Ardrahan Housing Development

2022 Updated Tier 2 Hydrogeological Assessment

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Galway County Council

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1 INTRODUCTION

1.1 GENERAL

BlueRock Environmental Limited (BREL) were requested by McKenna Consulting Engineers (MCE), on behalf of Galway County Council (GCC), to undertake a Tier 2 Hydrogeological Assessment of an existing housing development (Caislean Rathlin) and associated wastewater treatment plant (WWTP) located on the outskirts of Ardrahan Village, approximately 17km southeast of Galway city.

An initial Tier 2 Assessment was issued on the 11th February 2021 (Ref: BRE19015Rp02A01) by BREL. The assessment provided a number of recommendations including further consideration of the abstraction well at the Caislean Rathlin housing development.

This 2022 Updated Tier 2 Assessment report provides a more up-to-date assessment of the WWTP and includes a more detailed assessment of the housing development abstraction well. It supersedes the findings of the 2020 Tier 2 assessment report.

This updated report is intended to provide a review of all available background geological and hydrogeological information pertaining to the site and its general environs, 2020 Site Investigation data, the existing WWTP and the Caislean Rathlin abstraction well. This report will also facilitate the submission of a discharge licence application for the WWTP, when required.

The existing current housing development comprises 24 no. residential houses, a wastewater treatment plant including soil filter. An abstraction well to supply water to the housing development is also located on site.

According to the Environmental Protection Agency (EPA) Code of Practice '*Guidance dealing with the Authorisation of Discharges to Groundwater, 2011*' wastewater discharges between 5 and 20 m^3/day requires a Tier 2 hydrogeological investigation and discharges greater than 20 m^3/day to ground require a Tier 3 investigation. A Tier 2 investigation typically requires the drilling of boreholes, excavation of trial pits, soil and water sampling and interpretation of the hydrogeological data recorded.

Based on a current estimated discharge rate of 9.7 m^3/day, a Tier 2 Hydrogeological Assessment was deemed necessary. GCC are currently considering extending the existing development by an additional 10 no. residential units utilising the existing WWTP and water supply on site. This would further increase the loading to 15.0 m^3/day.

A draft Phase 1 Hydrogeological Assessment report (Ref: BRE19015Rp01F01, dated 19th June 2019) was previously issued by BREL based on a site walkover and a desk top data collation exercise. The report indicated that given the uncertainty surrounding background and site-specific geological and bedrock aquifer conditions, the preliminary risk posed by the WWTP discharge to sensitive receptors was deemed to be Moderate to High. A series of recommendations was provided which included assessing the existing WWTP, an investigation of the filter currently on-site and undertaking a Tier 2 Hydrogeological Assessment of the site.

1.2 SCOPE OF WORK

The following scope of works was subsequently undertaken to address points 1, 2, 5 and 6 as outlined in Section 1.1:

- A detailed desk study comprising a review of all available background geological, hydrogeological and hydrological information pertaining to the site and its general environs;
- A detailed site walkover of the site and its environs to confirm the findings of the desk study and to scope a suitably detailed Tier 2 Site investigation;
- Supervision of a Hydrogeological Site Investigation including borehole drilling, monitoring well installations, infiltration testing, groundwater level monitoring and groundwater sampling;

- Additional site investigation works consisting of trial pits and infiltration testing to address data gaps relating to the initial site investigation, and,
- Completion of an interpretative Tier 2 Hydrogeological Site Assessment Report.

1.3 METHODOLOGY

The following sources of information were used in the compilation of this assessment:

- Ordnance survey of Ireland (OSI) online historical maps and aerial photographs;
- Geological Survey of Ireland (GSI) On-line Groundwater database. Geological Mapping, Aquifer Classification, Aquifer Vulnerability, Teagasc Soil Classification;
- National Parks and Wildlife Service (NPWS) On-line database www.npws.ie;
- EPA Online Water Quality Mapping; https://gis.epa.ie/EPAMaps/;
- Online Water Quality Mapping; https://www.catchments.ie/maps/.
- Galway County Council (GCC) On-line planning files.
- Office of Public Works (OPW) Flood Risk Maps & hydro-data (https://www.floodinfo.ie/map/floodmaps/) (http://www.opw.ie/hydro-data); and
- Met Eireann - met.ie – hourly rainfall data.

2 LEGISLATION & IMPACT ASSESSMENT CRITERIA

The control of discharges to aquifers is governed by S.I. No. 42 of 1999: Local Government (Water Pollution) (Amendment) Regulations, 1999. Article 40 (2) details the requirements of the required Hydrogeological Assessment as follows:

(2) The prior investigation referred to in sub-article (1) shall include—

(a) An assessment of the environmental impact of alternative methods of disposal of the harmful substance, and

(b) An examination of the aquifer to which the licence application relates in respect of the following—

(i) The extent and estimated volume of water therein;
(ii) The quality of water therein;
(iii) The estimated rate of recharge;
(iv) The identification of any existing or proposed uses of the water therein;
(v) The hydrogeological conditions of the area in which the aquifer is located;
(vi) The nature and depth of overlying soil and subsoil and its effectiveness in preventing or reducing the entry of the harmful substance to water in the aquifer;
(vii) The risk of deterioration in the quality of the water therein due to the entry of the harmful substance;
(viii) The risk of the water therein being affected by the harmful substance so as to endanger human health or water supplies, harm living resources and the aquatic ecosystem or interfere with the use of the water for agricultural, commercial, domestic, fisheries, industrial or recreational purposes; and,
(ix) Such other matters as the local authority may reasonably require for the purpose of establishing whether the discharge of the harmful substance to the aquifer is a satisfactory method of disposal having regard to its environmental impact and the results of the assessment referred to in paragraph (a).

A "harmful substance" means substances and groups of substances specified in the First Schedule or in the Second Schedule, except where otherwise provided (S.I. No. 271/1992: Local Government (Water Pollution) Regulations, 1992). It is noted that some of the constituents of the treated wastewater proposed for discharge from the site to groundwater constitute definition as a "harmful substance" under the schedules of the Local Government (Water Pollution) Regulations (1992). Therefore, this report details the alternative strategies considered and the results of the 'examination of the aquifer'

The discharge must also be considered in the context of the Groundwater Regulations (2010), which do not specify groundwater limit concentrations but rather require no upward trend in groundwater concentrations. EPA Guidance on the Authorisation of Discharges to Groundwater (2011) requires that the proposed discharge is assessed according to the risk posed, which is assigned according to the magnitude of hydraulic loading proposed and the nature of the receiving environment.

2.1 HYDRAULIC LOADING

Based on EPA loading rates of 150 litres/person/day for 24 existing houses and 10 no. proposed houses, the anticipated hydraulic loading of the entire development post construction will be at least 14.58 m^3/day assuming **2.7 persons per house**[1] - see Table 2.1 below.

Ardrahan Site Development						
EPA 2009 Classification user type	**Source**	**Expected Users Per Day**	**EPA 2009 Flow (l/p/day**	**Calculated Total Flow (l/day)**	**EPA 2009 BOD_5 g/p/day**	**Calculated BOD_5 load (g/day)**
Existing units	Residential Occupants only	**(24 No. houses x 2.7 people per house) = 64.8**	150	9,720	60	3,888
Proposed units	Residential Occupants only	**(10 No. houses x 2.7 people per house) = 27**	150	4,050	60	1,620
Total				**13,770 l/day**		**5,508 (91.8PE)**

Table 2.1 EPA 2009 loadings determinations for the site

The above calculations in Table 2.1 confirms a hydraulic loading of **13.77 m^3/day** and an organic loading of **91.8 PE**. Based on these calculations it is apparent that the existing WWTP which has a PE of 100 is theoretically capable to treating the loading from the existing and proposed development.

2.2 EXISTING WASTEWATER TREATMENT PLANT

Following consultations with the original suppliers of the WWTP (i.e. EPS), the following information was supplied.

- The treatment system installed is a 100 PE SAF wastewater treatment system comprising a 4 no. tank concrete unit system including 2 no. settlement tanks, an aeration tank and a second settlement tank with media, sludge return pump and controls.

- The design specification for the system based on the design load was:
  - BOD 20 mg/l
  - Suspended Solids 30 mg/l
  - Total Phosphorus <5 mg/l (with dosing)

- Treated secondary treated wastewater is pumped to a treatment percolation area. Initial inspection pits along the face of the filter suggested it comprised a soil filter bed measuring 26m x 24m in area with a distribution system. The thickness of the filter appeared to be 1.2 metres in depth; however, subsequent investigation confirmed the structure to comprise a gravel distribution bed only.

- A number of inspection pits were excavated surrounding the perimeter of the filter (i.e. IP1 To IP3). An additional 2 no. inspection pits (i.e. IP4 and IP5) were excavated within the footprint of

[1] Based on Irish Water average occupancy rate and agreed with Galway County Council Environment Dept

the filter. Inspection pit IP6 was excavated within the French drain surrounding the filter with pits IP7 and IP8 excavated to the east and southeast of the filter (Figure 5.1).

