018 19:25
29/11/2018 09:52	7.76	98.37	26/11/2018 07:51	6.77	98.53				03/12/2018 11:25	6.14	99.38	03/12/2018 15:26	6.15	98.03	26/11/2018 07:43
29/11/2018 15:57	7.77	98.36	26/11/2018 14:17	6.78	98.52				03/12/2018 11:38	6.11	99.41	03/12/2018 16:32	6.11	98.07	26/11/2018 14:09
30/11/2018 09:46	7.80	98.33	26/11/2018 18:14	6.78	98.52				03/12/2018 11:53	6.08	99.44	03/12/2018 18:38	6.08	98.10	26/11/2018 18:05
30/11/2018 15:44	7.80	98.34	27/11/2018 08:50	6.79	98.51				03/12/2018 12:14	6.05	99.47	04/12/2018 06:55	5.90	98.28	27/11/2018 08:43
01/12/2018 08:56	7.75	98.39	27/11/2018 14:12	6.79	98.51				03/12/2018 12:26	6.03	99.49	05/12/2018 08:46	5.04	99.14	27/11/2018 14:05
01/12/2018 15:51	7.75	98.38	27/11/2018 18:28	6.79	98.51				03/12/2018 12:52	6.00	99.53	17/12/2018 10:53	4.98	99.20	27/11/2018 18:10
02/12/2018 11:02	7.77	98.37	28/11/2018 08:43	6.76	98.54				03/12/2018 13:27	5.95	99.57	22/01/2019 09:50	3.80	100.38	28/11/2018 08:33
02/12/2018 16:21	7.75	98.39	28/11/2018 15:08	6.78	98.52				03/12/2018 13:50	5.93	99.60	15/02/2019 12:47	4.20	99.98	28/11/2018 14:58
03/12/2018 09:36	7.79	98.35	28/11/2018 21:02	6.82	98.48				03/12/2018 14:34	5.89	99.63	08/03/2019 13:37	4.20	99.98	28/11/2018 20:53
03/12/2018 10:52	7.78	98.35	29/11/2018 08:48	6.79	98.51				03/12/2018 15:28	5.85	99.67	11/04/2019 12:11	4.48	99.70	29/11/2018 08:19
03/12/2018 11:16	7.71	98.43	29/11/2018 14:26	6.80	98.50				03/12/2018 16:35	5.81	99.71	10/05/2019 12:31	5.33	98.85	29/11/2018 14:18
03/12/2018 12:00	7.78	98.35	29/11/2018 19:18	6.80	98.50				03/12/2018 18:41	5.76	99.77				29/11/2018 19:07
03/12/2018 12:23	7.78	98.35	30/11/2018 08:25	6.83	98.47				04/12/2018 06:57	5.58	99.94				30/11/2018 08:17
03/12/2018 13:54	7.77	98.36	30/11/2018 16:08	6.84	98.46				05/12/2018 09:14	5.21	100.32				30/11/2018 16:15
03/12/2018 14:18	7.78	98.35	30/11/2018 19:10	6.94	98.36				17/12/2018 11:00	4.60	100.92				30/11/2018 19:05
03/12/2018 14:43	7.78	98.36	01/12/2018 08:45	6.83	98.47				23/01/2019 10:22	3.84	101.68				01/12/2018 08:38
03/12/2018 19:20	7.78	98.35	01/12/2018 19:20	6.86	98.44				15/02/2019 12:58	3.87	101.65				01/12/2018 19:13
04/12/2018 07:35	7.78	98.36	02/12/2018 09:47	6.87	98.43				08/03/2019 13:38	3.83	101.69				02/12/2018 09:40
05/12/2018 11:15	7.64	98.49	02/12/2018 14:16	6.88	98.42				11/04/2019 12:08	3.96	101.56				02/12/2018 14:10
17/12/2018 11:46	7.45	98.68	02/12/2018 18:30	6.89	98.41				10/05/2019 12:34	4.69	100.83				02/12/2018 18:22
23/01/2019 09:46	7.41	98.73	03/12/2018 10:35	6.91	98.39										03/12/2018 10:32
15/02/2019 14:00	7.31	98.82	03/12/2018 11:16	6.77	98.53										03/12/2018 10:46
08/03/2019 12:54	7.33	98.80	03/12/2018 11:54	6.71	98.59										03/12/2018 10:57
11/04/2019 11:48	7.93	98.20	03/12/2018 12:09	6.69	98.61										03/12/2018 11:07
10/05/2019 11:54	9.025	97.11	03/12/2018 12:58	6.65	98.65										03/12/2018 11:19
			03/12/2018 13:22	6.64	98.66										03/12/2018 11:33
			03/12/2018 14:06	6.62	98.68										03/12/2018 11:43
			03/12/2018 14:27	6.62	98.68										03/12/2018 12:08
			03/12/2018 15:40	6.60	98.70										03/12/2018 12:19
			03/12/2018 16:29	6.59	98.71										03/12/2018 12:38
			03/12/2018 18:43	6.56	98.74										03/12/2018 13:22
			04/12/2018 07:05	6.48	98.82										03/12/2018 13:45
			05/12/2018 09:45	6.30	99.00										03/12/2018 14:26
			17/12/2018 12:29	5.83	99.47										03/12/2018 15:23
			22/01/2019 11:00	5.61	99.69										03/12/2018 16:32
			15/02/2019 13:04	5.54	99.76										03/12/2018 18:34
			08/03/2019 13:42	5.49	99.81										04/12/2018 06:49
			11/04/2019 12:14	6.16	99.14										05/12/2018 09:26
			10/05/2019 12:37	7.27	98.03										17/12/2018 10:39
															22/01/2019 10:30
															15/02/2019 12:39
															08/03/2019 13:37
															11/04/2019 12:04
🟩	**or Long-Term Monitoring**														10/05/2019 12:21
🟦	**stant Rate Test**														

Manual Groundwater Level Measurements

		BH25		
		BH25		
Datum		105.182	Datum	
Unit		LF	Unit	
m bTOC	maOD	Date/Time	m bTOC	maOD
3.82	102.22	15/11/2018 14:12	6.07	99.11
3.82	102.22	20/11/2018 09:24	6.09	99.10
3.74	102.30	20/11/2018 10:08	6.09	99.10
3.74	102.30	20/11/2018 10:34	6.09	99.10
3.74	102.30	20/11/2018 11:16	6.09	99.09
3.72	102.32	20/11/2018 11:45	6.10	99.08
3.69	102.35	20/11/2018 12:19	6.09	99.10
3.67	102.37	20/11/2018 13:45	6.09	99.09
3.80	102.24	20/11/2018 14:21	6.09	99.09
3.81	102.23	20/11/2018 14:52	6.09	99.09
3.53	102.51	20/11/2018 15:24	6.10	99.08
3.54	102.50	21/11/2018 09:41	6.05	99.13
3.77	102.27	21/11/2018 12:17	6.05	99.13
3.72	102.32	21/11/2018 15:51	6.04	99.14
3.76	102.28	22/11/2018 10:15	6.05	99.14
3.92	102.12	22/11/2018 14:33	6.04	99.14
3.97	102.07	23/11/2018 08:41	6.05	99.13
4.05	101.99	23/11/2018 15:37	6.05	99.13
3.87	102.17	24/11/2018 09:28	6.07	99.12
4.02	102.02	24/11/2018 14:09	6.06	99.12
4.13	101.91	24/11/2018 16:16	6.06	99.12
4.36	101.68	25/11/2018 10:41	6.08	99.11
4.40	101.64	25/11/2018 16:39	6.07	99.11
4.43	101.61	26/11/2018 09:10	6.07	99.11
4.41	101.63	26/11/2018 15:33	6.08	99.11
4.45	101.59	27/11/2018 09:59	6.07	99.11
4.60	101.44	27/11/2018 16:06	6.06	99.13
4.55	101.49	28/11/2018 10:12	6.04	99.14
4.96	101.08	28/11/2018 16:10	6.05	99.13
5.01	101.03	29/11/2018 09:54	6.03	99.15
5.05	100.99	29/11/2018 15:58	6.03	99.16
5.03	101.01	30/11/2018 09:49	6.03	99.16
5.07	100.97	30/11/2018 15:45	6.03	99.15
5.25	100.79	01/12/2018 08:58	6.02	99.16
5.38	100.66	01/12/2018 15:53	6.03	99.15
7.72	98.32	02/12/2018 11:04	6.03	99.15
5.70	100.34	02/12/2018 16:22	6.03	99.16
5.75	100.29	03/12/2018 09:37	6.03	99.15
5.77	100.27	03/12/2018 10:54	6.02	99.16
5.76	100.28	03/12/2018 11:19	6.01	99.17
5.89	100.15	03/12/2018 12:04	6.02	99.17
6.03	100.01	03/12/2018 12:25	6.02	99.17
6.20	99.84	03/12/2018 13:57	6.01	99.17
6.31	99.73	03/12/2018 14:22	6.01	99.17
6.40	99.64	03/12/2018 14:46	6.01	99.17
6.47	99.57	03/12/2018 15:22	6.02	99.17
6.55	99.49	04/12/2018 07:36	6.02	99.16
6.64	99.40	05/12/2018 12:05	5.98	99.21
6.76	99.28	17/12/2018 11:52	5.89	99.29
6.84	99.20	22/01/2019 09:55	5.76	99.42
6.89	99.15	15/02/2019 13:47	5.72	99.46
6.99	99.05	08/03/2019 13:04	5.835	99.35
7.04	99.00	11/04/2019 11:52	6.77	98.41
7.10	98.94	10/05/2019 12:07	8.375	96.81
7.13	98.91			
7.15	98.89			
7.17	98.87			
7.22	98.82			
7.28	98.76			
7.28	98.76			
7.30	98.74			
7.34	98.70			
7.36	98.68			
7.38	98.66			
7.45	98.59			
7.47	98.57			
7.50	98.54			
7.55	98.49			
7.55	98.49			
7.57	98.47			
7.61	98.43			
7.62	98.42			
7.63	98.41			
7.61	98.43			
7.63	98.41			
7.66	98.38			
7.63	98.41			
7.66	98.38			
7.73	98.31			
7.67	98.37			
7.72	98.32			
7.73	98.31			
7.79	98.25			
7.82	98.22			
7.81	98.23			
7.78	98.26			
7.82	98.22			
7.84	98.20			
7.84	98.20			
7.86	98.18			
7.91	98.13			
7.83	98.21			
7.71	98.33			
7.61	98.43			
7.52	98.52			
7.43	98.61			
7.37	98.67			
7.26	98.78			
7.22	98.82			
7.16	98.88			
7.06	98.98			
7.02	99.02			
6.96	99.08			
6.91	99.13			
6.87	99.17			
6.81	99.23			
6.63	99.41			
6.35	99.69			
5.68	100.36			
4.95	101.09			
4.66	101.38			
4.20	101.84			
5.08	100.96			
5.83	100.21			