The findings of these pits confirmed the following:

- The existing filter is measured at approximately 26m x 24m in area.
- The construction of the filter appears to comprise a layer of topsoil (0.2m in thickness) overlying a geotextile membrane which separates the topsoil from a layer of gravel (0.2 to 0.4m in thickness). The gravel layer overlies undisturbed natural subsoils comprising of very stiff slightly sandy slightly gravelly SILT with occasional to frequent limestone small to large cobbles and small boulders (see Figure 5.2).
- Distribution pipework was exposed overlying the gravel layer. This 1“ HDPE pipework was confirmed to be spaced at approximately 1.2m intervals and perforated with small holes (approximately 5mm diameter). The pipework was visually dry with no evidence of wastewater within the pipes.
- The gravel layer was observed to be very dry and clean with no evidence of wastewater present.
- An inspection of the underground pipe connecting the WWTP to the filter uncovered a discontinuity within the pipe that was releasing wastewater to the French drain with no flows recorded to the filter area. This would explain why the gravel and distribution pipework at the filter were clean and dry.
- Additional pits (IP7 and IP8) were excavated to the east and south of IP6. No water was encountered within these pits (Figure 5.1).

Based on the above, it was concluded that:

a) The filter is effectively a gravel distribution bed only and is not a soil or sand filter as originally understood. The filter was also not constructed in line with the EPA Code of Practice, 2009 as it would appear the filter was constructed circa 2007 and prior to the publication of the 2009 guidance.

b) No wastewater from the WWTP is currently being pumped to the gravel bed with all wastewater being discharged into the French drain along the eastern side of distribution bed (Figure 2.2). This wastewater is eventually seeping into the surrounding soils and eventually into the bedrock aquifer likely via discontinuities within the low permeability silts and clays.

c) A new filter bed is required to be constructed in line with the Code of Practice.

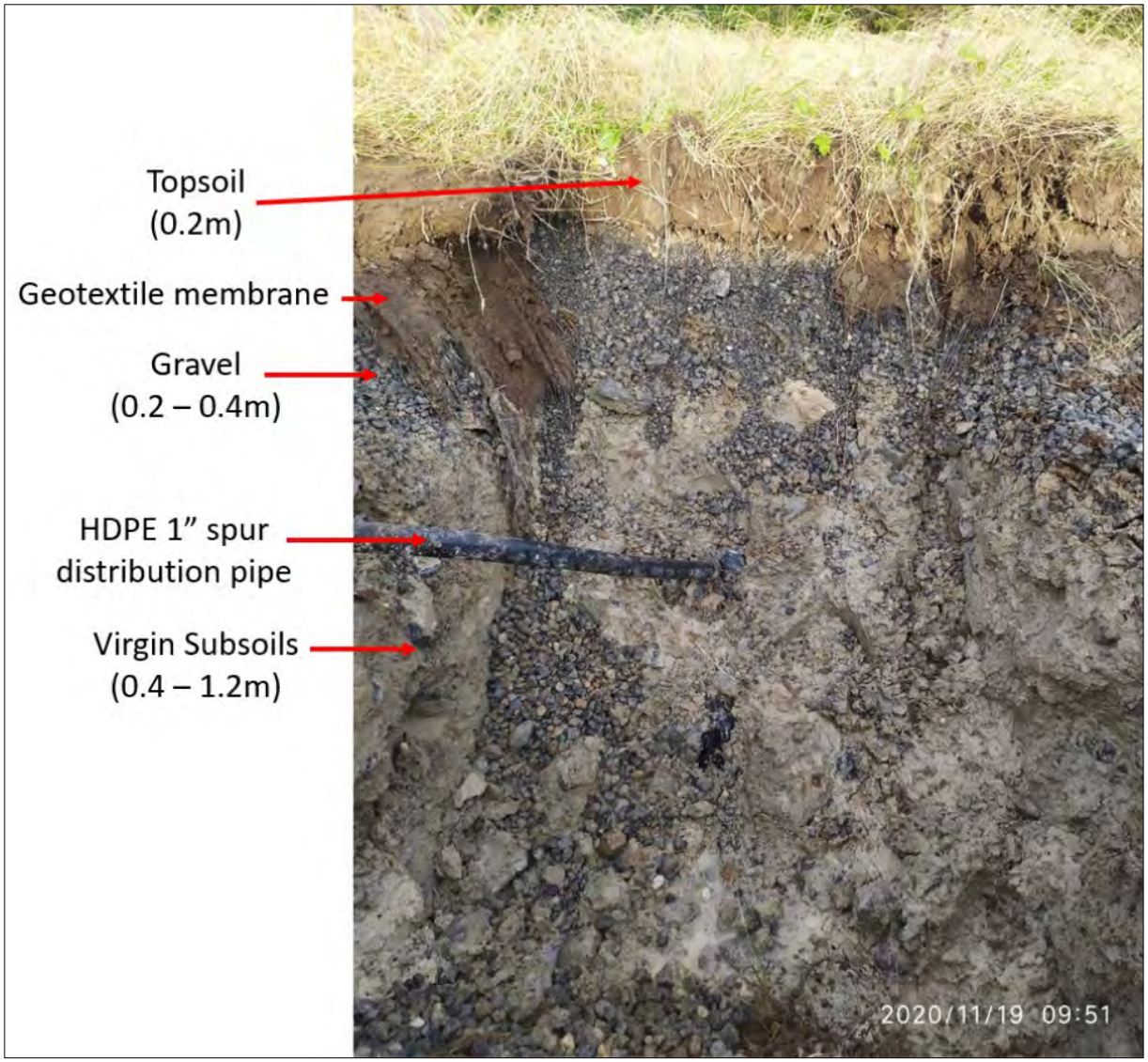

Figure 2.1 Cross Section of Filter Bed

3 BACKGROUND SITE INFORMATION

3.1 SITE LOCATION

The proposed development site is located in the village environs of Ardrahan, Co. Galway approximately 17km southeast of Galway City. The proposed development is located in a greenfield site to the east of the R458 Road and immediately northeast of an existing housing development i.e. Caislean Raithlin. There are several private houses located immediately to the south and southeast of the site. The northern portion of the site is bounded by the Galway-Sligo Railway Line. The proposed site is currently a greenfield site (see Figure 3.1).

The existing housing development is connected to a Wastewater Treatment Plant (WWTP) and associated tertiary filter located approximately 170m to the northeast of the development within council lands.

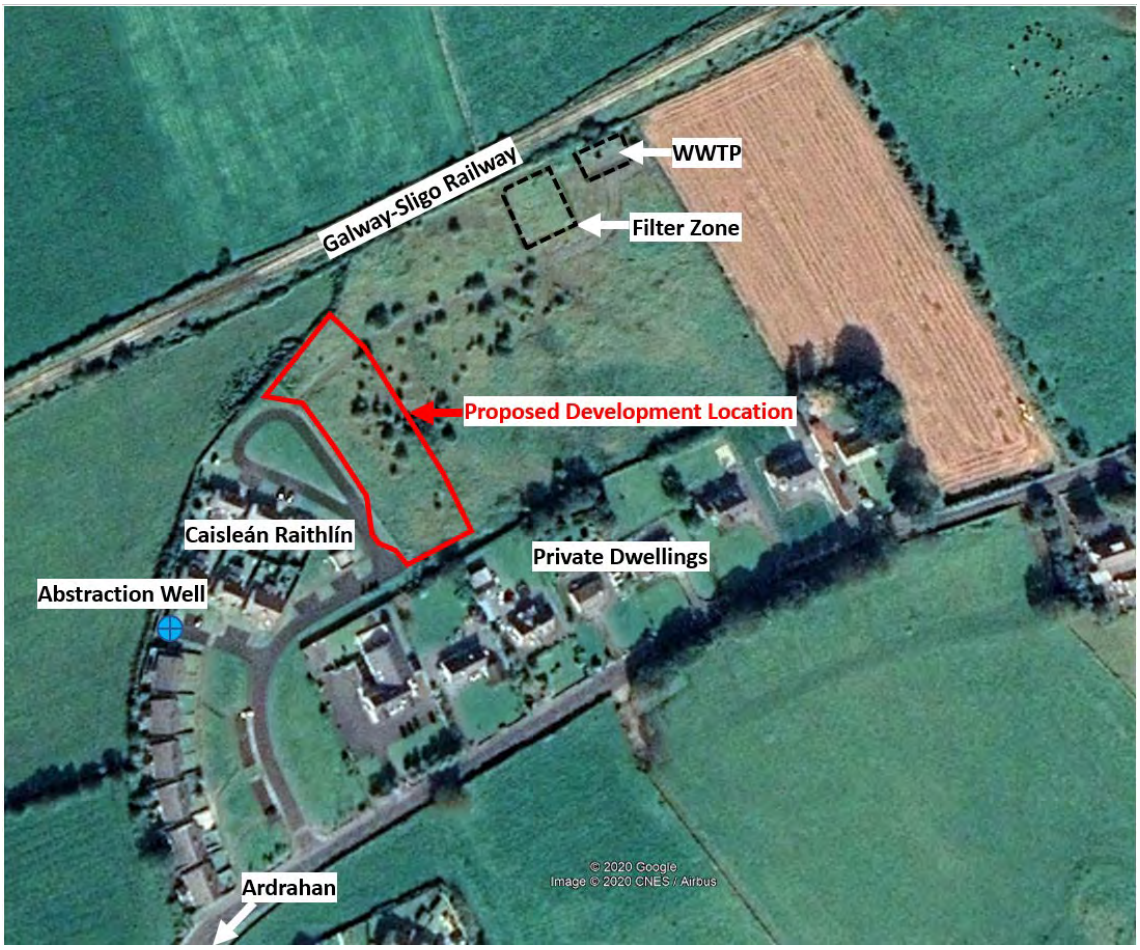

Figure 3.1 Site Location & Setting

3.2 TOPOGRAPHY

The site has an elevation of between 29 mOD and 32 mOD and gently slopes in a southwesterly direction. Regionally, the topography ranges from a high point of 338 mOD, 12km southeast of Ardrahan, to approximately 0 mOD, at the coastline of Kinvara Bay, approximately 9km west of the Ardrahan village. The topographical relief in the vicinity of the site is also gently sloping.