Manual Groundwater Level Measurements

BH26			BH27			BH28			BH29			BH30			TW07
BH26			BH27			BH28			BH29			BH30			TW07 (Offsite)
105.15	**Datum**		**106.321**	**Datum**		**125.88**	**Datum**		**123.415**	**Datum**		**123.979**	**Datum**		**69.32**
Nam	**Unit**		**Nam**	**Unit**		**Nam**	**Unit**		**Nam**	**Unit**		**LF**	**Unit**		**Nam**
Date/Time	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**	**m bTOC**	**maOD**	**Date/Time**
18/10/2018 16:00	4.89	100.26	15/11/2018 12:13	6.64	99.68	24/08/2018	27.53	98.35	24/08/2018	24.37	99.05	23/02/2018	23.83	100.15	06/09/2018
31/10/2018 10:55	4.74	100.41	20/11/2018 09:13	6.71	99.62	27/08/2018	27.58	98.30	27/08/2018	24.40	99.02	26/02/2018	23.84	100.14	13/09/2018
08/11/2018 11:40	5.95	99.20	20/11/2018 10:16	6.70	99.62	05/09/2018	27.26	98.62	05/09/2018	24.48	98.94	05/03/2018	23.78	100.20	20/09/2018
15/11/2018 11:43	4.58	100.57	20/11/2018 10:43	6.72	99.61	13/09/2018	26.70	99.18	13/09/2018	24.56	98.86	06/03/2018	23.78	100.20	27/09/2018 16:20
20/11/2018 09:06	4.64	100.51	20/11/2018 10:51	6.72	99.60	20/09/2018 16:51	26.77	99.11	20/09/2018 17:00	24.35	99.07	08/03/2018	23.77	100.21	02/10/2018 16:30
20/11/2018 10:09	4.62	100.53	20/11/2018 10:53	6.71	99.61	27/09/2018 13:50	26.75	99.13	27/09/2018 13:37	24.49	98.93	13/03/2018	23.76	100.22	10/10/2018 15:40
20/11/2018 10:26	4.69	100.46	20/11/2018 11:38	6.75	99.57	03/10/2018 15:29	26.78	99.10	03/10/2018 13:37	24.54	98.88	27/03/2018	23.94	100.04	18/10/2018 11:37
20/11/2018 10:38	4.77	100.39	20/11/2018 12:08	6.75	99.57	10/10/2018 15:58	26.84	99.04	10/10/2018 13:56	24.58	98.84	06/04/2018	23.82	100.16	31/10/2018 16:25
20/11/2018 10:47	4.82	100.34	20/11/2018 13:37	6.78	99.54	18/10/2018 15:25	26.65	99.23	18/10/2018 15:38	24.52	98.90	13/04/2018	23.90	100.08	08/11/2018 15:00
20/11/2018 11:02	4.89	100.26	20/11/2018 14:12	6.80	99.53	31/10/2018 12:00	26.70	99.18	31/10/2018 12:05	24.60	98.82	20/04/2018	23.90	100.08	16/11/2018 08:30
20/11/2018 11:21	4.97	100.19	20/11/2018 14:44	6.80	99.52	08/11/2018 12:23	26.80	99.08	08/11/2018 12:37	24.86	98.56	27/04/2018	23.75	100.23	20/11/2018 08:15
20/11/2018 11:37	5.02	100.13	20/11/2018 15:17	6.82	99.50	26/11/2018 15:40	27.46	98.43	16/11/2018 12:48	24.70	98.72	04/05/2018	23.82	100.16	20/11/2018 11:19
20/11/2018 11:50	5.06	100.10	21/11/2018 11:22	6.99	99.33	27/11/2018 10:08	27.40	98.49	20/11/2018 09:06	24.70	98.72	18/05/2018	23.72	100.26	20/11/2018 11:56
20/11/2018 12:37	5.16	99.99	21/11/2018 14:15	7.01	99.31	27/11/2018 16:13	27.47	98.41	20/11/2018 10:13	24.71	98.71	25/05/2018	23.86	100.12	20/11/2018 13:17
20/11/2018 13:38	5.25	99.90	21/11/2018 16:32	7.02	99.30	28/11/2018 10:18	27.42	98.46	20/11/2018 10:26	24.73	98.69	01/06/2018	23.76	100.22	20/11/2018 13:51
20/11/2018 14:46	5.31	99.85	21/11/2018 20:45	7.04	99.28	28/11/2018 16:16	27.50	98.38	20/11/2018 10:51	24.77	98.65	08/06/2018	23.42	100.56	20/11/2018 14:31
20/11/2018 15:35	5.35	99.81	22/11/2018 08:29	7.07	99.26	29/11/2018 10:05	27.49	98.39	20/11/2018 11:10	24.80	98.62	15/06/2018	23.49	100.49	20/11/2018 15:10
20/11/2018 16:34	5.37	99.78	22/11/2018 14:25	7.08	99.25	29/11/2018 16:05	27.53	98.35	20/11/2018 11:22	24.81	98.61	22/06/2018	23.76	100.22	21/11/2018 08:12
20/11/2018 19:12	5.45	99.71	22/11/2018 18:22	7.09	99.23	30/11/2018 10:09	27.60	98.28	20/11/2018 11:33	24.82	98.60	29/06/2018	23.80	100.18	21/11/2018 10:15
21/11/2018 07:34	5.47	99.69	23/11/2018 08:23	7.13	99.20	30/11/2018 15:51	27.60	98.28	20/11/2018 11:46	24.84	98.58	06/07/2018	24.04	99.94	21/11/2018 12:21
21/11/2018 11:17	5.53	99.63	23/11/2018 14:21	7.15	99.18	01/12/2018 09:05	27.53	98.35	20/11/2018 12:43	24.89	98.53	13/07/2018	24.17	99.81	21/11/2018 15:14
21/11/2018 14:10	5.54	99.61	23/11/2018 18:16	7.16	99.16	01/12/2018 15:59	27.56	98.33	20/11/2018 12:59	24.90	98.52	20/07/2018	24.31	99.67	22/11/2018 08:28
21/11/2018 16:28	5.58	99.57	24/11/2018 08:45	7.22	99.11	02/12/2018 11:10	27.59	98.29	20/11/2018 13:45	24.93	98.49	27/07/2018	24.31	99.67	22/11/2018 11:36
21/11/2018 20:39	5.64	99.51	24/11/2018 13:47	7.24	99.09	02/12/2018 16:28	27.58	98.31	20/11/2018 14:12	24.95	98.47	01/08/2018	24.44	99.54	22/11/2018 15:27
22/11/2018 08:23	5.68	99.47	24/11/2018 19:36	7.26	99.07	03/12/2018 09:43	27.65	98.23	20/11/2018 14:52	24.97	98.45	09/08/2018	24.39	99.59	23/11/2018 08:42
22/11/2018 14:16	5.69	99.46	25/11/2018 10:45	7.31	99.01	03/12/2018 10:43	27.65	98.23	20/11/2018 15:27	24.99	98.43	17/08/2018	24.25	99.73	23/11/2018 14:08
22/11/2018 18:14	5.71	99.44	25/11/2018 14:10	7.32	99.00	03/12/2018 11:08	27.65	98.23	20/11/2018 15:50	25.00	98.42	24/08/2018	24.51	99.47	23/11/2018 15:57
23/11/2018 08:11	5.75	99.41	25/11/2018 19:36	7.34	98.98	03/12/2018 11:23	27.65	98.24	21/11/2018 08:28	25.18	98.24	27/08/2018	24.80	99.18	24/11/2018 10:28
23/11/2018 14:16	5.77	99.38	26/11/2018 07:52	7.39	98.94	03/12/2018 11:50	27.64	98.24	21/11/2018 11:55	25.21	98.21	05/09/2018	24.76	99.22	24/11/2018 15:37
23/11/2018 18:10	5.78	99.37	26/11/2018 14:18	7.40	98.92	03/12/2018 12:17	27.64	98.24	21/11/2018 15:34	25.25	98.17	13/09/2018	24.72	99.26	25/11/2018 09:55
24/11/2018 08:41	5.86	99.30	26/11/2018 18:15	7.41	98.91	03/12/2018 12:50	27.63	98.25	22/11/2018 10:37	25.36	98.06	20/09/2018 17:04	24.84	99.14	25/11/2018 16:02
24/11/2018 13:43	5.88	99.28	27/11/2018 08:51	7.43	98.89	03/12/2018 13:29	27.62	98.27	22/11/2018 14:54	25.36	98.06	27/09/2018 13:40	24.78	99.20	26/11/2018 08:27
24/11/2018 19:32	5.90	99.25	27/11/2018 14:13	7.44	98.88	03/12/2018 13:59	27.61	98.27	23/11/2018 09:10	25.40	98.02	03/10/2018 13:41	24.86	99.12	26/11/2018 14:53
25/11/2018 10:51	5.95	99.21	27/11/2018 18:30	7.45	98.87	03/12/2018 14:34	27.61	98.28	23/11/2018 16:42	25.41	98.01	10/10/2018 13:51	24.90	99.08	27/11/2018 09:12
25/11/2018 14:06	5.94	99.22	28/11/2018 08:45	7.44	98.88	03/12/2018 15:32	27.60	98.28	24/11/2018 09:38	25.48	97.94	18/10/2018 15:53	24.98	99.00	27/11/2018 15:18
25/11/2018 19:30	5.98	99.18	28/11/2018 15:10	7.45	98.88	03/12/2018 16:25	27.60	98.28	24/11/2018 14:31	25.50	97.92	31/10/2018 12:10	25.01	98.97	28/11/2018 09:16
26/11/2018 07:48	5.99	99.16	28/11/2018 21:04	7.47	98.85	04/12/2018 07:41	27.50	98.38	24/11/2018 16:21	25.50	97.92	08/11/2018 12:45	25.25	98.73	28/11/2018 15:27
26/11/2018 14:13	6.02	99.13	29/11/2018 08:49	7.46	98.86	05/12/2018 12:23	27.24	98.65	25/11/2018 11:07	25.55	97.87	15/11/2018 09:05	25.17	98.81	29/11/2018 09:06
26/11/2018 18:10	6.03	99.12	29/11/2018 14:28	7.47	98.86	17/01/2019 11:07	26.76	99.12	25/11/2018 16:47	25.56	97.86	20/11/2018 09:05	25.13	98.85	29/11/2018 15:10
27/11/2018 08:48	6.01	99.14	29/11/2018 19:20	7.47	98.85	22/01/2019 10:51	26.38	99.50	26/11/2018 09:19	25.59	97.83	20/11/2018 10:11	25.13	98.85	30/11/2018 08:44
27/11/2018 14:09	5.98	99.17	30/11/2018 08:27	7.49	98.84	15/02/2019 14:14	26.32	99.56	26/11/2018 15:46	25.62	97.80	20/11/2018 10:24	25.14	98.84	30/11/2018 15:04
27/11/2018 18:24	6.05	99.10	30/11/2018 16:07	7.49	98.83	08/03/2019 13:52	26.39	99.50	27/11/2018 10:13	25.58	97.84	20/11/2018 10:38	25.16	98.82	01/12/2018 10:22
28/11/2018 08:38	6.02	99.14	30/11/2018 19:11	7.50	98.83	11/04/2019 12:22	26.825	99.06	27/11/2018 16:16	25.63	97.79	20/11/2018 10:49	25.18	98.80	01/12/2018 15:14
28/11/2018 15:03	6.04	99.11	01/12/2018 08:46	7.49	98.84	10/05/2019 13:10	27.68	98.20	28/11/2018 10:24	25.59	97.83	20/11/2018 11:08	25.20	98.78	02/12/2018 10:21
28/11/2018 20:58	6.14	99.02	01/12/2018 19:22	7.50	98.82				28/11/2018 16:20	25.65	97.77	20/11/2018 11:20	25.22	98.76	02/12/2018 15:48
29/11/2018 08:30	6.04	99.11	02/12/2018 09:48	7.53	98.80				29/11/2018 10:08	25.66	97.76	20/11/2018 11:31	25.23	98.75	03/12/2018 08:39
29/11/2018 14:21	6.12	99.04	02/12/2018 14:17	7.53	98.79				29/11/2018 16:09	25.69	97.73	20/11/2018 11:44	25.24	98.74	03/12/2018 12:00
29/11/2018 19:12	6.14	99.01	02/12/2018 18:32	7.54	98.78				30/11/2018 10:13	25.76	97.66	20/11/2018 12:41	25.28	98.70	03/12/2018 12:44
01/12/2018 08:41	6.18	98.97	03/12/2018 10:36	7.58	98.74				30/11/2018 15:56	25.77	97.65	20/11/2018 12:57	25.30	98.68	03/12/2018 14:00
01/12/2018 19:17	6.22	98.94	03/12/2018 11:15	7.57	98.76				01/12/2018 09:10	25.72	97.70	20/11/2018 13:43	25.34	98.64	03/12/2018 14:55
02/12/2018 09:44	6.24	98.91	03/12/2018 11:56	7.55	98.77				01/12/2018 16:03	25.74	97.68	20/11/2018 14:10	25.35	98.63	04/12/2018 08:43
02/12/2018 14:13	6.25	98.90	03/12/2018 12:11	7.55	98.78				02/12/2018 11:14	25.77	97.65	20/11/2018 14:50	25.37	98.61	05/12/2018 14:09
02/12/2018 18:27	6.26	98.89	03/12/2018 12:57	7.53	98.79				02/12/2018 16:32	25.77	97.65	20/11/2018 15:29	25.39	98.59	17/12/2018 09:43
03/12/2018 08:05	6.32	98.83	03/12/2018 13:24	7.52	98.80				03/12/2018 09:47	25.84	97.58	20/11/2018 15:47	25.40	98.58	23/01/2019 08:07
03/12/2018 10:41	5.96	99.19	03/12/2018 14:04	7.51	98.81				03/12/2018 10:50	25.79	97.63	21/11/2018 08:26	25.59	98.39	15/02/2019 08:51
03/12/2018 10:52	6.30	98.85	03/12/2018 14:28	7.51	98.82				03/12/2018 11:04	25.77	97.65	21/11/2018 11:53	25.63	98.35	10/05/2019 00:00
03/12/2018 11:02	6.23	98.92	03/12/2018 15:38	7.49	98.83				03/12/2018 11:30	25.72	97.70	21/11/2018 15:32	25.66	98.32	
03/12/2018 11:13	6.17	98.98	03/12/2018 16:28	7.49	98.84				03/12/2018 11:44	25.70	97.72	22/11/2018 10:35	25.79	98.19	
03/12/2018 11:24	6.13	99.03	03/12/2018 18:45	7.46	98.87				03/12/2018 12:24	25.66	97.76	22/11/2018 14:53	25.79	98.19	
03/12/2018 11:36	6.08	99.08	04/12/2018 07:06	7.34	98.98				03/12/2018 12:42	25.64	97.78	23/11/2018 09:08	25.83	98.15	
03/12/2018 11:52	6.02	99.13	05/12/2018 10:13	7.10	99.22				03/12/2018 13:35	25.59	97.83	23/11/2018 16:30	25.84	98.14	
03/12/2018 12:13	5.96	99.19	17/12/2018 10:17	6.61	99.71				03/12/2018 13:54	25.58	97.84	24/11/2018 09:37	25.92	98.06	
03/12/2018 12:25	5.93	99.22	22/01/2019 10:17	6.14	100.19				03/12/2018 14:41	25.56	97.86	24/11/2018 14:29	25.94	98.04	
03/12/2018 12:50	5.88	99.28	15/02/2019 13:15	6.04	100.28				03/12/2018 15:28	25.53	97.89	24/11/2018 16:20	25.94	98.04	
03/12/2018 13:26	5.81	99.34	08/03/2019 13:43	5.95	100.37				03/12/2018 16:21	25.52	97.90	25/11/2018 11:06	25.99	97.99	
03/12/2018 13:49	5.78	99.37	11/04/2019 12:15	6.55	99.78				04/12/2018 07:46	25.33	98.09	25/11/2018 16:45	26.00	97.98	
03/12/2018 14:33	5.74	99.42	10/05/2019 12:42	7.505	98.82				05/12/2018 10:41	25.05	98.37	26/11/2018 09:17	26.03	97.95	
03/12/2018 15:27	5.70	99.46							17/12/2018 11:18	24.55	98.87	26/11/2018 15:44	26.06	97.92	
03/12/2018 16:32	5.66	99.49							23/01/2019 11:07	24.13	99.29	27/11/2018 10:12	26.01	97.97	
03/12/2018 18:40	5.61	99.54							15/02/2019 14:25	24.12	99.30	27/11/2018 16:15	26.06	97.92	
04/12/2018 06:56	5.45	99.71							08/03/2019 14:20	24.14	99.28	28/11/2018 10:22	26.02	97.96	
05/12/2018 08:58	5.14	100.02							11/04/2019 12:29	24.55	98.87	28/11/2018 16:19	26.08	97.90	
17/12/2018 10:50	4.50	100.65							10/05/2019 13:25	25.425	97.99	29/11/2018 10:07	26.10	97.88	
23/01/2019 10:46	3.82	101.33										29/11/2018 16:07	26.13	97.85	
15/02/2019 12:50	3.87	101.28										30/11/2018 10:11	26.21	97.77	
08/03/2019 13:36	3.73	101.42										30/11/2018 15:55	26.22	97.76	
11/04/2019 12:10	3.87	101.29										01/12/2018 09:08	26.16	97.82	
10/05/2019 12:33	4.63	100.52										01/12/2018 16:02	26.18	97.80	
												02/12/2018 11:13	26.21	97.77	
												02/12/2018 16:31	26.21	97.77	
												03/12/2018 09:46	26.28	97.70	
												03/12/2018 10:48	26.26	97.72	
												03/12/2018 11:02	26.24	97.74	
												03/12/2018 11:28	26.21	97.77	
												03/12/2018 11:42	26.18	97.80	
												03/12/2018 12:22	26.15	97.83	
												03/12/2018 12:40	26.12	97.86	
												03/12/2018 13:33	26.07	97.91	
												03/12/2018 13:52	26.06	97.92	
												03/12/2018 14:40	26.03	97.95	
												03/12/2018 15:27	26.01	97.97	
												03/12/2018 16:20	26.00	97.98	
												04/12/2018 07:45	25.81	98.17	
												04/12/2018 07:45	25.81	98.17	
												05/12/2018 10:34	25.50	98.48	
												17/12/2018 11:15	24.97	99.01	
												22/01/2019 10:59	24.52	99.46	
												15/02/2019 14:19	24.51	99.47	
												08/03/2019 14:30	24.54	99.44	
												11/04/2019 12:27	24.91	99.07	
												10/05/2019 13:21	25.79	98.19	

🟩	**Background or Long-Term Monitoring**
🟦	**Constant Rate Test**

Manual Groundwater Level Measurements

		TW10			BH31-OS	
		TW10 (Offiste)			BH31-OS	
Datum		52.478	Datum		128.427	Datum
Unit		Nam	Unit		Nam	Unit
m bTOC	maOD	Date/Time	m bTOC	maOD	Date/Time	m bTOC
7.65	61.67	06/09/2018	15.45	37.03	20/11/2018 16:30	25.11
7.69	61.63	13/09/2018	15.47	37.01	20/11/2018 08:40	25.07
7.62	61.70	20/09/2018	15.48	37.00	20/11/2018 11:39	25.07
7.60	61.72	27/09/2018 15:55	15.41	37.07	20/11/2018 12:18	25.14
7.58	61.74	02/10/2018 16:50	15.40	37.08	20/11/2018 13:30	25.14
7.62	61.70	10/10/2018 15:20	15.21	37.27	20/11/2018 13:55	25.14
7.68	61.64	18/10/2018 11:47	15.17	37.31	20/11/2018 14:15	25.14
7.60	61.72	31/10/2018 16:00	- *		20/11/2018 15:00	25.14
7.58	61.74	08/11/2018 15:30	- *		20/11/2018 15:23	25.14
7.67	61.65	20/11/2018 08:35	- *		21/11/2018 08:33	24.98
7.61	61.71	20/11/2018 11:27	- *		21/11/2018 10:40	24.98
7.61	61.71	20/11/2018 12:08	- *		21/11/2018 12:42	24.99
7.61	61.71	20/11/2018 13:21	- *		21/11/2018 15:24	25.07
7.61	61.71	20/11/2018 13:55	- *		22/11/2018 08:50	25.15
7.61	61.71	20/11/2018 14:41	- *		22/11/2018 11:57	25.59
7.61	61.71	20/11/2018 15:18	- *		22/11/2018 15:52	25.16
7.61	61.71	21/11/2018 08:45	- *		23/11/2018 08:56	25.00
7.57	61.75	21/11/2018 10:30	- *		23/11/2018 14:28	24.94
7.57	61.75	21/11/2018 12:37	19.78	32.70	23/11/2018 16:12	24.94
7.57	61.75	21/11/2018 15:52	19.62	32.86	24/11/2018 10:44	25.01
7.57	61.75	22/11/2018 08:42	19.52	32.96	24/11/2018 15:54	25.20
7.62	61.71	22/11/2018 11:44	19.47	33.01	25/11/2018 10:10	25.12
7.62	61.70	22/11/2018 15:43	19.42	33.06	25/11/2018 16:18	25.01
7.62	61.70	23/11/2018 08:21	19.27	33.21	26/11/2018 08:42	25.16
7.62	61.70	23/11/2018 14:16	19.24	33.24	26/11/2018 15:08	25.08
7.60	61.72	23/11/2018 16:05	19.23	33.25	27/11/2018 09:28	24.83
7.60	61.73	24/11/2018 10:36	19.15	33.33	27/11/2018 15:35	25.18
7.61	61.71	24/11/2018 15:46	19.12	33.36	28/11/2018 09:32	24.98
7.61	61.72	25/11/2018 10:00	19.05	33.43	28/11/2018 15:40	25.09
7.61	61.71	25/11/2018 16:10	19.88	32.60	29/11/2018 09:21	24.95
7.61	61.72	26/11/2018 08:35	18.97	33.51	29/11/2018 15:23	25.18
7.62	61.70	26/11/2018 15:01	18.99	33.49	30/11/2018 09:03	25.04
7.62	61.71	27/11/2018 09:18	18.88	33.60	30/11/2018 15:09	25.12
7.58	61.74	27/11/2018 15:27	18.86	33.62	01/12/2018 10:36	24.90
7.57	61.75	28/11/2018 09:23	18.63	33.85	01/12/2018 15:30	24.79
7.55	61.78	28/11/2018 15:33	18.58	33.90	02/12/2018 10:36	24.62
7.55	61.77	29/11/2018 09:14	18.37	34.11	02/12/2018 16:00	24.59
7.54	61.78	29/11/2018 15:17	18.31	34.17	03/12/2018 08:54	24.61
7.55	61.77	30/11/2018 08:52	18.04	34.44	03/12/2018 12:20	24.65
7.59	61.73	30/11/2018 15:11	17.92	34.56	03/12/2018 13:37	24.69
7.59	61.73	01/12/2018 10:29	17.58	34.90	03/12/2018 14:27	24.74
7.58	61.75	01/12/2018 15:22	17.52	34.96	03/12/2018 15:20	24.81
7.58	61.75	02/12/2018 10:28			04/12/2018 08:54	24.86
7.57	61.76	02/12/2018 15:54	17.14	35.34	05/12/2018 14:54	24.45
7.56	61.76	03/12/2018 08:46	16.90	35.58	17/12/2018 10:01	23.85
7.59	61.74	03/12/2018 12:10	16.90	35.58	22/01/2019 14:28	21.57
7.59	61.74	03/12/2018 13:30	16.83	35.65	15/02/2019 09:25	21.10
7.59	61.74	03/12/2018 14:07	16.81	35.67	08/03/2019 15:25	20.50
7.59	61.74	03/12/2018 15:10	16.85	35.63	11/04/2019 13:33	18.14
7.59	61.74	04/12/2018 08:48	18.56	33.92	10/05/2019 14:36	19.28
7.65	61.67	05/12/2018 14:39	16.01	36.47		
7.58	61.75	17/12/2018 09:55	12.92	39.56		
7.62	61.70	22/01/2019 14:00	15.17	37.31		
7.59	61.73	15/02/2019 09:10	15.40	37.08		
7.48	61.85	08/03/2019 15:12	15.12	37.36		
		11/04/2019 13:20	14.88	37.60		
		10/05/2019 14:16	15.23	37.25		

Bog of the Ring Time Series Data

BOTR OW2D		BOTR OW3D (Deep)	
Date and Time	m OD		m OD
01/09/2018 01:00	16.275	20/11/2018 00:00	30.945
02/09/2018 01:00	16.25	21/11/2018 00:00	31.106
03/09/2018 01:00	16.187	22/11/2018 00:00	31.238
04/09/2018 01:00	16.16	23/11/2018 00:00	31.234
05/09/2018 01:00	16.134	24/11/2018 00:00	31.195
06/09/2018 01:00	16.134	25/11/2018 00:00	31.167
07/09/2018 01:00	16.117	26/11/2018 00:00	31.198
08/09/2018 01:00	16.101	27/11/2018 00:00	31.268
09/09/2018 01:00	16.047	28/11/2018 00:00	31.356
10/09/2018 01:00	15.995	29/11/2018 00:00	31.383
11/09/2018 01:00	15.94	30/11/2018 00:00	31.37
12/09/2018 01:00	15.864	01/12/2018 00:00	31.367
13/09/2018 01:00	15.859	02/12/2018 00:00	31.404
14/09/2018 01:00	15.844	03/12/2018 00:00	31.397
15/09/2018 01:00	15.798	04/12/2018 00:00	31.342
16/09/2018 01:00	15.801	05/12/2018 00:00	31.431
17/09/2018 01:00	15.811	06/12/2018 00:00	31.495
18/09/2018 01:00	15.797	07/12/2018 00:00	31.514
19/09/2018 01:00	16.328	08/12/2018 00:00	31.492
20/09/2018 01:00	17.233	09/12/2018 00:00	31.435
21/09/2018 01:00	18.496	10/12/2018 00:00	31.395
22/09/2018 01:00	19.054	11/12/2018 00:00	31.425
23/09/2018 01:00	19.395	12/12/2018 00:00	31.469
24/09/2018 01:00	19.62	13/12/2018 00:00	31.564
25/09/2018 01:00	19.761	14/12/2018 00:00	31.55
26/09/2018 01:00	20.024	15/12/2018 00:00	31.623
27/09/2018 01:00	20.263	16/12/2018 00:00	31.68
28/09/2018 01:00	19.664	17/12/2018 00:00	31.649
29/09/2018 01:00	18.47	18/12/2018 00:00	31.682
30/09/2018 01:00	17.706	19/12/2018 00:00	31.694
01/10/2018 01:00	17.414	20/12/2018 00:00	31.668
02/10/2018 01:00	17.114	21/12/2018 00:00	31.677
03/10/2018 01:00	16.596	22/12/2018 00:00	31.656
04/10/2018 01:00	16.369	23/12/2018 00:00	31.732
05/10/2018 01:00	16.129	24/12/2018 00:00	31.775
06/10/2018 01:00	15.693	25/12/2018 00:00	31.768
07/10/2018 01:00	15.428	26/12/2018 00:00	31.763
08/10/2018 01:00	15.254	27/12/2018 00:00	31.752
09/10/2018 01:00	15.092	28/12/2018 00:00	31.722
10/10/2018 01:00	14.972	29/12/2018 00:00	31.709
11/10/2018 01:00	15.01	30/12/2018 00:00	31.699
12/10/2018 01:00	15.531	31/12/2018 00:00	31.696
13/10/2018 01:00	15.709	01/01/2019 00:00	31.685
14/10/2018 01:00	15.753	02/01/2019 00:00	31.669
15/10/2018 01:00	15.795	03/01/2019 00:00	31.675
16/10/2018 01:00	15.82	04/01/2019 00:00	31.674
17/10/2018 01:00	15.599	05/01/2019 00:00	31.682
18/10/2018 01:00	15.571	06/01/2019 00:00	31.682
19/10/2018 01:00	15.614	07/01/2019 00:00	31.689
20/10/2018 01:00	15.58	08/01/2019 00:00	31.671
21/10/2018 01:00	15.559	09/01/2019 00:00	31.662
22/10/2018 01:00	15.49	10/01/2019 00:00	31.659
23/10/2018 01:00	15.471	11/01/2019 00:00	31.66
24/10/2018 01:00	15.246	12/01/2019 00:00	31.677
25/10/2018 01:00	15.173	13/01/2019 00:00	31.688
26/10/2018 01:00	15.085	14/01/2019 00:00	31.661
27/10/2018 01:00	14.966	15/01/2019 00:00	31.675
28/10/2018 01:00	14.909	16/01/2019 00:00	31.696
29/10/2018 00:00	14.955	17/01/2019 00:00	31.639
30/10/2018 00:00	14.897	18/01/2019 00:00	31.666
31/10/2018 00:00	14.793	19/01/2019 00:00	31.667
01/11/2018 00:00	14.696	20/01/2019 00:00	31.622
02/11/2018 00:00	14.616	21/01/2019 00:00	31.644
03/11/2018 00:00	14.685	22/01/2019 00:00	31.698
04/11/2018 00:00	14.635	23/01/2019 00:00	31.68
05/11/2018 00:00	14.599	24/01/2019 00:00	31.657
06/11/2018 00:00	14.602	25/01/2019 00:00	31.652
07/11/2018 00:00	14.492	26/01/2019 00:00	31.703
08/11/2018 00:00	14.391	27/01/2019 00:00	31.667
09/11/2018 00:00	14.486	28/01/2019 00:00	31.641
10/11/2018 00:00	14.453	29/01/2019 00:00	31.685