3.3 SITE LAYOUT AND SIZE

The total area of proposed site is 0.4 hectares. The site layout and the location of the existing WWTP are outlined in Figure 3.1 above.

3.4 HISTORICAL LAND-USE

A number of historical land-uses of the site were identified from historical maps as summarised in the draft Phase 1 Hydrogeological report issued by BREL in 2019 (Report Reference *BRE19015Rp01F01 - Ardrahan Housing Development Phase 1 Hydrogeology Report).* The site was agricultural land until the first phase of the housing development was built as shown on Aerial Map 2005 – 2012. The surrounding land saw the expansion of Ardrahan village and some local rural one-off housing.

4 BACKGROUND SITE CONDITIONS

The background environmental setting was previously described in detail within the draft BREL Phase 1 Report Reference *BRE19015Rp01F01, dated 19th June 2019* and is summarised in Table 4.1 below for completeness.

Regional & Site Geology	
Bedrock	Carboniferous Limestone Formation of the Dinantian Pure Bedded Limestones Group (Burren Formation). Karstified bedrock outcrop and subcrop dominate the area with the closest outcrop circa 3 km to the northeast of the site.
Karst Features	Numerous karst features (turloughs, swallow holes, enclosed depressions etc.) occur in these karstified limestones. There are two cave features approximately 500m west and southwest of the site. Two turloughs, two springs and an enclosed depression are mapped within 1 km east and southeast of the site – see Figure 4.1.
Overburden	Topsoil at the site is mapped by Teagasc as deep well drained mineral soil derived from mainly basic parent materials (BminDW) of limestone tills (TLs). There are areas of karstified rock at the surface (kRck) mapped in the wider area in addition to a small gravel body (GLs) located to the west of the site (Figure 4.2). The limestone tills ('boulder clays') are considered to have moderate permeability.
Site investigation	2018 site investigation (4 no. Trial Pits) were excavated to a maximum depth of 2.3 mbgl. Overburden was generally consistent across the site and comprised Topsoil/Surfacing overlying Cohesive Deposits of a firm brown sandy slightly gravelly clay overlying firm to stiff grey brown sandy gravelly clay with some subangular cobbles and boulders'. Groundwater was not encountered during site investigations.
Hydrogeology	
Aquifer Classification	Regionally Important Karstified Bedrock Aquifer dominated by conduit karst flow (Rkc). As with most karstic systems, permeability and transmissivity is expected to be highly variable. Groundwater flow direction can vary over time. The site is located within the Clarinbridge Groundwater Body (GWB). The GWB is almost entirely dominated by Dinantian Pure Bedded Limestones with widespread karstification. Yields are highly variable and extensive conduit systems exist. The site is not mapped within a groundwater flood area.
Aquifer Vulnerability	High vulnerability, indicating ground conditions comprising permeable overburden with an average depth of less than 3.0 mbgl – see Figure 4.3.
Groundwater Flow	Tracer tests indicate groundwater flow direction within the karstified bedrock in this region is generally in a westerly and southwesterly direction. Groundwater is not expected to be present within the overburden at the site based on existing investigation data. As the region is underlain by karst limestone, groundwater flow will be dictated by preferential pathways in the subsurface, conduits created by the dissolution of the limestone over time.
Groundwater Wells & Local Groundwater Use	Five (5 no.) groundwater wells are mapped by the GSI within 3 km of the site. The Ardrahan Group Water Scheme (GWS) wells are located ~1km southwest of the site, with a current abstraction rate of between 229 m^3/day and 264 m^3/day and a total of 245 connections. The abstraction wells are located less than 1 km southwest of the boundary of the proposed site. An existing groundwater abstraction well is located within the Caislean Rathlin housing development and is located approximately 215 metres southwest of the WWTP filter zone. The well is reported to abstract an average rate of 5-7 m^3/day based on recent flow readings. The depth of the abstraction well is reportedly 50-55 metres deep. The zone of contribution (ZOC) surrounding the well is unclear but anticipated to be relatively small based on the low volumes

	currently being abstracted. The shape or extent of this ZOC has not been mapped to-date. The outer zone of a Group Scheme Preliminary Source Protection Area is located approximately 0.45 km to the north of the site i.e. Kiltiernan Turlough (EU Site Code: 001285). This turlough is a Groundwater Dependent Terrestrial Ecosystem (GWDTE) – see Figure 4.4.
Background Groundwater Quality	Groundwater within this groundwater body typically has a calcium bicarbonate signature. A review of available water quality test results from sample collected from a number of houses within the existing housing development in 2013 to 2018 indicates that the current water supply is of a good quality in terms of drinking water supply.
Groundwater WFD Status	The Clarinbridge Groundwater Body (IE_WE_G_0008) has a Groundwater WFD Status of 'Good'. The Groundwater Waterbody Risk Score is 'At Risk' of not meeting environmental objectives from agriculture and domestic wastewater.
Hydrology	
Catchment Description	There are no surface water rivers or streams located within proximity of the site. The Dunkellin River and the Kilcolgan River exist approximately 6km and 9km north of the proposed site. Both systems drain into Galway Bay. Surface water percolates rapidly to become groundwater, including via discrete points at swallow holes and enclosed depressions in the area.
Catchment Water Bodies	A number of lakes and rivers are mapped in the wider area; however, it is likely that a majority of water ways are underground in the area. There are a number of turloughs and lakes present locally. There have been no reports by the Office of Public Works (OPW) of flooding at the site or in the vicinity of the site. However, anecdotal evidence suggests that localised ponding of rainwater historically occurred in the general vicinity of the WWTP.
Sensitive Sites	
Designated or Protected Sites	• Caherglassaun Turlough SAC (000238) - 6.4 km south west • Kiltartan Cave SAC (000268) - 6.2 km south west • Coole-Garryland Complex SAC (000252) - 3.9 km south west • Carrowbaun, Newhall and Ballylee Turloughs SAC (002293) - 5.4 km southeast • Lough Coy SAC (002117) - 4.7 km south east • Coole Garryland Complex SPA (0004107) - 5.1 km south west • Kiltiernan Turlough SAC (EU Site Code: 001285) – Group Scheme Preliminary Source Protection Area – 0.45 km north of the site • Ardrahan Group Water Scheme Supply – 1.0 km south of the site