11/11/2018 00:00	14.413	30/01/2019 00:00	31.694
12/11/2018 00:00	14.372	31/01/2019 00:00	31.712
13/11/2018 00:00	14.284	01/02/2019 00:00	31.674
14/11/2018 00:00	14.317	02/02/2019 00:00	31.623
15/11/2018 00:00	14.276	03/02/2019 00:00	31.627
16/11/2018 00:00	14.222	04/02/2019 00:00	31.64
17/11/2018 00:00	14.197	05/02/2019 00:00	31.646
18/11/2018 00:00	14.171	06/02/2019 00:00	31.667
19/11/2018 00:00	14.202	07/02/2019 00:00	31.734
20/11/2018 00:00	14.211	08/02/2019 00:00	31.829
21/11/2018 00:00	14.182	09/02/2019 00:00	31.808
22/11/2018 00:00	14.121	10/02/2019 00:00	31.787
23/11/2018 00:00	14.163	11/02/2019 00:00	31.704
24/11/2018 00:00	14.153	12/02/2019 00:00	31.709
25/11/2018 00:00	14.164	13/02/2019 00:00	31.719
26/11/2018 00:00	14.183	14/02/2019 00:00	31.717
27/11/2018 00:00	14.311	15/02/2019 00:00	31.738
28/11/2018 00:00	14.41	16/02/2019 00:00	31.744
29/11/2018 00:00	14.443	17/02/2019 00:00	31.76
30/11/2018 00:00	14.539	18/02/2019 00:00	31.736
01/12/2018 00:00	14.895	19/02/2019 00:00	31.715
02/12/2018 00:00	15.164	20/02/2019 00:00	31.729
03/12/2018 00:00	15.274	21/02/2019 00:00	31.705
04/12/2018 00:00	15.381	22/02/2019 00:00	31.687
05/12/2018 00:00	15.688	23/02/2019 00:00	31.686
06/12/2018 00:00	15.872	24/02/2019 00:00	31.669
07/12/2018 00:00	16.116	25/02/2019 00:00	31.673
08/12/2018 00:00	16.269	26/02/2019 00:00	31.678
09/12/2018 00:00	16.311	27/02/2019 00:00	31.692
10/12/2018 00:00	16.389	28/02/2019 00:00	31.704
11/12/2018 00:00	16.603	01/03/2019 00:00	31.693
12/12/2018 00:00	16.735	02/03/2019 00:00	31.734
13/12/2018 00:00	16.835	03/03/2019 00:00	31.775
14/12/2018 00:00	16.921	04/03/2019 00:00	31.908
15/12/2018 00:00	17.185	05/03/2019 00:00	31.924
16/12/2018 00:00	17.237	06/03/2019 00:00	32.073
17/12/2018 00:00	17.33	07/03/2019 00:00	32.035
18/12/2018 00:00	17.573	08/03/2019 00:00	31.975
19/12/2018 00:00	17.69	09/03/2019 00:00	31.973
20/12/2018 00:00	17.79	10/03/2019 00:00	32.004
21/12/2018 00:00	17.916	11/03/2019 00:00	32.009
22/12/2018 00:00	17.904	12/03/2019 00:00	32.075
23/12/2018 00:00	18.001	13/03/2019 00:00	32.039
24/12/2018 00:00	18.084	14/03/2019 00:00	32.066
25/12/2018 00:00	18.284	15/03/2019 00:00	32.076
26/12/2018 00:00	18.475	16/03/2019 00:00	32.182
27/12/2018 00:00	18.441	17/03/2019 00:00	32.177
28/12/2018 00:00	18.269	18/03/2019 00:00	32.117
29/12/2018 00:00	18.684	19/03/2019 00:00	32.098
30/12/2018 00:00	18.803	20/03/2019 00:00	32.086
31/12/2018 00:00	18.888	21/03/2019 00:00	32.087
01/01/2019 00:00	18.919	22/03/2019 00:00	32.115
02/01/2019 00:00	18.923	23/03/2019 00:00	32.09
03/01/2019 00:00	18.972	24/03/2019 00:00	32.096
04/01/2019 00:00	19.002	25/03/2019 00:00	32.087
05/01/2019 00:00	19.049	26/03/2019 00:00	32.088
06/01/2019 00:00	19.08	27/03/2019 00:00	32.083
07/01/2019 00:00	19.126	28/03/2019 00:00	32.085
08/01/2019 00:00	19.07	29/03/2019 00:00	32.102
09/01/2019 00:00	19.084	30/03/2019 00:00	32.103
10/01/2019 00:00	19.143	31/03/2019 00:00	32.085
11/01/2019 00:00	19.182	01/04/2019 01:00	32.108
12/01/2019 00:00	19.245	02/04/2019 01:00	32.139
13/01/2019 00:00	19.289	03/04/2019 01:00	32.137
14/01/2019 00:00	19.234	04/04/2019 01:00	32.159
15/01/2019 00:00	19.277	05/04/2019 01:00	32.145
16/01/2019 00:00	19.333	06/04/2019 01:00	32.123
17/01/2019 00:00	19.211	07/04/2019 01:00	32.122
18/01/2019 00:00	19.264	08/04/2019 01:00	32.119
19/01/2019 00:00	19.248	09/04/2019 01:00	32.112
20/01/2019 00:00	19.132	10/04/2019 01:00	32.103
21/01/2019 00:00	19.159	11/04/2019 01:00	32.101
22/01/2019 00:00	19.246	12/04/2019 01:00	32.105

23/01/2019 00:00	19.186	13/04/2019 01:00	32.108
24/01/2019 00:00	19.12	14/04/2019 01:00	32.11
25/01/2019 00:00	18.846	15/04/2019 01:00	32.143
26/01/2019 00:00	18.39	16/04/2019 01:00	32.159
27/01/2019 00:00	18.158	17/04/2019 01:00	32.157
28/01/2019 00:00	18.287	18/04/2019 01:00	32.143
29/01/2019 00:00	18.862	19/04/2019 01:00	32.126
30/01/2019 00:00	19.044	20/04/2019 01:00	32.121
31/01/2019 00:00	19.146	21/04/2019 01:00	32.155
01/02/2019 00:00	19.076	22/04/2019 01:00	32.18
02/02/2019 00:00	18.953	23/04/2019 01:00	32.18
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11/04/2022 01:00	18.729
12/04/2022 01:00	18.539
13/04/2022 01:00	18.323
14/04/2022 01:00	18.278
15/04/2022 01:00	18.164
16/04/2022 01:00	18.043
17/04/2022 01:00	18.043
18/04/2022 01:00	18.017
19/04/2022 01:00	18.154
20/04/2022 01:00	18.564
21/04/2022 01:00	18.506
22/04/2022 01:00	18.36
23/04/2022 01:00	18.209
24/04/2022 01:00	18.037
25/04/2022 01:00	17.992
26/04/2022 01:00	17.867
27/04/2022 01:00	17.735
28/04/2022 01:00	17.682
29/04/2022 01:00	17.63
30/04/2022 01:00	17.603
01/05/2022 01:00	17.604
02/05/2022 01:00	17.556
03/05/2022 01:00	17.532
04/05/2022 01:00	17.489
05/05/2022 01:00	17.428
06/05/2022 01:00	
07/05/2022 01:00	17.349
08/05/2022 01:00	17.531
09/05/2022 01:00	17.517
10/05/2022 01:00	
11/05/2022 01:00	17.397
12/05/2022 01:00	
13/05/2022 01:00	
14/05/2022 01:00	17.68
15/05/2022 01:00	19.302
16/05/2022 01:00	
17/05/2022 01:00	19.16
18/05/2022 01:00	18.689
19/05/2022 01:00	18.823
20/05/2022 01:00	18.461
21/05/2022 01:00	18.15
22/05/2022 01:00	18
23/05/2022 01:00	17.945
24/05/2022 01:00	17.811
25/05/2022 01:00	17.672
26/05/2022 01:00	17.564
27/05/2022 01:00	17.417
28/05/2022 01:00	17.321
29/05/2022 01:00	17.396
30/05/2022 01:00	17.428

Surface Water Results at SW1 upstream monitoring point

Parameter	Units	Surface Water Regulations (2016)	EPA licence Trigger Level	2014 Q4	2015 Q2	2015 Q4	2016 Q2	2016 Q4	2017 Q2	2017 Q4	2018 Q2	2018 Q4	2019 Q2	2019 Q4	2020 Q2	2020 Q4	2021 Q2	2021 Q4
Ammoniacal Nitrogen	mg/l NH_{4}- N	3.11	-	0.03	0.1	0.61	0.28	0.07	0.12	0.12	0.05	0.05	0.04	0.15	0.10	0.16	0.09	0.03
Calcium	mg/l	-	-	-	96.6	-	110.3	-	122.6	-	105.4	-	118.8	-	97.3	94.4	102.3	102.8
Chemical Oxygen Demand	mg/l	40	-	15	9	25	7	7	28	11	16	<7	9	9	12	11	18	24
Chloride	mg/l	250	-	36.4	28.5	31.5	29.9	39	40.8	34.2	36.7	42.6	40.0	30.3	38.8	23.1	37.5	41.3
Conductivity	mS/cm	1	-	0.67	0.56	0.62	0.68	0.76	0.82	0.43	0.43	0.51	0.48	0.29	0.66	0.61	0.67	0.64
Dissolved Oxygen	mg/l	-	-	10	10	11	7	10	8	10	8	9	6	11	8	9	10	10
Magnesium	mg/l	-	-	-	10.9	-	14	-	14.1	-	12.8	-	13.5	-	12	9.7	11.4	10.8
Manganese	mg/l	1	-	-	0.161	-	**2.274**	-	<0.002	-	0.454	-	<0.002	-	0.636	0.515	0.531	0.217
Orthophosphate	mg/l	-	-	-	<0.06	-	0.07	-	0.26	-	<0.06	-	<0.03	-	<0.06	<0.06	0.08	0.11
Phosphorus	mg/l	-	-	-	0.048	-	0.116	-	0.077	-	0.042	-	0.048	-	0.029	0.046	0.095	0.091
pH	pH Unit	5.5 to 9.0	-	8	8	7.1	7.7	8.5	8.6	8.01	8.1	8.4	8.3	8.1	8.25	8.12	8.26	8.27
Sodium	mg/l	-	-	-	19.6	-	17.2	-	23.1	-	20.5	-	22.8	-	19.2	14.5	19.6	18.5
Sulphate	mg/l	200	-	-	91.24	-	85.31	-	118.1	-	83.9	-	76.5	-	60.3	71.7	71.3	69.2
Temperature	°C	25	-	8.2	11.3	9.1	9.1	8.9	15.3	6.8	10.4	9.4	11.3	8.3	<15	<15	<15	<15
Total Alkalinity	mg/l	-	-	-	212	-	224	-	268	-	226	-	234	-	232	222	230	246
Total Suspended Solids	mg/l	-	35	<10	<10	<10	<10	**60**	11	**162**	<10	12	<10	<10	<10	<10	<10	27

*Exceedances marked in bold

Surface Water Results at SW2 downstream monitoring point

Parameter	**Units**	**Surface Water Regulations (2016)**	**EPA Trigger Level**	**2014 Q4**	**2015 Q2**	**2015 Q4**	**2016 Q2**	**2016 Q4**	**2017 Q2**	**2017 Q4**	**2018 Q2**	**2018 Q4**	**2019 Q2**	**2019 Q4**	**2020 Q2**	**2020 Q4**	**2021 Q2**	**2021 Q4**
Ammoniacal Nitrogen	mg/l NH4- N	3.11	-	0.03	0.03	0.05	0.03	0.04	0.04	0.05	0.04	0.05	0.03	0.03	<0.03	0.16	0.03	0.04
Calcium	mg/l	-	-	-	141.3	-	144.6	-	148.5	-	147.7	-	173.7	-	123.2	95.1	145.2	98.6
Chemical Oxygen Demand	mg/l	40	-	<7	<7	19	11	7	34	11	17	<7	9	8	10	<7	<7	21
Chloride	mg/l	250	-	32.7	28.9	32.8	31.2	34.9	35.4	32.5	34.3	35.8	57.3	31.4	43.5	22.5	33.3	31
Conductivity	mS/cm	1	-	0.8	0.74	0.76	0.86	0.81	0.83	0.51	0.54	0.52	0.69	0.36	0.84	0.62	0.82	0.60
Dissolved Oxygen	mg/l	-	-	11	10	10	11	9	9	10	11	11	8	11	9	9	10	10
Magnesium	mg/l	-	-	-	12.6	-	11.2	-	10.9	-	11.7	-	12.6	-	9.5	9.8	11.9	10.7
Manganese	mg/l	1	-	-	0.002	-	<0.002	-	<0.02	-	<0.002	-	<0.002	-	0.043	0.524	0.068	0.224
Orthophosphate	mg/l	-	-	-	<0.06	-	0.1	-	0.32	-	0.08	-	<0.03	-	<0.06	<0.06	0.09	0.09
Phosphorus	mg/l	-	-	-	0.108	-	0.106	-	3.81	-	0.42	-	0.11	-	0.026	0.046	0.053	0.099
pH	pH Unit	5.5 to 9.0	-	8.4	8.4	7.2	8.3	8.4	8.9	8.3	8.5	8.0	8.3	8.2	8.29	8.13	8.38	8.27
Sodium	mg/l	-	-	-	16.3	-	16.3	-	16.7	-	17.1	-	35	-	22.1	14.6	16.8	18.3
Sulphate	mg/l	200	-	-	169.99	-	173.67	-	179	-	188	-	**237**	**-**	185.5	70.4	162	68.1
Temperature	°C	25	-	9.2	11.8	8.9	7.6	9.4	16.3	6	10.5	10.0	13.4	7.8	<15	<15	<15	<15
Total Alkalinity	mg/l	-	-	-	220	-	208	-	290	-	236	-	196	-	202	216	234	236
Total Suspended Solids	mg/l	-	35	**125**	**57**	34	**41**	**351**	**1537**	34	**226**	**338**	90	24	<10	<10	<10	<10

*Exceedances marked in bold

Appendix G

EPA Groundwater Body Summary Sheets

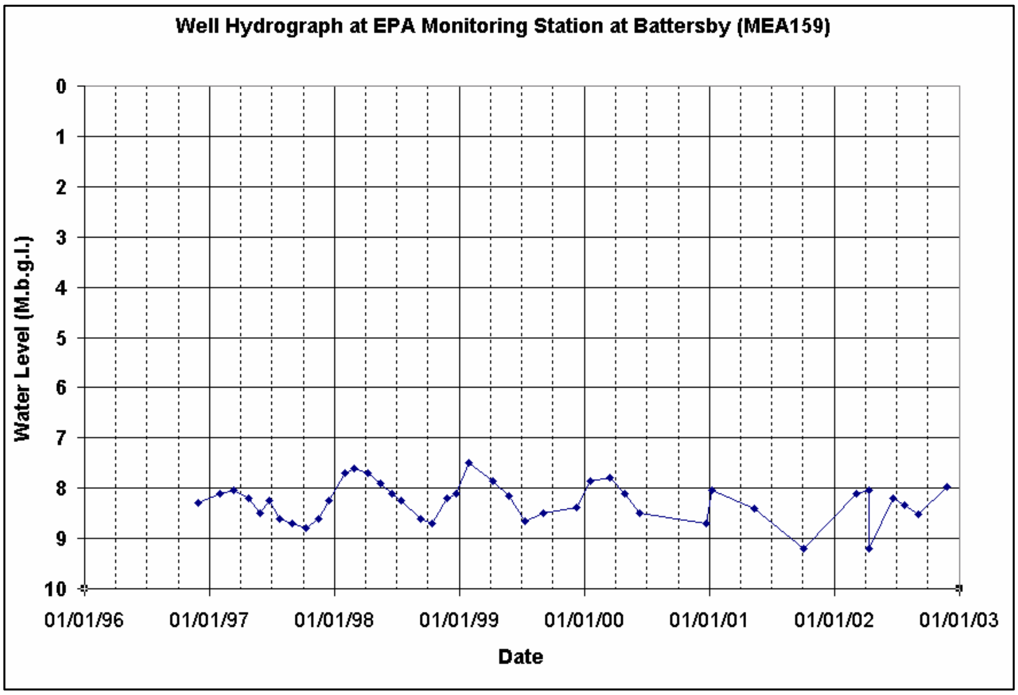
Lusk GWB: Summary of Initial Characterisation.

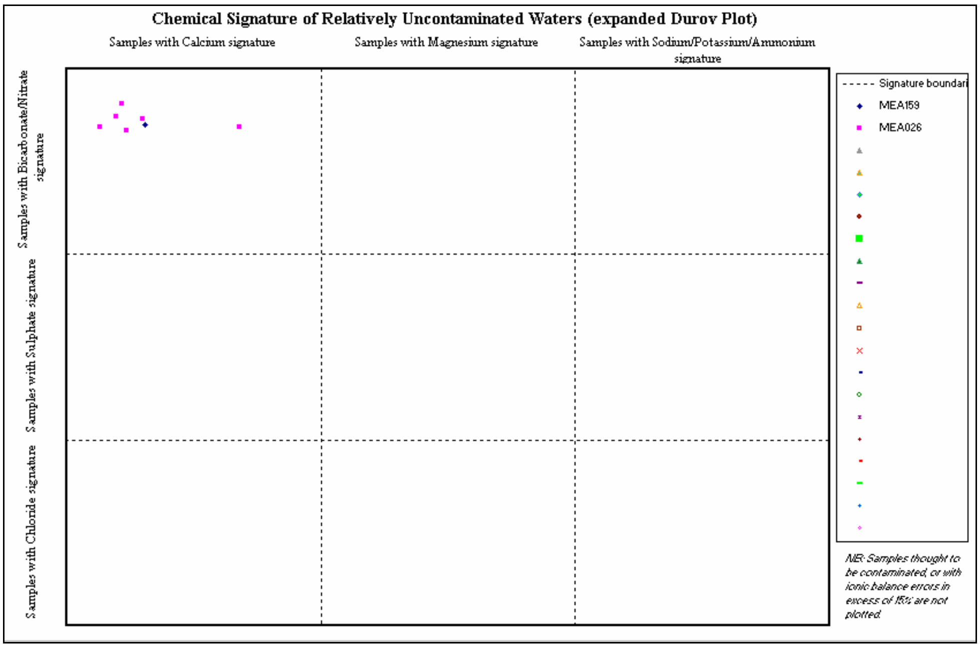
Hydrometric Area Local Authority	Associated surface water bodies	Associated terrestrial ecosystems	Area (km^2)
Dublin Co. Co. Meath Co. Co. Hydrometric Area 08	Ballough Stream, Ballybog Hill, Delvin, Hurley, Broadmeadow, Fairyhouse Stream, Nanny	Bog of the Ring (1204)	209

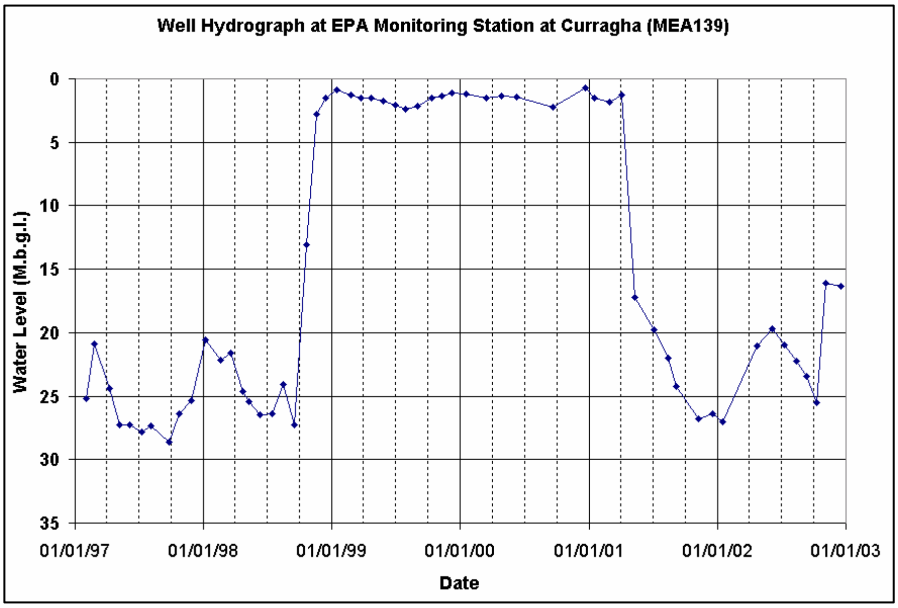
Topography		This GWB extends east from Dunshaughlin in Meath towards the coast of north Dublin. The area is mostly low lying with some areas of higher elevations along the centre of the GWB at Garristown and the Nags Head, Co. Dublin, and also along the western boundary of the GWB, which separates the Boyne catchment from Hydrometric Area 8. The higher elevations are in the order of 160 m OD. Elevation falls off from these hills along the centre of the body to the north and south and also towards the coast.
Geology and Aquifers	Aquifer type(s)	**Lm:** Locally important aquifer which is generally moderately productive Small areas ($12km^2$ ~ 5.7%) of **Rk^d**: Regionally important karstified aquifer dominated by diffuse flow
	Main aquifer lithologies	Dinantian Upper Impure Limestones (Calp Limestones). Smaller areas of Dinantian Pure Bedded Limestones. (5.7%) The limestones in this area tend to be cleaner in nature than the more typical Calp limestones and the faulting and the associated folding result in higher than usual groundwater yields.
	Key structures.	In this area the rocks are intensely folded and faulted. The severe deformation can be seen in the upper impure limestones at Loughshinny beach, where the folds are angular and partially overturned (McConnell *et al.*, 2001). The results of a drilling programme in the area of the Bog of the Ring have shown that the hydrogeology is strongly related to the structural deformation associated with the faulting in that area. Along the northern boundary of the body there is a large fault that runs east-west and separates the Lower Palaeozoic Rocks of the Balbriggan Inlier to the north from the limestones to the south. The faulting has fractured the limestones in the area, making them susceptible to karstification.
	Key properties	Transmissivity and storativity values in the aquifer appear to be better than is normal for the Calp limestone. Hydrogeological investigations (K.T. Cullen 2000) in the Bog of the Ring area, located along the northern boundary of the GWB, east of Naul, have estimated the transmissivity of the aquifer as very high, in the region of $580m^2/d$. This high transmissivity may be influenced in part by presence of some gravel deposits in the area. At Curragha PWS, Co. Meath, transmissivity values of 60 - $130m^2/d$ have been estimated. Although not in the order of the Bog of the Ring values these are considered to be high values, indicative of a regional flow system. The specific yield of 0.002 was calculated from the pumping test data from the GSI Observation Well No.2 and indicated that the aquifer is unconfined. The pumping tests indicate that a higher permeability zone has been developed close to the surface, and the permeabilities decreases with increasing depth below ground level. During the drilling of the Curragha boreholes major inflows were found at 25 and 30m below ground. The hydrograph at Curragha (MEA139) shows the water table fluctuating at around 25m underground. The levels then rise to 2.5 below ground and fall again two years later. At the lower level the annual fluctuation of the water table is around 8m and at the higher level it is only 2m. This illustrates the increase in storativity when a larger section of the aquifer is saturated. Also the storativity of the upper layers will be higher as the degree of faulting and weathered material increases. The period of recovery, from 25m below ground to about 5m is 2 weeks. A hydrograph from the EPA station MEA159, around one kilometre from the Curragha source, shows the water table situated around 8m below ground with an annual fluctuation of less than 2m, this would suggest there is a significant degree of storativity in the aquifer. This hydrograph shows no influence of the rise in groundwater levels experienced in 1999 & 2000 suggesting the cone of depression of the aquifer is less than the 1.2km separating the boreholes. Analysis of pumping test data at the Kilmoon, Bunnan Bridge borehole indicates the aquifer is semi confined here with a transmissivity of $8.8m^2/d$ and a storativity value of 7×10^{-4}. (Cullen 1983)
	Thickness	The limestone bedrock at the Curragha PWS, located at the center of the GWB, is extensively fissured and highly broken, particularly between 32 to 35 metres b.g.l. which provides large inflows of water. Numerous calcite veins were noted, and their thickness increased with depth, with major fracturing and cavities being encountered below 30 metres. The return water was lost during the drilling from 33m below ground level, which would suggest higher permeabilities occur in this zone, due to the increased fracturing. Drilling in the Bog of the Ring area has shown inflow significant from limestone fissures at depths of 30m, 70m and 90m. Drilling in the area of Kilmoon suggests the total bedrock thickness is thinning out towards the Lower Paleozoic rocks in the area. Two individual boreholes in the area record limestone thickness of 14 and 25m. These were in both cases overlain by very thick tills (~20m) and underlain in the first instance by “red sandstones” and in the second by “green grits and slates of the underlying Lower Paleozoic basement” (Cullen 1983 & 1984). It is also of note that the wells in this area are artesian with overflows up to $200m^3/d$.