Table 4.1 Environmental Setting

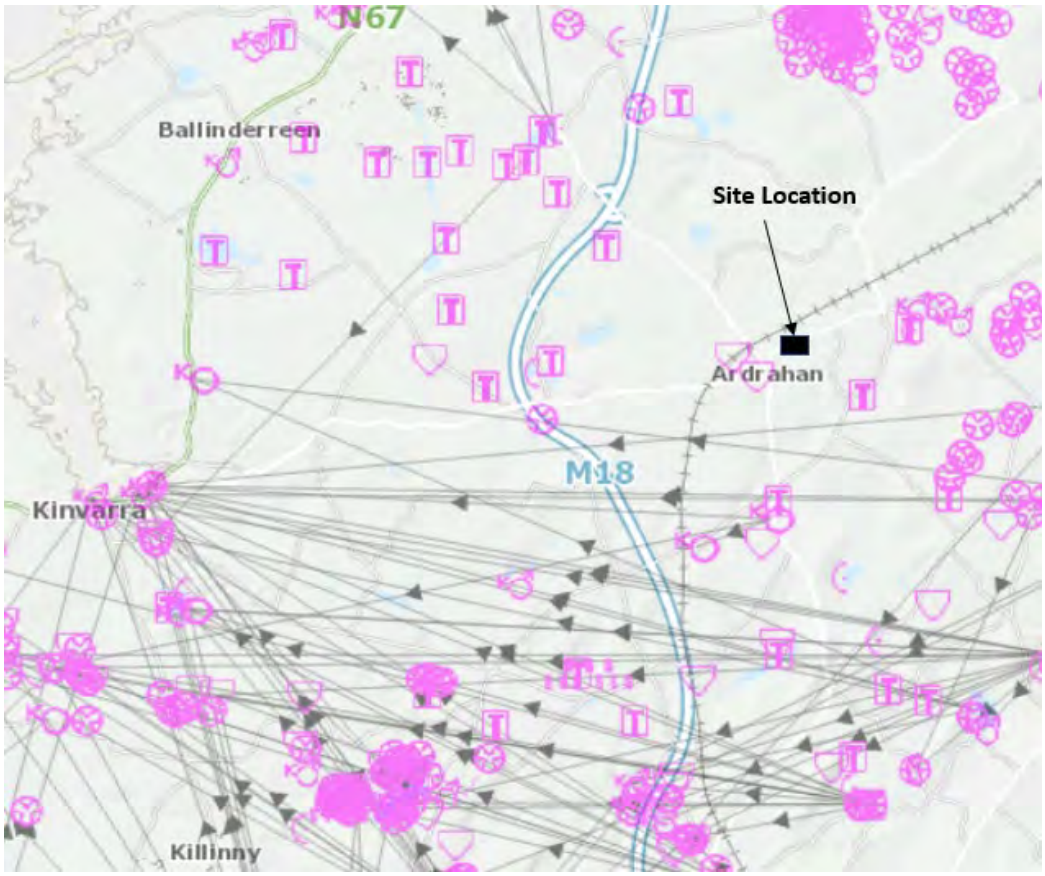

Figure 4.1 GSI mapped Karst Features and Tracer Lines

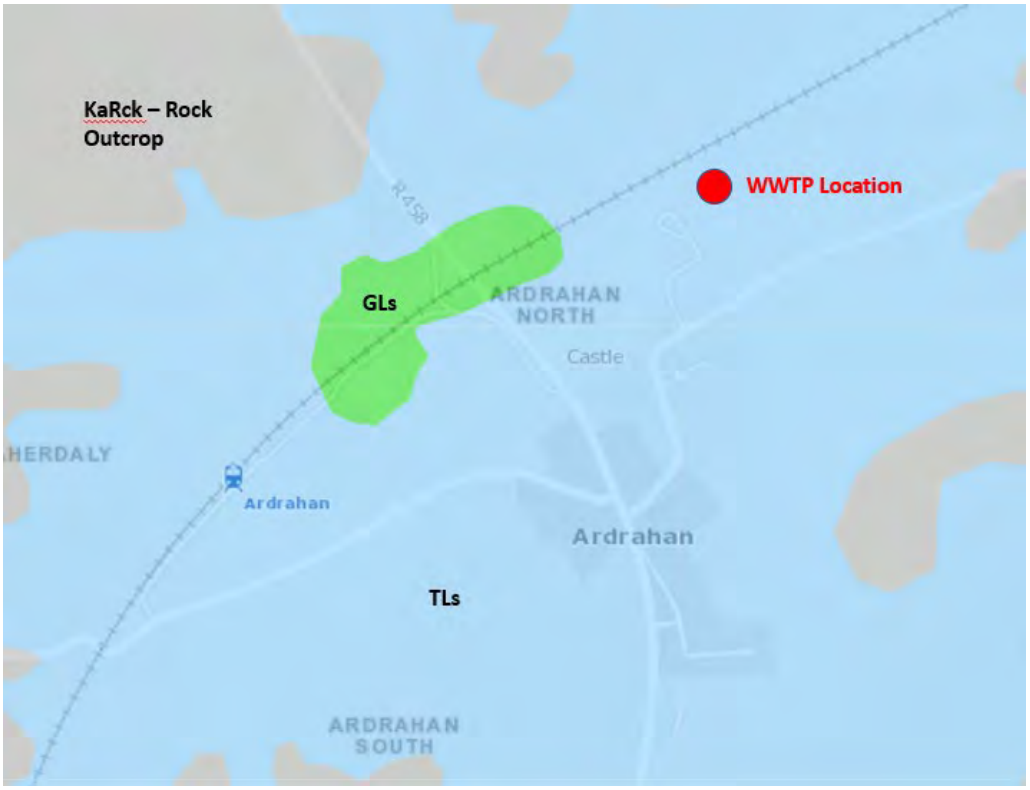

Figure 4.2 Subsoils

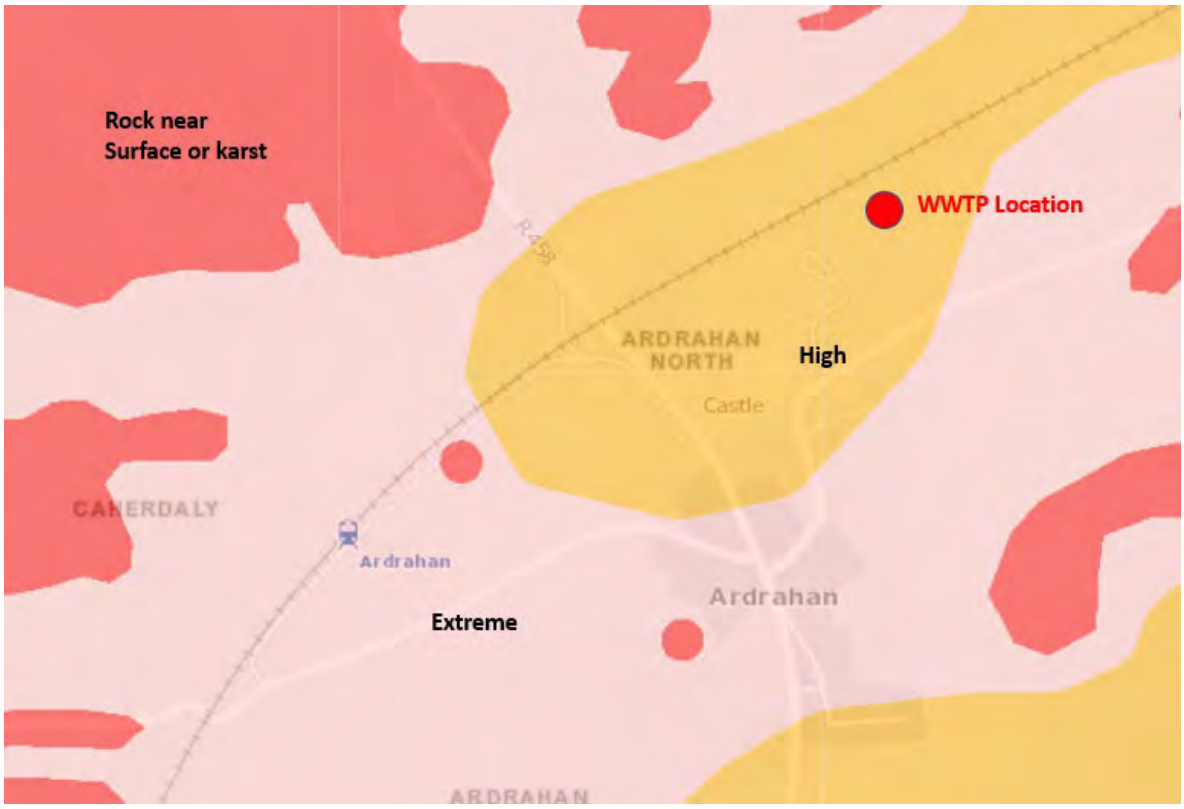

Figure 4.3 Groundwater vulnerability

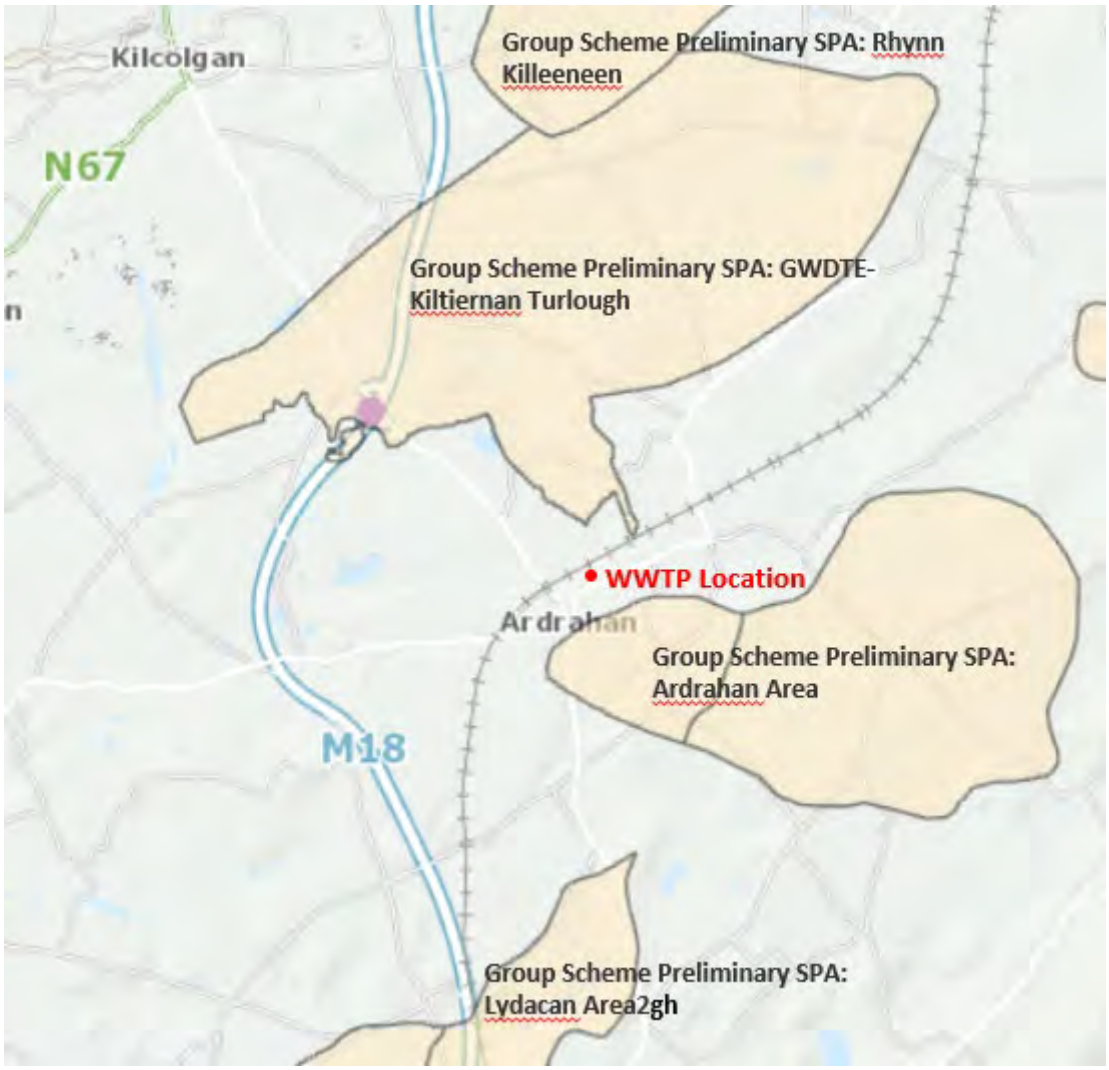

Figure 4.4 Group Water Schemes SPAs

5 TIER 2 SITE INVESTIGATION

5.1 2020 SITE INVESTIGATION

An intrusive site Investigation was undertaken by Ground Check site investigation contractors between the 2nd and 4th June 2020. The scope of works comprised the excavation of 2 no. trial pits (PT1 and PT2), the drilling of 3 no. rotary boreholes (MW01, MW02 and MW03), infiltration/percolation testing with the trail pits and hydraulic conductivity testing within the monitoring wells. Three (3 no.) inspection pits (i.e. IP1 to IP3) were excavated around the perimeter of the filter.

A follow-up investigation was undertaken by Galway County Council between the 18th and 19th November 2020 that comprised the excavation of an additional 5 no. trial pits (i.e. PT3 to PT7) and 5 no. inspection pits (i.e. IP4 to IP8) within and adjacent to the filter bed. Infiltration testing was undertaken within selected trial pits (i.e. PT4, PT5, PT6 and PT7).

The trial pits were excavated using a 13-tonne excavator and the boreholes were drilled using a Comacchio MC305 rig with 150mm symmetrix casing and tools continued by open-hole with down-hole hammer into the bedrock. Each borehole was installed with a 50 mm diameter monitoring well to facilitate groundwater sampling and groundwater level monitoring.

Hydraulic conductivity testing undertaken within the bedrock monitoring wells using the variable head test method (falling-head test) in accordance with BS5930.

All investigation activities were undertaken under the direct supervision of a BREL Hydrogeologist as required by the EPA Code of Practice and guidance.

All site investigation logs are presented in Appendix A and the locations are presented on Figure 5.1 below.

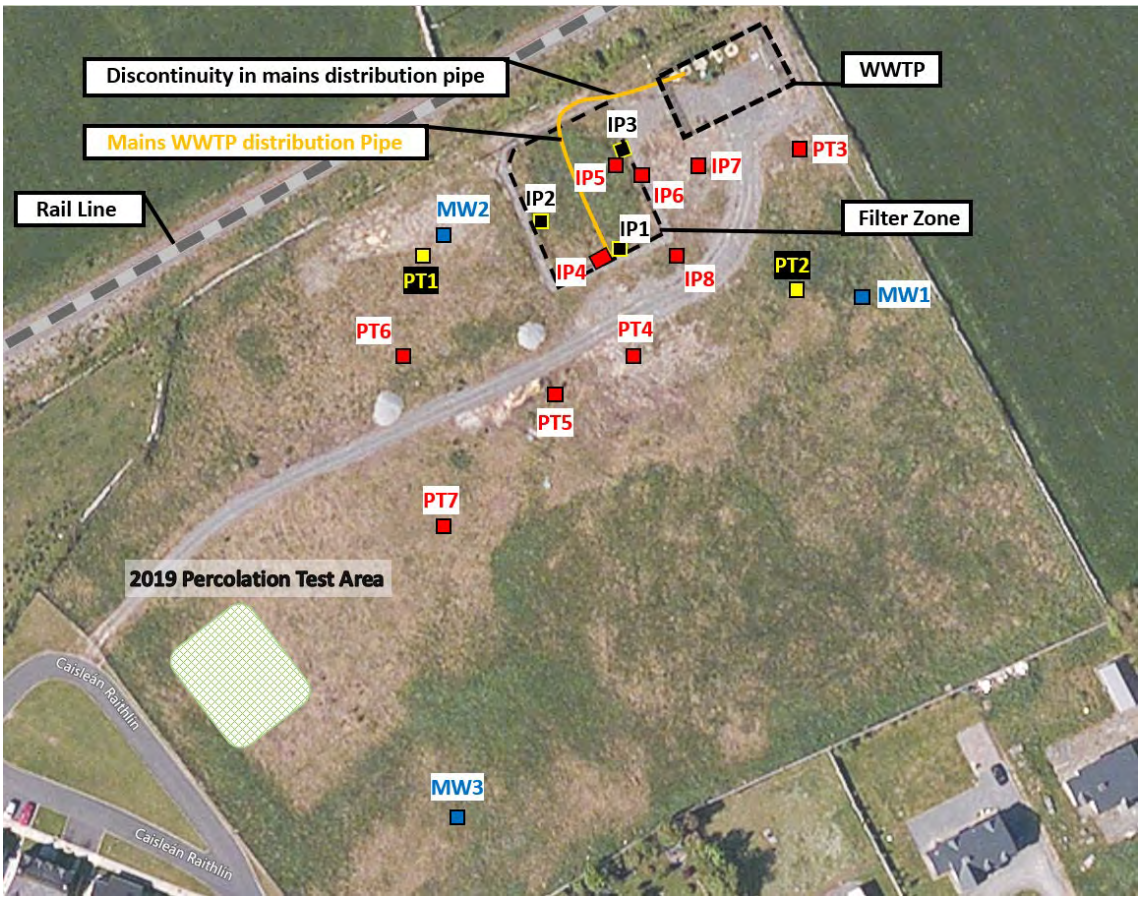

Figure 5.1 Site Investigation Locations

5.2 GROUND CONDITIONS

A summary of the ground conditions recorded within trial pits (PT1 to PT7) and boreholes (MW01 to MW03) across the site is outlined in Table 5.1 below.

Four (4 no.) voids were recorded within borehole MW02 at depths between 6.0m and 22.0m. The voids ranged in size between 1.0m and 5.6m with the shallowest void infilled with brown slightly gravelly sandy silty clay. No recovery was recorded from the deeper voids due to loss of compressed air into the void spaces.