Overlying Strata	Lithologies	The dominant subsoil type overlying this GWB is Limestone-derived Till which covers all but the northern and coastal area of the GWB. The thickness of the till is highly variable: in general it is thicker towards the south and thinner towards the north. In the east there are deposits of Irish Sea Till which is a low permeability boulder clay derived from ice sheets which occupied the Irish Sea during the last glaciation. In the north there are areas covered by Till derived from the Lower Paleozoic rock. There are small areas of gravel deposits and also alluvium deposits along some channels. Drilling in the Bog of the Ring area has shown the subsoil layers generally consist of till layers, in some places underlain by thick gravel deposits.
	Thickness	Available borehole information suggests that there is a highly variable thickness of subsoil overlying the aquifer. There are large areas where the subsoil is less than 5 metres thick, whereas other evidence suggests subsoil thickness of up to 40m in places.
	% area aquifer near surface	<5%
	Vulnerability	At the current time GSI groundwater vulnerability mapping has not been carried out for Co. Dublin, therefore only the portion of the GWB in Co. Meath is assessed. In general the groundwater vulnerability is Moderate. Along the western boundary and at isolated hills, where the subsoil covering thins, the vulnerability is Extreme.
Recharge	Main recharge mechanisms	There are two mechanisms for recharge in this GWB, point recharge and diffuse recharge. Diffuse recharge occurs over the majority of the area, it will be higher in the areas where subsoil is thinner and / or more permeable. Due to the Karstic nature of the aquifer it is possible to have point recharge. An example of this is at a swallow hole where a large amount of concentrated recharge occurs over a small area. In areas where the subsoil is not thick, and where the impure limestones occupy lowlands adjacent to Namurian strata, there may be karstification at the boundary between the two rock types, since the relatively corrosive runoff from the Namurian rocks would facilitate solution of the impure limestones
	Est. recharge rates	*[Information will be added at a later date]*
Discharge	Springs and large known abstractions	Curragha PWS (1200) - Fingal County Council: Bog of the Ring PWS 4000 - 5000m^3/d
	Main discharge mechanisms	Groundwater can discharge from this aquifer as baseflow to streams, as springs and as abstractions via wells, for human consumption. The main discharge areas are to the north and southeast. To the east a number of springs are recorded in the GSI Karst Database. There is an absence any major river channels here and it is likely that groundwater is forced to discharge to the surface as the system reaches capacity. The water from these springs forms streams which flow east towards the coast. There will also be groundwater discharge at the geological contact between the limestones and the less permeable Lower Paleozoic rocks to the north and with the less permeable limestones in the south.
	Hydrochemical Signature	The hydrochemical analyses of groundwater indicate a very hard water (355 - 435 mg/l ($CaCO_3$)), with a high alkalinity (310 - 325 mg/l ($CaCO_3$)). Conductivities are also high ranging from 520 - 810 μS/cm. Alkalinity values range from 200 to 350mg/l with the majority of values around 300mg/l. This groundwater can be classed as a calcium bicarbonate water.
Groundwater Flow Paths		The nature of groundwater flow in this aquifer will be determined by the degree of karstification and fracturing and the purity of the limestones. Where there is a highly karstified limestone flow will be concentrated into conduits, which may draw water very deep underground. Where the limestone is not as karstified the flow systems will be shallower and more diffuse. Although groundwater will still flow main along fractures, there will not have been the large-scale dissolution of the rocks to convert these into large conduits and groundwater flow will be less likely to take place at depths below 30m. In most of the area groundwater flow will be unconfined. Exceptions to this will be where there are thick layers of low permeability till and also where the Namuiran strata, which form the hills within the GWB, overlie the limestone.
Groundwater & surface water interactions		Bog of the Ring is a protected ecosystem, which lies to the northeast of the GWB. During pumping tests carried out in that area the water levels in the Bog were measured to asses the reaction of the Bog to local groundwater abstraction. The connection between the Bog and the groundwater system is related to the lithology of the subsoil material underlying the bog. Where the bog is underlain by till there was little or no reduction in water level caused by pumping. In areas where there are gravel deposits there was a direct connection with some monitored locations drying out completely. Groundwater and surface water are more closely linked at certain karst features such as springs and swallow holes. In this area there are a number of springs located in the eastern area of the GWB. At this point Groundwater is directly discharging into the surface water systems.

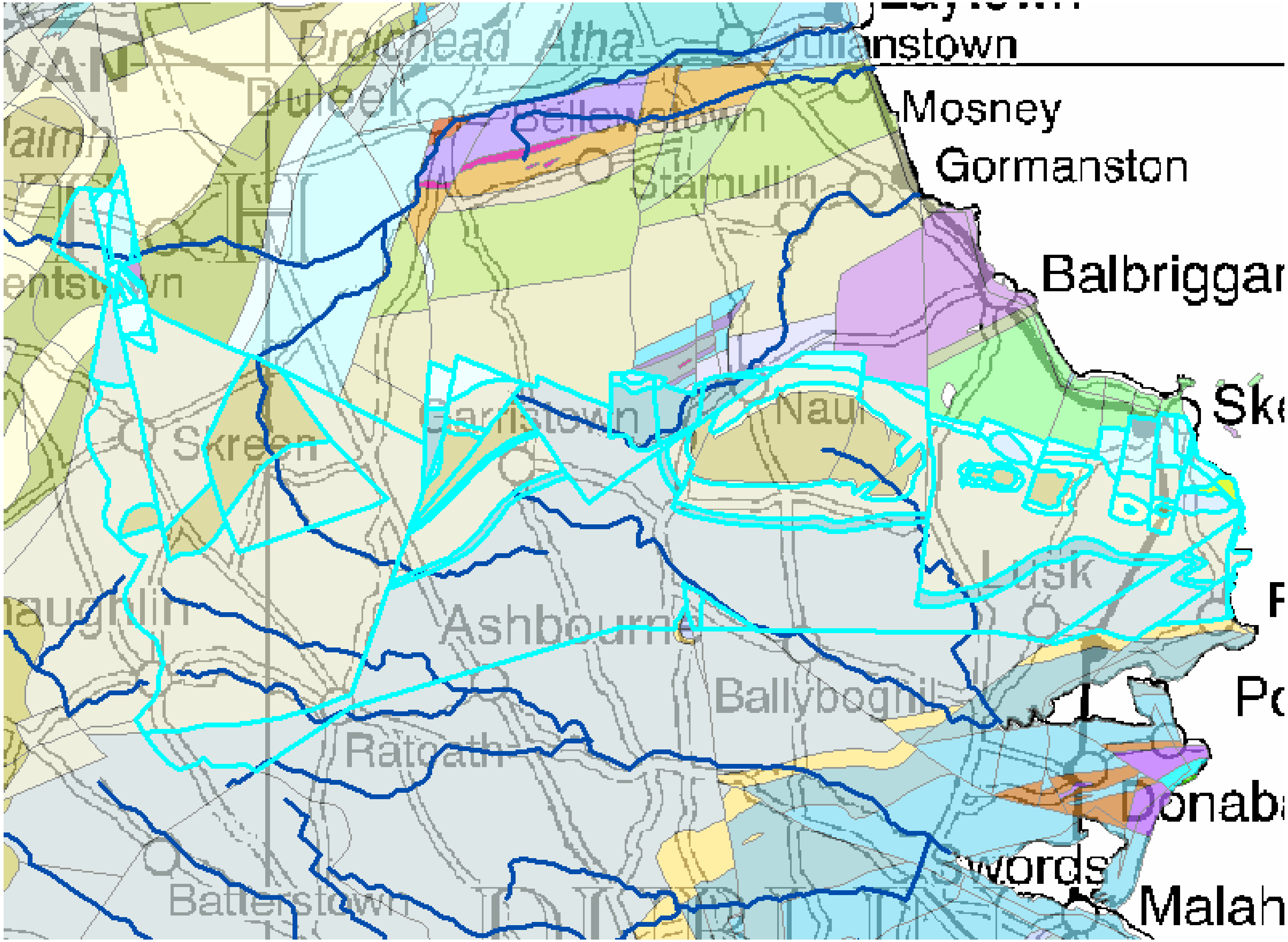
Conceptual model	This GWB is located in the North Dublin – East Meath Area. The area is low lying with higher elevations to the east and some isolated hills along the centre. The GWB is composed of moderate permeability limestone, which in some places is karstified. The extent of the groundwater body is defined to the west by the extent of Hydrometric Area 09, to the North by the contact with the Lower Paleozoic strata and to the south by the extent of the Lm Lucan formation, which in turn is a boundary of a structural region (Dumphy 2003). Very small areas of low permeability impure limestones are incorporated with this GWB, since they are isolated and do not alter significantly the flow system. Karstification of the limestone and increased transmissivity has been found in the north close to the fault, which displaces the Lower Paleozoic rocks alongside the limestone. This area has undergone structural deformation. Groundwater flow occurs along fractures and in place through solutionally enlarged karst conduits. Recharge occurs diffusely through the subsoils and via outcrops. There may be some locations where recharge is more focused i.e. within enclosed depressions, which a common in a Karst landscape. The aquifers within the GWB are generally unconfined, but may become locally confined where the subsoil is thicker and/or lower permeability and where the aquifer is overlain by Namurian Strata. Most flow in this aquifer will occur in a zone near the surface. In general, the majority of groundwater flow occurs in the upper 30 m, comprising a weathered zone of a few metres and a connected fractured zone below this. However, deep-water strikes in more isolated faults/ fractures have been encountered to 90 mbgl in the more structurally deformed area. Flow path lengths are variable, from examining the drainage density it is clear that in some instances groundwater flow paths of up to a couple of kilometres may exist, although distances of a few hundred metres area more likely. The groundwater discharges directly to the Irish Sea in the east and also to the north and south via baseflow to rivers. Analysis of water levels in the area of the Bog of the Ring has shown a direct connection between the bog and the water table in areas where the subsoil is compose of permeable material.
Attachments	
Instrumentation	Stream gauge: 08013, 08010, 08002 Borehole Hydrograph: Battersby (MEA159), Curragha (MEA139) EPA Representative Monitoring boreholes: Battersby (MEA159), Curragha (MEA026), Hayestown, Rush (DUB004)
Information Sources	Cullen KT (1983) *Report on the Drilling and Testing of Trial and Production Water Wells at Kilmoon, Co. Meath*. Report to Meath Co. Co. Cullen KT (1984) *Report on the Drilling and Testing of Water Well No. 3 at Kilmoon, Co. Meath*. Report to Meath Co. Co. K T Cullen & Co Ltd (2000) Bog of the Ring Groundwater Development Drilling and Testing Programme. Woods L, Meehan R, Wright GR (1998) *County Meath Groundwater Protection Scheme*. Report to Meath County Council. Geological Survey of Ireland. 54 p. McConnell B, Philcox M, Geraghty M (2001) *Geology of Meath: A geological description to accompany the bedrock geology 1:100,000 scale map series, Sheet 13*. Geological Survey of Ireland. 77 p. O'Connor Sutton Cronin (2003) Environmental Assessment of Proposed Loughbarn Landfill Facility.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae







Formation Name	Code	Description	Rock Unit Group	Aquifer Classification
Balrickard Formation	BC	Coarse sandstone, shale	Namurian Undifferentiated	Pl
Crufty Formation	CU	Peloidal wackestone-grainstone, shale	Dinantian Pure Bedded Limestones	Rkd
Holmpatrick Formation	HO	Grainstone-packstone, micrite	Dinantian Pure Bedded Limestones	Rkd
Lane Formation	LE	Argillaceous biocastic limestone, oolite	Dinantian Lower Impure Limestones	Ll
Loughshinny Formation	LO	Dark micrite & calcarenite, shale	Dinantian Upper Impure Limestones	Lm
Lucan Formation	LU	Dark limestone & shale (`Calp)	Dinantian Upper Impure Limestones	Lm
Lucan Formation & Mudbank Limestones	mkLU	Dark limestone & shale (`Calp)	Dinantian Upper Impure Limestones	Lm
Mudbank Limestones	mk	Massive grey micritic limestone	Dinantian Pure Unbedded Limestones	Ll
Mullaghfin Formation	MF	Pale peloidal calcarenite	Dinantian Pure Bedded Limestones	Rkd
Naul Formation	NA	Calcarenite & calcisiltite	Dinantian Upper Impure Limestones	Lm
Platin Formation	PT	Crinoidal peloidal grainstone-packstone	Dinantian Pure Bedded Limestones	Rkd
Smugglers Cave Formation	SR	Conglomerate & lithic sandstone	Dinantian Sandstones	Lm
Walshestown Formation	WL	Shale, sandstone, limestone	Namurian Undifferentiated	Pl



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aughlin
Ashbourne
Ballyboghil
Po
Ratoath
Donaba
Swords
Malah
Batterstown

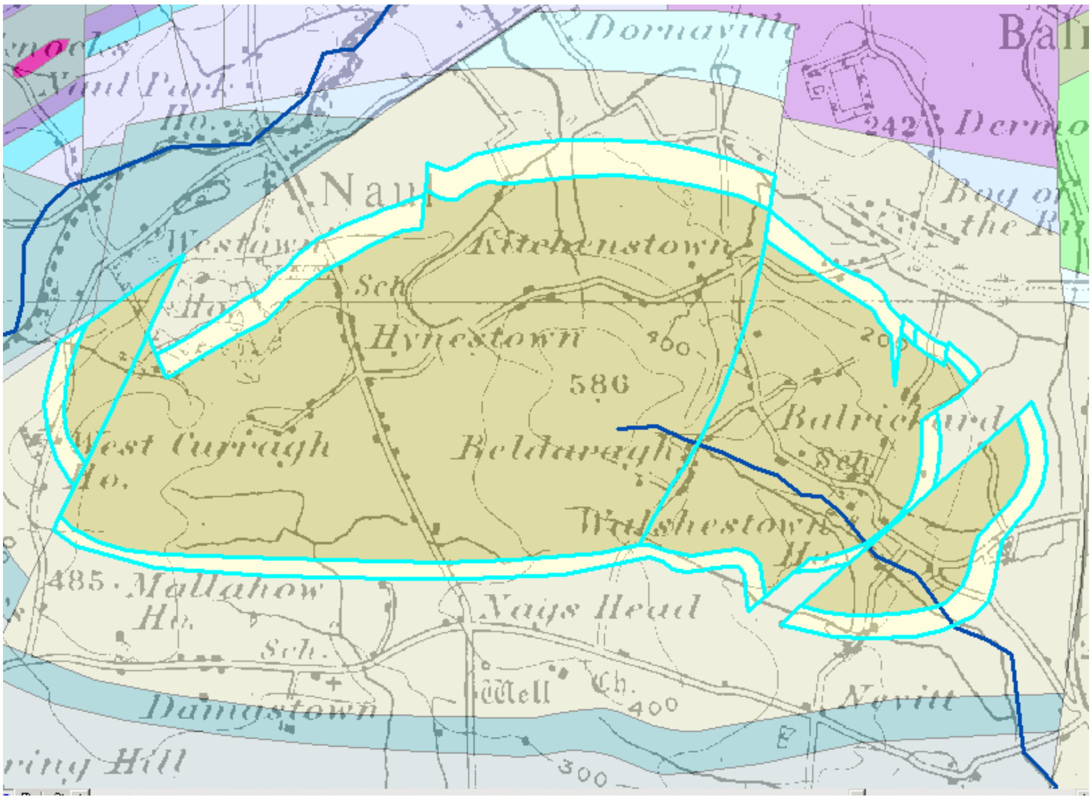
Hynestown GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	**Associated surface water bodies**	**Associated terrestrial ecosystems**	**Area (km^2)**
Dublin Co. Co. Hydrometric Area 08	Ballough Stream	Bog of the Ring (1204)	30