Two (2 no.) voids were recorded within borehole MW03 at depths between 10.8m and 12.7m. The voids ranged in size between 1.4m and 1.8m and were each infilled with brown silty sand with bands of sandy silty clay and sandy clayey silt.

The trial pit excavated in the western region of the site by Mr. Brendan Reddan in 2019 recorded loam overlying sand & clay with cobbles and boulders up to 2.3m (see Appendix B).

Lithology	Depth to top range (m)	Thickness range (m)	Description
Made Ground	-	0.1 – 1.0	Made ground comprising a thin layer of topsoil with grass rootlets, in some locations overlying reworked light grey/brown, gravelly, very sandy gravelly clayey silt with frequent cobbles and occasional boulders.

Silt	0.1	2.0 - 2.3	Light brown and grey, soft to stiff, slightly sandy slightly gravelly SILT with frequent cobbles and small boulders of limestone.
Clay	0.1 – 1.0	1.4 - 6.9*	Firm to stiff, light grey/ brown gravelly, sandy, silty CLAY containing cobbles.
Weathered Rock	2.1 - 8.1*	0.2 - 0.9*	Weathered limestone in MW01 and MW03.
Bedrock	2.3 - 9.0 *	-	Light grey, fine grained LIMESTONE (Burren Formation).
*based on boreholes only			

Table 5.1 Summary of Ground Conditions in vicinity of Soil Filter

5.3 MONITORING WELL INSTALLATIONS

The 3 no. rotary boreholes drilled were installed with a 50 mm nominal diameter HDPE well pipe, with screened sections positioned within the limestone bedrock. The positioning of the screened intervals was based on geological and hydrogeological conditions encountered during the drilling activities. The locations of the monitoring wells MW01 to MW03 are presented on Figure 5.1 and the details are summarised in Table 5.2.

During the drilling of MW01 a water seepage was recorded at 14.5 mbgl. Upon completion of the borehole at a total depth of 23m, the borehole was dry. After a period of 1 hour the water level rose up by 1.54m and after a period of 4 hours the water level rose up by 6.0m. The following morning (3rd June 2020) the water level was at 15.8 mbgl (rose up by 7.2m).

During the drilling of MW02 on 3rd June 2020 no water strikes were recorded, moisture was observed at 13.1 mbgl. Upon completion of the borehole at a total depth of 23m, the borehole remained dry. After a period of 8 hours the water level was recorded at 16.3 mbgl and remained at the same level the following morning.

During the drilling of MW03 on 3rd June 2020 a water strike was recorded (as a seepage) at 28 mbgl. When drilling was completed at 33m the borehole was dry. After a period of 3 hours the water level rose to 21.9 mbgl.

Well	Datum (mOD) [2]	Upstand (m)	Total Depth (m)	Water Strikes (mbgl)[3]	Screened horizon (mbgl)	Top of Weathered Bedrock (mbgl)
MW01	28.91	0.54	23.45	14.5	10.0 - 24.5	2.1
MW02	29.69	0.71	23.0	-	10.5 - 22.3	5.3
MW03	31.87	0.64	33.0	28.0	9.0 - 33.0	8.1

Table 5.2 Monitoring Wells

[2] meters above ordnance datum
[3] meters below ground level

5.4 GROUNDWATER LEVELS

Five (5 no.) rounds of manual dips were recorded by BREL between the 4th June and the 9th September 2020 – see Table 5.3.

A groundwater contour map was developed created using manual dip groundwater levels recorded on-site on the 18th June 2020. The data indicates that groundwater is consistently flowing to the south, southeast and southwest (Figure 5.4). Subsequent water level monitoring indicates a consistent groundwater flow direction over time.

Groundwater data loggers recording groundwater levels at hourly intervals were installed within each well between the 3rd July 2020 and the 9th September 2020. The groundwater levels during this period are presented on Figure 5.5 in addition to rainfall data for the same period.

The groundwater level signature within each well is broadly similar over time (Figure 5.5) with water levels highest in the northern region of the site and lowest in the southern region. Groundwater levels appear to respond to rainfall events at certain times and on other occasions does not respond with water levels varying between 7.79 and 10.57m during the monitoring period. The shallowest groundwater level was recorded at a depth of 7.81 metres below ground level – see Table 5.3 below.

Well	Water Level Range (mbgl)	Water Level Range (mOD)
MW01	7.81 to 16.61	12.3 to 21.1
MW02	8.74 to 16.53	13.16 to 20.95
MW03	11.31 to 21.88	9.99 to 20.56

Table 5.3 Groundwater Level Range

In the upper part of the karst aquifer (from the bedrock surface to approximately 20 m below) a zone of epikarst occurs, in which fissures and fractures are numerous and well connected with one another and with the surface. This zone is highly transmissive of groundwater flow and groundwater flowing in this zone has a high degree of connectivity with the surface. The presence of an epikarst zone adjacent to the abstraction borehole is recorded in the monitoring boreholes in the form of shallow weathered zone at the surface of the bedrock and as karst voids to depths of 20 m below the top of bedrock. The increased hydraulic conductivity of this epikarst zone is reflected in groundwater levels shown in Figure 5.5. At water levels above c 14 mOD, which is the lowest level at which voids appear in the monitoring boreholes, water levels converge. This reduced gradient between the borehole water levels is indicative of increased hydraulic conductivity in this zone.

Recharge rate of the upper epikarst zone of the pure limestones is discontinuously across the surface, being highest where sub-soils are thin and at any discrete point recharge locations (swallow holes, enclosed depressions). Deeper in the aquifer profile, beneath the epikarst, karst conduits and fissures occur. These are less well connected and may, or may not be, connected with and recharged from the overlying epikarst. Recharge typically enters these fissures and conduits at discrete point recharge locations at the surface and groundwater flow thereafter is constrained within them.

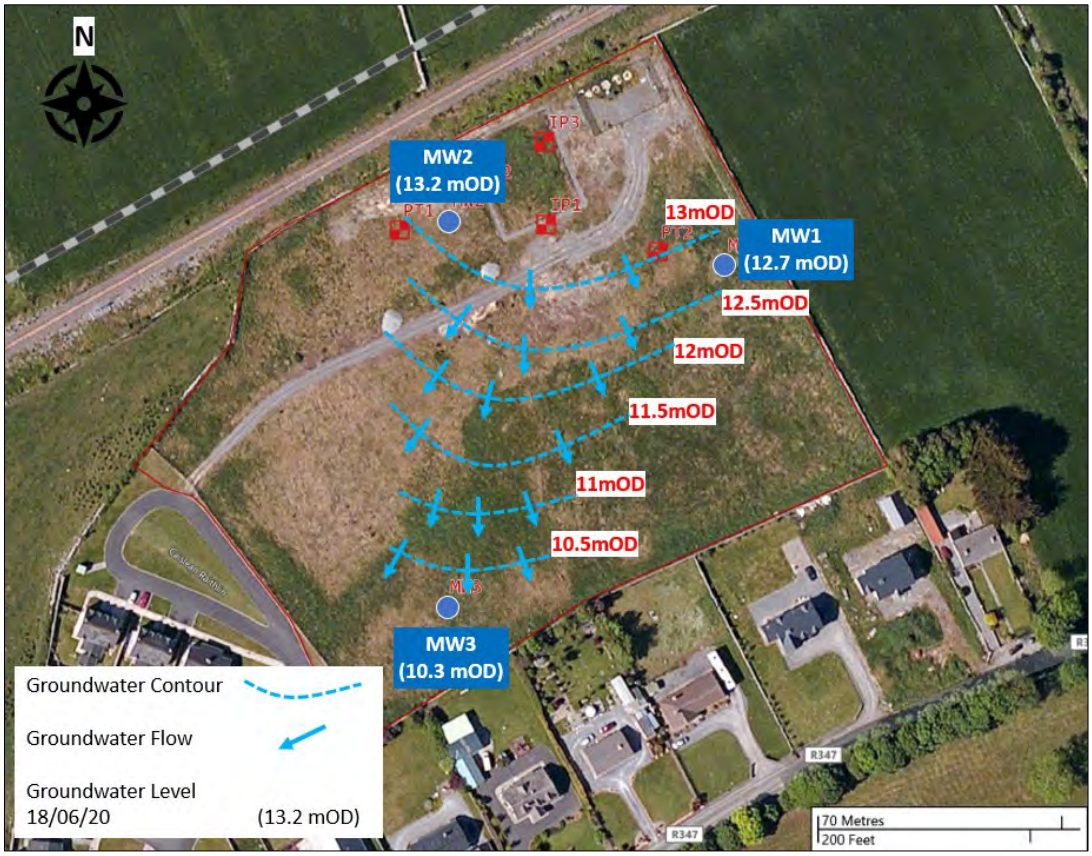

Figure 5.2 Groundwater Contours and Flow Direction (18th June 2020)

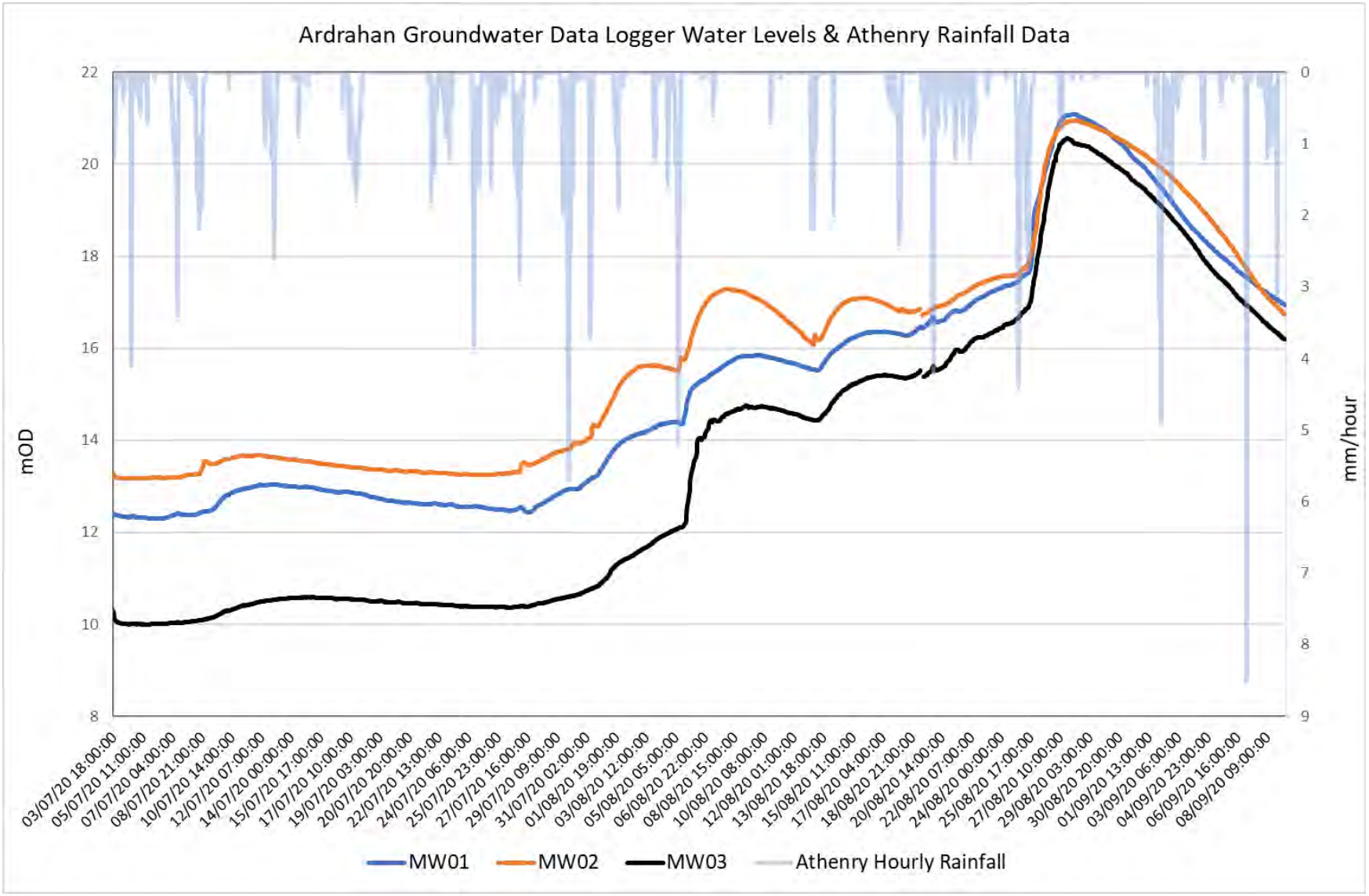

Figure 5.3 Groundwater Data Logger Levels (July 3rd to September 9th 2020)