Topography		This GWB is located in north County Dublin. The area is comprised of a hill, which rises to 170 m OD. Elevations fall from this peak to around 50 m OD at the perimeter of the GWB.
Geology and Aquifers	Aquifer type(s) Main aquifer lithologies	**Ll:** Locally important aquifer, moderately productive only in local zones Undifferentiated Namurian Rock (NAM) Shale & Sandstone.
	Key structures.	At the end of the Carboniferous Period, the Variscan Orogeny uplifted and folded the Namurian rocks into a series of broad shallow folds, which are also cut by faults. The deformation front was located in the south of the country, meaning that its effects are seen most strongly in the southwest, diminishing further north. Faulting in the Namurian appears to be less common than in the underlying rocks, faults are likely to have become infilled by weathered shale.
	Key properties	There are no data on the aquifer properties of this GWB. Transmissivity and storativity are expected to be low but enhanced in local zones.
	Thickness	The depth to which open fractures are encountered below ground will determine the depth of significant groundwater flow in the aquifer since it is not considered that the rock has any primary porosity. In such low permeability rocks it is considered that the majority of groundwater flow will occur in the upper 3m and groundwater flow in fractures does not typically occur below 10m.
Overlying Strata	Lithologies	The subsoils in this area are limestone-derived tills.
	Thickness	The subsoil thickness will thin towards the top of hill and then thicken towards the river valley at the base of the hill.
	% Area aquifer near surface	High.
	Vulnerability	There is no vulnerability mapping available for Dublin but it is expected that the vulnerability in this area will be Extreme in the peaks of the hills and then reduce further from the top of the hill.
Recharge	Main recharge mechanisms	Diffuse recharge will occur via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. Due to the generally low permeability of the aquifers within this GWB, a high proportion of the recharge will then discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Springs and large known abstractions	None
	Main discharge mechanisms	Groundwater will discharge from this GWB to the streams overlying the aquifer where the rock is in hydraulic continuity with the riverbed. This discharge is the baseflow flow of the rivers, which supports summer flows. Dry Weather flow in other areas where this rock type is present values suggest the summer baseflow is quite low and therefore it is likely that discharge from this aquifer will be peaky and the majority of flow to the river will occur shortly after a rainfall event. Groundwater may also discharge from this aquifer along the geological contact with the limestone, which forms the boundary of the body.
	Hydrochemical Signature	There are no hydrochemical data available for this GWB at this time. The groundwater is expected to be soft to moderately hard with a calcium bicarbonate signature. It is expected the groundwater will be **Siliceous**.
Groundwater Flow Paths		In general, groundwater movement in these rock units is expected to occur relatively rapidly and at shallow depths. The rock unit's permeability depends on the presence of faults and joints along which groundwater can flow. In the shaley portions of the unit, movement of water along faults and joints is likely to be impeded by clay. The more productive portions of the unit are likely to be the thicker beds of sandstone, where brittle fracturing is likely to have occurred, and where groundwater flow is likely to be better developed. The flow is generally in localised systems with little continuity between them. Examination of the data in the GSI well database shows that water levels in these Namurian rocks are shallow, usually less than 10 m below surface, although deeper levels are encountered which may be a reflection of the higher topography. Local groundwater flow directions will be dictated by local topographic, and hence hydraulic, gradients, which will converge at rivers. On a more regional scale groundwater flows from these Namurian mounds is radial, down towards the limestone.

Groundwater & surface water interactions	Typically, swallow holes and collapse features are located at the boundary between Namurian and Limestone Rocks. This is due to the acidic waters from the Namurian flowing on to the pure limestones and causing increased dissolution over a small area. Such features are of great importance to the surface water and groundwater interactions of the adjacent water body. Special care must be taken in consideration of the pressures on the adjacent limestone GWB because of the ability of surface pollutants in rivers from the Namurian to pass directly into the groundwater of the limestone with out any attenuation in the unsaturated zone.
Conceptual model	This GWB is located in north County Dublin near Naul and located near the Bog of the Ring. The area is comprised of a hill, which rises to 170 m OD. Elevations drop of from these peaks to around 50 m OD at the perimeter of the GWB. The area of the body is defined by the extent of the Namurian rock. The GWB is composed primarily of low permeability rocks, although localized zones of enhanced permeability do occur. Recharge occurs diffusely through the subsoils and via outcrops. It takes place mainly in the upland areas where subsoils are thinner and more permeable. The aquifers within the GWB are generally unconfined, but may become locally confined where the subsoil is thicker and/or lower permeability. Most flow in this aquifer will occur near the surface. In general, the majority of groundwater flow occurs in the upper 10 m, comprising a weathered zone of a few metres and a connected fractured zone below this. However, deep-water strikes in more isolated faults/ fractures can be encountered at 30-50 mbgl. Flow path lengths are relatively short, and in general are between 100 and 500 m. Groundwater discharges to the numerous small streams crossing the aquifer, and to the springs and seeps.
Attachments	
Instrumentation	Stream gauge: None Borehole Hydrograph: None EPA Representative Monitoring boreholes: None
Information Sources	McConnell B, Philcox M & Geraghty M, 2001. *Geology of Meath: A geological description to accompany the bedrock geology 1:100,000 scale map series, Sheet 13, Meath*. Geological Survey of Ireland. 77 p. Woods L, Meehan R & Wright G R, 1998. *County Meath Groundwater Protection Scheme*. Report to Meath County Council. Geological Survey of Ireland. 54 p.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Formation Name	**Code**	**Description**	**Rock Unit Group**	**Aquifer Classification**
Balrickard Formation	BC	Coarse sandstone, shale	Namurian Undifferentiated	Pl
Walshestown Formation	WL	Shale, sandstone, limestone	Namurian Undifferentiated	Pl


Dornaville
Bal
Naul Park Ho.
242 Dermo
Naul
Bog of the R
Westown Ho.
Kitchenstown
Sch.
Hynestown
200
205
586
Balrickard
Sch.
West Curragh Ho.
Beldaragh
Walshestown Ho.
485 Mallahow Ho.
Sch.
Nags Head
Well
Ch.
400
Damastown
Nevitt
ring Hill
300

Appendix H

Updated Hydrogeological Assessment

H.1. SITE SETTING

1.1.1 The potential effect that the proposed development may have on the hydrogeological regime of the site represents the principal consideration for this Appendix. To understand the nature of the hydrogeological regime relevant to the Hollywood Great landfill site, the spatial scope of the study area must be sufficiently large to enable the general hydrogeological setting and associated conceptual hydrogeological model (CSM) to be defined. As such, the study area relevant to consideration of geology, soil and hydrogeology extends outside of the proposed development boundaries, to include the groundwater catchment area in which the landfill site is located. The study area in relation to the hydrogeology been extended to include the Bog of the Ring public water supply situated c. 3km to the northeast of the IMS facility owing to its general sensitivity.

1.1.2 Integrated Materials Solutions Limited Partnership (IMS) are seeking planning permission for landfilling of non-hazardous waste and an EPA licence review for a proposed Integrated Waste Management Facility (IWMF) at their current inert landfill facility at Hollywood Great, Nag's Head, Naul, Co. Dublin (hereinafter referred to as the IMS facility).

1.1.3 The IMS facility is a former limestone and shale quarry that has been operating as an engineered landfill site since 2003.Under the terms of the current planning permissions and the existing Waste Licence (Ref. W0129-02) issued by the Environmental Protection Agency (EPA), only waste which meets the criteria for inert landfill as set out in the Landfill Directive (Directive 1999/31/EC) may be accepted at the site. The current cap on the waste volumes accepted at the site is restricted to 500,000 tonnes per annum both by the planning consents and the Waste Licence.

H.2. GEOLOGY

H.2.1. Regional Geology

2.1.1 The regional geology and structure have been determined from the Geological Survey of Ireland online Spatial Data and Resources and are summarised in **Table H.1**.

H.2.2. Geological Protected Site

2.1.2 Three Geological Heritage Sites (GHSs) are present in the study area. GHSs are defined by the GSI through an audit of County Geological Sites as sites considered to be of national importance. These sites provide type sections of the key Lower Carboniferous and Upper Carboniferous bedrock unit and include:

- *Nags Head Quarry (DF016) [IGH 8 - Lower Carboniferous]* Exposure of Lower Carboniferous rocks of the Loughshinny Formation, comprising a mixture of thin to medium bedded limestone and shale. The structural deformation seen here, for example as chevron folds, reflects the geology also visible 12km away on the coast at Loughshinny;
- *Balrickard Quarry (DF017) [IGH 9 – Upper Carboniferous]* Displays good exposures of thickly bedded coarse grained sandstone interbedded with dark grey shale, all dipping shallowly to the west; and
- *Walshestown Stream Section (DF018) [IGH 9 - Upper Carboniferous and Permian]* Upper Carboniferous (Namurian) shale, sandstone and limestone of the Walshestown and Balrickard Formations. A small deeply incised stream with exposed long sections of dark shale, which is occasionally interbedded with limestone and sandstone. This stream section displays bedding, jointing and the occurrence of a fault.

2.1.3 The Balrickard Quarry and Walshestown Stream Section are both located in the inlier of Namurian bedrock situated beneath the Knockbrack Hill high ground to the north of the IMS facility. These three sites therefore provide exposure

Table H.1: Regional Geological Sequence

Age		Name	Lithological Description*	Estimated Maximum Thickness (m)
Quaternary		Alluvium	Post-glacial deposit comprising gravel, sand, silt or clay in a variety of mixes, usually includes a high percentage of organic carbon	-
		Glacial Till (TNSSs) - derived from Namurian sandstones and shales	‘Clayey’ till dominating the area around the site.	-
		Glacial Till (IrSTLPSsS) - Irish Sea Till derived from Lower Palaeozoic sandstones and shales.	Dominating the area to north of the site, Clayey in texture.	-
		Glacial Till (TLs) - Till derived from limestones	-	-
Carboniferous	Upper (Namurian)	Walshestown Formation (WL)	Predominantly black shales, with subordinate siltstones, fine sandstones bands with rippled lenses, calcareous mudstone and occasional limestones.	> 200
		Balrickard Formation (BC)	Feldspathic micaceous sandstone with shale and argillaceous fossiliferous micrite interbeds. At the type section sandstones are medium-grey, well sorted, coarse to very coarse grained, feldspathic sub-litharenite.	75-100
	(Visean / Namurian)	Donore Formation (DR)	Transitional unit between the Balrickard and Loughshinny Formations.	-
	Lower (Visean)	Loughshinny Formation (LO)	Laminated to thinly-bedded, argillaceous, pyritic, locally cherty limestone interbedded with dark-grey to black shale. The limestones include argillaceous micrites and graded calcarenites	100-150
		Naul Formation (NA)	Calcarenite and, with minor chert and occasional thin shales. It is similar to the Loughshinny Formation, but the limestones are paler and less argillaceous, and there is less shale.	100
		Lucan Formation (LU)	Dark-grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey. There are rare dark coarser grained calcarenitic limestones, sometimes graded, and interbedded dark-grey calcar	210

** Lithological descriptions taken from GSI Bedrock Geology 100K (Link); GSI, 1999; and McConnell et al., 2001.*

2.1.4 of all the key geological; units of relevance to this hydrogeological assessment.

H.3. HYDROGEOLOGY

3.1.1 The hydrogeological assessment considers the entire area potentially affected by the proposed development and/or the area that could potentially affect the development in the long-term. The study area is defined by the IMS facility and its geological setting in context of the Bog of the Ring (BOTR) wellfield.

H.3.1. Aquifer Characteristics

3.1.2 The aquifer categories defined in Groundwater Protection Schemes (DELG/EPA/GSI, 1999) are intended to describe both resource potential (Regionally or Locally important, or Poor) and groundwater flow type (through fissures, karst conduits or intergranular). **Table H.2** provides a brief description of the GSI aquifer categories.