5.5 HYDRAULIC CONDUCTIVITY (K-TESTING)

Hydraulic conductivity (falling head) testing was undertaken by BREL on the 4th June 2020 within each monitoring well, in accordance with BS5930 Code of Practice for Site Investigations (Section 4 Permeability).

The calculated hydraulic conductivity (K) values, representative of permeability within the bedrock are as follows:

	K value m/day	K value m/sec
MW01	$2.04x10^{-4}$	$5.67x10^{-8}$
MW02	6.2	$7.17x10^{-5}$
MW03	5.46E-01	$6.32x10^{-6}$

Table 5.4 Hydraulic Conductivity (K)

These calculated K values indicate a high variability in the permeability of the bedrock aquifer underlying the site ranging between 0.00024 and 6.2 metres/day. It is noted that the permeabilities calculated are based on the monitoring well installations at depth within the bedrock with greater velocities likely within the weathered bedrock horizon at the interface between the subsoils and the bedrock. K-test results are provided in Appendix C.

5.6 INFILTRATION TESTING

Infiltration testing in accordance with BRE Digest 365 was undertaken within a number of trial pits in both June and November 2020. The objective of the testing was to assess the permeability of the overburden underlying the filter and its surrounding environs. The tests were undertaken within pits PT1 to PT7. The tests failed within 6 no. pits with drawdowns < 100mm in each pit. A T-value of 240 minutes was recorded within PT7 between 1.0 and 1.6 mbgl equating to a soil infiltration rate of 1.5×10^{-5} m/s (see Appendix C).

5.7 SITE SUITABILITY ASSESSMENT

Percolation testing was undertaken at the site in 2019 by Brendan Reddan, Site Suitability Assessor. The pits were located to the south of the site entrance. Permeability readings of the subsoils between 0.4 and 0.8 metres were recorded at the site entrance with T-values ranging between 420 and 455 mins representing very low permeability conditions in this area of the site (see Appendix B). This is consistent with the ground conditions encountered in the vicinity of the WWTP.

5.8 HYDRAULIC GRADIENT

The hydraulic gradient within the bedrock across the site ranged between 0.005 and 0.025 (see Table 5.5).

Date	Wells	Hydraulic Gradient
18/06/2020	MW02 to MW03	0.024
03/07/2020		0.025
19/08/2020		0.01
18/06/2020	MW01 to MW03	0.017
03/07/2020		0.015
19/08/2020		0.005

Table 5.5 Calculated Hydraulic Gradients

5.9 PARTICLE SIZE DISTRIBUTION (PSD)

A number of particle size distribution (PSD) curves were generated from selected soil samples in the trial pits. The results confirm the description of the trial pit logs and are presented in Appendix D.

5.10 INTERPRETATION OF HYDROGEOLOGICAL CONDITIONS

Based on the data collated during the site investigation work in both June and November 2020 and the groundwater level monitoring throughout this period, the following interpretation of the hydrogeological regime is provided below:

- Groundwater was recorded at depths ranging between 7.83 m and 21.88 mbgl (9.99 and 21.08 mOD) within the limestone bedrock. No groundwater was recorded within the overburden.
- The hydraulic gradient between upstream and downstream wells varies between 0.002 and 0.025.
- The highest water level variation was recorded within monitoring well MW03 (10.57 mbgl).
- Groundwater flow within bedrock is interpreted to be consistently flowing in a south/southwesterly direction across the site.
- The groundwater data loggers installed on 3rd July 2020 indicate that groundwater level variation is broadly consistent across the site with a similar signature within all 3 no. wells recorded (Figure 5.3).
- Calculated permeability values within bedrock varied between 0.00024 and 6.2 m/day;
- Infiltration tests undertaken within trial pits in proximity to the soil filter recorded very low permeabilities within the overburden above the bedrock. This is consistent with the percolation testing within the overburden undertaken in 2019 at the site entrance.

5.11 WATER QUALITY SAMPLING

In-situ groundwater monitoring was undertaken by BREL on 18th June 2020 from the 3 no. groundwater monitoring wells. A repeat round of monitoring was undertaken on the 15th March 2022 from the same monitoring wells, raw water from the housing development abstraction well and from the discharge wastewater from the WWTP.

Groundwater levels were recorded in each well prior the monitoring even using a water level probe. Field parameters - electrical conductivity, pH, temperature, and dissolved oxygen were recorded before and during the groundwater sampling.

Groundwater sampling was undertaken in accordance with the following recognised standards:

- ISO 5667-1:2006 - Guidance on the design of sampling programmes and sampling techniques;
- ISO 5667-3:2012 - Preservation and handling of water samples;
- ISO 5667-14:1998 - Guidance on quality assurance of environmental sampling & handling; and
- ISO 5667-11:2009 - Guidance on sampling groundwaters.

Groundwater samples were collected from each well using dedicated sterilised Waterra tubing and a non-return foot valve. Separate tubing and foot valves were used at each monitoring well to eliminate the possibility of cross contamination.

Groundwater resting in the monitoring well is generally not considered representative of equilibrium groundwater conditions in the underlying aquifer. To account for this, the monitoring well water was purged using a suction pump until the Electrical Conductivity (EC), pH and Temperature of the water stabilised. A stable conductivity reading over several readings is a strong indicator that equilibrium conditions have been achieved. In addition, a minimum of 3 times the water volume within each well was abstracted as per national and international best practice.

Upon reaching representative and stabilised conditions a groundwater sample was retrieved from each well using a dedicated sterilized bailer and laboratory supplied containers and cooler boxes. The laboratory was Element Materials Technology (EMT, formerly Exova Jones Environmental) who are a UKAS and MCERT accredited laboratory.

All samples were collected with dedicated laboratory supplied sample containers and transported within specialised designed cooler transport boxes and ice packs to unsure all samples were kept at a suitable cool temperature during transport. Samples were transported to the laboratory on the same day as collected and arrived in the laboratory within 24 hours.

5.12 WATER QUALITY ANALYSIS

Two (2 no.) rounds of water samples were collected for analysis by BREL - June 2020 and March 2022 from the 3 no. monitoring wells on-site. Raw water from the abstraction well and the WWTP were collected during the March 2022 sampling event.

The borehole results were analysed against the groundwater regulations Interim EPA Guideline 2004 (IGV) and the European Communities Environmental Objectives Groundwater Regulations 2010 and Amendment Regulations 2016 (GTV). The water quality results are summarised in Table 5 below, and laboratory certificates are contained in Appendix E.

All results were recorded below their respective guideline levels with the exception of Manganese and Ammoniacal Nitrogen as follows:

- Slightly elevated levels of Manganese in 2020 (MW03 at 95 mg/l).
- Elevated levels of Ammoniacal Nitrogen were recorded in 2022 (MW02 at 1.1 mg/l). MW02 is located in proximity and immediately downgradient of the existing filter bed.
- The water is hard and Electrical Conductivity (EC) levels are elevated in all groundwater samples, which is consistent with the pure limestone bedrock setting.
- Lower Total Hardness and EC levels in the abstraction well in comparison with the 3 no. monitoring wells may indicate that shallow ground water, influenced by rainwater or subsoil chemistry, is entering the well due to its construction allowing shallow inflows. This is compared with the monitoring wells which are constructed so as to exclude shallow groundwater flows. Alternatively, or in addition, the abstraction well, which is drilled to circa 20 m deeper than the monitoring wells, may be intercepting groundwater from a different or mixed bedrock lithology source.
- The abstraction well water sample is of good quality. It is below the drinking water limits, as well as the groundwater environmental objective threshold values for all parameters including microbiological parameters total coliforms and faecal coliforms. This represents a low level of contamination.
- Ammonium in the groundwater sample from well MW02 exceeds the drinking water limit. Chloride levels in this sample, while being well below the drinking water limit and at the threshold value, are slightly higher than in the other samples. This combination of parameter values likely indicates an anthropogenic source of organic pollution.
- The Potassium:Sodium (K:Na) ratio in all borehole samples is below the background Potassium:Sodium ratio in most Irish groundwater of less than 0.4 and often less than 0.3. (A K:Na ratio of >0.4 can be used to indicate contamination by plant organic matter (e.g. slurry)).