Table H.2: GSI Descriptions of Aquifer Categories

Aquifer Category	Description
Regionally Important Fissured Bedrock Aquifer (Rf)	Aquifer in which the network of fractures, fissures and joints, through which groundwater flows, is well connected and widely dispersed, resulting in a relatively even distribution of highly permeable zones. There is good aquifer storage and groundwater flow paths can be up to several kilometres in length. There is likely to be substantial groundwater discharge to surface waters ('baseflow') and large (>2,000 m^3/d), dependable springs may be associated with these aquifers
Regionally Important Karstified Bedrock Aquifer (Rk)	'Karstification' is the process whereby limestone is slowly dissolved away by percolating waters. It most often occurs in the upper bedrock layers and along certain fractures, fissures and joints, at the expense of others. Karstification frequently results in the uneven distribution of permeability through the rock, and the development of distinctive karst landforms at the surface (e.g. swallow holes, caves, dry valleys), some of which provide direct access for recharge/surface water to enter the aquifer. The landscape is characterised by largely underground drainage, with most flow occurring through the more permeable, solutionally-enlarged, interconnected fissure/conduit zones, which may be several kilometres long. Groundwater velocities through fissures/conduits may be high and aquifer storage is frequently low. Groundwater often discharges as large springs (>2,000 m^3/d), which range from regular and dependable to highly variable ('flashy'). There is strong interconnection between surface water and groundwater. The degree of karstification ranges from slight to intense. GSI recognises two types of karst aquifer: those dominated by diffuse flow (Rkd) and those dominated by conduit flow (Rkc).
Regionally Important Sand/Gravel Aquifer (Rg)	A sand/gravel aquifer is classed as regionally important if it can supply regionally important abstractions (e.g. large public water supplies), or 'excellent' yields (>400 m^3/d). It is highly permeable, more than 10 m thick or has a saturated thickness of at least 5 m, and normally extends over at least 10 km^2. Groundwater flows through the pore spaces between sand/gravel grains, and the permeability is mainly determined by the grain size (larger grains give larger pore spaces), and the 'sorting' of the material (the more uniform, the higher the permeability). There is a relatively uniform distribution of groundwater, good aquifer storage and long groundwater flow paths, typically limited by the aquifer's extent. Groundwater gradients are typically low ('flatter' water tables), giving relatively low groundwater velocities. There is generally a strong interaction between surface water and groundwater, with groundwater discharging into streams if the water table is high, or conversely, the surface water moving into the aquifer, if the surface water level is high. Large, dependable springs (>2,000 m ^{3}/d) are often associated with sand/gravel aquifers, especially in low-lying areas or at the periphery of the aquifer.
Locally Important Bedrock Aquifer, Generally Moderately Productive (Lm)	Aquifer in which the network of fractures, fissures and joints, through which groundwater flows, is reasonably well connected and dispersed throughout the rock, giving a moderate permeability and groundwater throughput. Aquifer storage is moderate and groundwater flow paths can be up to several kilometres in length. There is likely to be a substantial groundwater contribution to surface waters ('baseflow') and large (>2,000 m^3/d), dependable springs may be associated with these aquifers. This classification also includes aquifers similar to the Regionally Important Fractured Bedrock Aquifer (Rf), but with a smaller continuous area (<c.25 km^2). Although the aquifer may supply 'excellent' yields, the small size limits the amount of recharge available to meet abstractions.
Locally Important Bedrock Aquifer, Moderately Productive only in Local Zones (Ll)	Aquifer with a limited and relatively poorly connected network of fractures, fissures and joints, giving a low fissure permeability which tends to decrease further with depth. A shallow zone of higher permeability may exist within the top few metres of more fractured/weathered rock, and higher permeability may also occur along fault zones. These zones may be able to provide larger 'locally important' supplies of water. In general, the lack of connection between the limited fissures results in relatively poor aquifer storage and flow paths that may only extend a few hundred metres. Due to the low permeability and poor storage capacity, the aquifer has a low 'recharge acceptance'. Some recharge in the upper, more fractured/weathered zone is likely to flow along the relatively short flow paths and rapidly discharge to streams, small springs and seeps. Groundwater discharge to streams ('baseflow') can significantly decrease in the drier summer months.
Locally Important Karstified Bedrock Aquifer (Lk)	Essentially similar to the Regionally Important Karstified Bedrock Aquifer (Rk), but with a smaller continuous area (<c. 25 km^2). Although the properties imply that this aquifer can supply 'excellent' yields, the smaller size limits the amount of recharge available to meet abstractions.
Locally Important Sand/Gravel Aquifer (Lg)	Similar to a Regionally Important Sand/Gravel Aquifer (Rg), but with a smaller continuous area (c. 1- 10 km^2) and/or less consistent permeability. Although the aquifer may supply 'excellent' yields, the smaller size limits the amount of recharge available to meet abstractions.
Poor Bedrock Aquifer, Moderately Productive only in Local Zones (Pl)	Similar to a Locally Important Bedrock Aquifer, Moderately Productive only in Local Zones (Ll), but with fewer and more poorly-connected fractures, fissures and joints, and with less permeable and/or more limited zones of higher permeability. Overall permeability, storage capacity, recharge acceptance, length of flow path and baseflow are likely to be less than in Ll aquifers.
Poor Bedrock Aquifer, Generally Unproductive (Pu)	Aquifer with generally few and poorly connected fractures, fissures and joints. This low fissure permeability tends to decrease further with depth. A shallow zone of slightly higher permeability may exist within the top few metres of more fractured/weathered rock, and higher permeability may rarely occur along large fault zones. In general, the poor fissure network results in poor aquifer storage, short flow paths (tens of metres) and low 'recharge acceptance'. Groundwater discharge to streams ('baseflow') is very limited.

3.1.3 The GSI aquifer classification for the key geological units identified within the study area are summarised in **Table H.3**.

Table H.3: GSI Aquifer Classification for Key Geological Units within the Study Area

Geological Unit	Age	Lithology	GSI Aquifer Classification
Walshestown Formation (WL)	Namurian Bedrock (Upper Carboniferous)	Shales, thin sandstones / siltstones, occasional thin limestones	Pl (Poor Aquifer – Bedrock which is generally unproductive except for local zones)
Balrickard Formation (BC)		Coarse micaceous sandstone with shale interbeds.	
Donore Formation (DR)		Transitional between Balrickard and Loughshinny Formations	
Loughshinny Formation (LO)	Visean (Lower Carboniferous)	Layered dark grey micrite and calcarenite (fine-coarse grained limestone) and shale	Lm (Locally Important Aquifer – Bedrock which is generally moderately productive)

3.1.4 Thus, the limestones of the Loughshinny Formation are designated a Locally Important Aquifer which is generally moderately productive (Lm). The overlying Namurian sequence constitute a Poor Aquifer, bedrock which is generally unproductive except for local zones (Pl).

H.3.2. Groundwater Vulnerability

3.1.5 Groundwater vulnerability defines the natural ground characteristics that determine the ease with which groundwater may be contaminated by human activities. A vulnerability category is assigned to a site or area based on the relative ease that infiltrating water and potential contaminants may reach groundwater in a vertical or sub-vertical direction. Groundwater vulnerability classes designated by the EPA are as follows:

- Extreme ‘X’ Groundwater Vulnerability;
- Extreme ‘E’ Groundwater Vulnerability;
- High ‘H’ Groundwater Vulnerability;
- Moderate ‘M’ Groundwater Vulnerability; and
- Low ‘L’ Groundwater Vulnerability.

3.1.6 Groundwater vulnerability is regionally mapped by the GSI and is typically extreme (E) or Extreme (X) in the vicinity of the IMS facility and local areas of high ground, where the bedrock commonly situated at or near the ground surface. Groundwater vulnerability within boundary of the IMS facility has been affected by the historical quarrying and infilling activities undertaken thereon. The removal of subsoils allied with alterations to the characteristics of the unsaturated zone.

H.3.3. Groundwater Protection Response

3.1.7 The Department of the Environment & Local Government (DoELG), EPA and GSI published general guidance regarding the determination of site suitability for non-hazardous wastes (DoELG, EPA and GSI, 1999) to assist the statutory authorities to meet their responsibility to protect groundwater. This provides Groundwater Protection Responses for the siting of landfills, as reproduced in Appendix B.

3.1.8 The Groundwater Protection Responses support decision making by the EPA regarding the suitability of new landfill sites. The guidance relies on a simple screening approach that considers aquifer vulnerability and aquifer resource potential, that utilises the matrix shown in **Table H.4**.

Table H.4: GSI Groundwater Protection Response Matrix for Landfill

Vulnerability Rating	Source Protection Area		Resource Protection Aquifer Category					
			Regionally Important (R)		Locally Important (L)		Poor Aquifers (P)	
	Inner	Outer	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	**R4**	**R4**	**R4**	**R4**	**R3^2**	**R2^2**	**R2^2**	**R2^1**
High (H)	**R4**	**R4**	**R4**	**R4**	**R3^1**	**R2^2**	**R2^1**	**R1**
Moderate (M)	**R4**	**R4**	R4	R3^1	R2^2	R2^1	R2^1	R1
Low (L)	R4	R3^1	R3^1	R3^1	R1	R1	R1	R1

3.1.9 Eight aquifer categories have been defined by the GSI on the basis of resource and the hydrogeological characteristics:

- Regionally Important (R) Aquifers:
  - Karstified aquifers (Rk)
  - Fissured bedrock aquifers (Rf)
  - Extensive sand/gravel aquifers (Rg)
- Locally Important (L) Aquifers:
  - Sand/gravel (Lg)
  - Bedrock which is Generally Moderately Productive (Lm)
  - Bedrock which is Moderately Productive only in Local Zones (Ll)
- Poorly Productive (P) Aquifers:
  - Bedrock which is Generally Unproductive except for Local Zones (Pl)
  - Bedrock which is Generally Unproductive (Pu)

3.1.10 The aquifer vulnerability rating identified in the matrix is dependent on the characteristics of overlying, unsaturated strata as defined in **Table H.5**.

Table H.5: Aquifer Rating Dependent on the Hydrogeological Conditions

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High Permeability (Sand/Gravel)	Moderate Permeability (e.g. Sandy Subsoil)	Low Permeability (e.g. Clayey subsoil, Clay, Peat)	(Sand/Gravel Aquifers Only)	(<30m radius)
Extreme (E)	0 – 3.0m	0 – 3.0m	0 – 3.0m	0 – 3.0m	-
High (H)	>3.0m	3.0-10.0m	3.0-5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0-10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes:
(1) N/A – Not Applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2m below ground surface.

3.1.11 The following descriptors are provided for each of the risk response categories (R1 – R4) identified in the matrix in Figure 2-1:

R1 Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

R2^1 Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence subject to significance of high permeability zones.

R2^2 Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence subject to significance of high permeability zones.

R3^1 Not generally acceptable, unless it can be shown that:

- the groundwater in the aquifer is confined; or
- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

R3^2 Not generally acceptable, unless it can be shown that:

- there is a minimum consistent thickness of 3 metres of low permeability subsoil present;
- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

R4 Not acceptable.

3.1.12 With regards to the Groundwater Protection Responses it is important to note:

- The matrix has been developed to assist decision making in relation to the site selection process for new landfill sites;
- The matrix has been developed to assist selection, design and management of landfill sites and is based on the precautionary principle;
- The concept of risk management should be used in the decision-making process for the selection of new landfill sites;
- The approach is principally designed for non-hazardous waste streams;
- R2 categories have a presumption of acceptability, whereas R3 has a presumption to object;
- The approach is designed for a single aquifer with overlying unsaturated zone / subsoils and does not therefore provide a methodology for considering more complex multi-layered aquifer systems.

3.1.13 The guidance explicitly states that faulting and associated hydraulic influence on groundwater flow is not in itself reason to deny a license given the ubiquitous presence of fault enhanced permeability within Irish aquifers and non-aquifers as follows:

‘*It is recommended that there should be no general prohibition of landfill siting on areas with geological faults. Rather, attention should be drawn to them by noting firstly that they are ubiquitous in Irish bedrock, that they often increase the permeability somewhat, and that investigations should take account of their possible presence. Construction of potentially polluting landfills in direct contact with faults should be avoided in situations where investigations show that the fault zone is excessively permeable.*’

3.1.14 Furthermore, and in keeping with the spirit of this acknowledgement, the GSI landfill selection matrix states:

‘*Special attention should be given to checking for the presence of more permeable zones, such as faults, particularly in fractured bedrock aquifers. Geophysical surveys may be used to identify zones which should be investigated further by drilling to determine their vertical and lateral extent. Hydrogeological tests should also be carried out to define the local and regional effects of the zones.*

Investigations should be carried out in accordance with the EPA's Landfill Manual Investigations for Landfills, 1995.'

H.3.4. Water Framework Directive Groundwater Bodies

3.1.15 Groundwater Bodies (GWB) have been designated for the purpose of the Water Framework Directive (WFD) (Directive 2000/60/EC). GWBs are subdivisions of large geographical areas of aquifers that allow more effective management to protect the groundwater and linked surface water or groundwater dependent features.

3.1.16 The two GWBs relevant to the study area are:

- Lusk-Bog of the Ring (IE_EA_G_014) - FI (Productive fissured bedrock); and
- Hynestown (IE_EA_G_033) - PP (Poorly productive bedrock).

3.1.17 The WFD requires 'Good Water Status' for all European waters by 2015 or at the latest by 2027, to be achieved through a system of river basin management planning and extensive monitoring. 'Good status' means both 'Good Ecological Status' and 'Good Chemical Status'. The overall objective of the river basin management plans is to restore the status to 'Good' by 2021.