- The most proximal pressure on the water quality of the abstraction well is the wastewater treatment plant serving the housing development. The percolation area of the WWTP is located approximately 200 m to the northeast of the abstraction well. The abstraction well sample collected in March 2022 shows no evidence of being impacted by discharge from the WWTP. This is also valid for the samples from monitoring wells MW1 and MW3.
- The water sample from MW2 shows evidence of potential pollution from an organic source. Sources of Ammonia in groundwater include farmyard manure, slurry and dirty water or wastewater treatment systems. Ammonia is not particularly mobile in soil or subsoil and elevated concentrations indicate either a proximal source or very rapid transport at high groundwater flow rates. The WWTP plant is a potential proximal source of this organic pollution. Well MW02 intercepts large karst voids and has the highest hydraulic conductivity, which will result in increased groundwater flow velocity in the vicinity. A more distance source of organic pollution, conveyed to the site at relatively higher velocity in the karst groundwater flow system, could also be the source of the exceedance.

			June 2020			March 2022						
Test	***Units***	***LOD***	**MW01**	**MW02**	**MW03**	**Abs Well**	**MW01**	**MW02**	**MW03**	**IGV[4]**	**GTV[5]**	**DWL[6]**
Dissolved Aluminium	*ug/l*	*<20*	<20	<20	<20	<20	<20	<20	<20	200	150	200
Dissolved Calcium	*mg/l*	*<0.2*	92.6	120.9	115.6	92.5	109.5	112.5	127.5	200	-	
Dissolved Manganese	*ug/l*	*<2*	19	3	**95**	<2	<2	<2	<2	50	-	50
Dissolved Potassium	*mg/l*	*<0.1*	1	1.5	1.2	1.4	0.3	3.7	0.3	5	-	
Dissolved Sodium	*mg/l*	*<0.1*	9.8	21.4	12.4	9.5	10.3	23.4	9.7	150	-	
Total Hardness (CaCO3)	*mg/l*	*<1*	378	360	388	274	381	330	369	-	-	
Sulphate as SO4	*mg/l*	*<0.5*	23.9	16.8	21.4	15	17.2	20.3	10		187.5	
Chloride	*mg/l*	*<0.3*	19.7	31.2	20.2	14.7	16.5	24.5	15.1		187.5	250
Nitrate as NO3	*mg/l*	*<0.2*	<0.2	5.2	3.4	14.3	1.2	17.7	1.5		37.5	50
Nitrite as NO2	*mg/l*	*<0.02*	<0.02	<0.02	0.03	<0.02	<0.02	0.32	<0.02		0.375	
Ortho Phosphate as P	*mg/l*	*<0.03*	<0.03	<0.03	<0.03	**1.0**	0.05	<0.03	<0.03	0.03	-	
Ammoniacal Nitrogen NH4	*mg/l*	*<0.03*	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	0.175	0.3
Electrical Conductivity	*µS/cm*	*<2*	736	742	600	558	719	716	619	1,000	1,875	2,500
Kjeldahl Nitrogen	*mg/l*	*<0.5*	0.8	3.1	0.7	0.7	<0.5	1.2	0.9	-	-	
pH	*pH units*	*<0.01*	7.74	7.51	7.58	7.86	7.67	7.62	7.38	≥6.5	-	
Total Organic Carbon	*mg/l*	*<2*	<2	<2	<2	<2	<2	<2	<2	-	-	
Total Dissolved Solids	*mg/l*	*<35*	424	461	476	338	410	412	431	1,000	-	
Total Coliforms#	cfu/100ml	-	-	-	-	<10	<10	<10	<10	0	0	0
Enterococci#	cfu/100ml	-	-	-	-	0	0	0	0	0	0	0
Faecal Coliforms#	cfu/100ml	-	-	-	-	<10	<10	<10	<10	0	0	0
Potassium:Sodium Ratio						0.15	0.03	0.16	0.03			

Table 5.6 Groundwater Quality Results

[4] EPA Interim Guideline Values (2004)
[5] European Communities Environmental Objectives (Groundwater) Regulations 2010/16
[6] Drinking Water Regulations (S.I. No. 122 of 2014)

5.13 HYDROGEOLOGICAL WATER BALANCE

A Regional Water Balance can be calculated based on both the total aquifer area, rainfall and groundwater recharge information presented by the GSI – see Table 5.6 below.

Calculations suggest that the proposal for the site's discharge is 0.004% of the annual groundwater flow in the Regional Aquifer. This percentage is deemed insignificant and is deemed 'Low Potential Impact' and 'Not at Significant Risk' under Water Framework Directive Working Group Guidance Document GWS (WFD, 2005).

Regional Aquifer Hydrogeology & Proposed Discharge	
GSI Stated Total Regional Aquifer Area (km^2)	375
Total Aquifer Area (m^2)	375,000,000
GSI Effective Rainfall (mm/yr)	682
GSI Groundwater Recharge Cap (mm/yr)	409
GSI Groundwater Recharge (m/yr)	0.409
Rainfall Recharge to Total Aquifer area (m^3/yr)	0.409m x 375,000,000 = 153,375,000
Daily Rainfall Recharge (m^3/d)	420,205
Average proposed daily discharge volume from the WWTP (m^3/d)	15.75
Annual Discharge based on daily average discharge (m^3/ yr)	5,749
Total Discharge as a % of the total aquifer volume	**0.004**

Table 5.6 Water Balance

6 ABSTRACTION WELL ZOC ASSESSMENT

6.1 METHODOLOGY

The zone of contribution (ZOC) for the groundwater supply well at the Caislean Rathlin housing estate has been delineated according to the principles set out in *Groundwater Protection Schemes* (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater SPZ Delineation. However, for this assessment the ZOC delineation is primarily the results of a desk study, since no access to the well for validation of depth, water level monitoring or testing of the borehole for estimation of hydrogeological parameters at and surrounding the well, was possible. As such, it should be considered as a preliminary ZOC only, which has a significant degree of uncertainty.

The delineation process uses hydrogeological site data collected as part of the updated Tier 2 Hydrogeological Assessment for the proposed wastewater discharge to the existing WWTP that serves the Caislean Rathlin housing estate.

As previously discussed in Section 5.3, 3 no. rotary core boreholes were drilled to depths of 23 to 33 m and screened as bedrock monitoring boreholes. The wells (i.e. MW01, MW02 and MW03) are located at distances of 0.13km (130 m), 0.21 km (210 m) and 0.26 km (260 m) respectively from the abstraction well. Wells MW02 and MW03 are located to the northeast of the abstraction well and MW03 to the east northeast. See Figure 3.1 Abstraction Well Location. The borehole logs are included in Appendix A**.**

The preliminary ZOC is delineated for the estimated abstraction required by the proposed development.

6.2 LOCATION, SITE DESCRIPTION & SUPPLY DETAILS

As mentioned in Table 4.1, the Caislean Rathlin housing estate is supplied with water from one abstraction borehole, located within the existing housing estate. There are limited details currently available about the well. The well chamber is sunken below the existing road within a cul-de-sac of the housing development and covered with a large manhole cover. The total depth is unknown but anecdotal evidence suggests the well is approximately 50-55m in depth. It is unknown if the steel well casing has been grouted from the top of bedrock to surface to prevent surface water ingress.

The current abstraction has been estimated by the caretaker as being 5-7 m^3/day. However, BREL understands that the housing development is not currently at full capacity and additional abstraction will be required for the proposed extension of the housing estate. The abstraction for which the preliminary ZOC is delineated is therefore the anticipated, post-development, hydraulic loading for the wastewater treatment plant of at least 15 m^3/day. This is based on EPA loading rates of 150 litres/person/day for 24 existing houses and 10 no. proposed houses, assuming 2.7 persons per house.

The treatment sequence comprises chlorination only. It is unknown if the system is currently set-up for the proposed additional abstraction.

Summary details are presented in Table 6.1.

Abstraction Borehole at Caislean Rathlin housing estate	
Grid reference	ITM: E54611, N712468
Townland	Rooghaun
Source type	Borehole
Drilled	Not know
Drilling Contractor	Not know
Owner	Galway County Council
Elevation in metres above Ordnance Datum	c. 32 m O.D.
Total depth	50-55 m reported by caretaker
Construction details	Not know
Depth to rock in metres below ground level	Unknown
Inflow zones (water strikes) mbgl	Not know
Static water level (SWL) (mbgl)	Not know
Pumping water level (PWL) (mbgl)	Not know
Pump intake depth (mbgl)	Not know
Current abstraction rate	5-7 m^3/day
Proposed abstraction rate	15 m^3/day
No. of proposed connections	36
Reported yield (m^3/d)	No yield test conducted
Specific Capacity (m^3/d/m)	Not available
Transmissivity (m^2/d)	Not known. In monitoring wells MW01, MW02 and MW03, drilled to depths of 22-33 mbgl, hydraulic conductivity (K) estimates are 0.00024, 6.2 and 0.546 m/d respectively. These monitoring wells are not necessarily representative of K values in the supply well which is reported as being 50-55m deep and in light of evident site heterogeneity.

Figure 6.1 Water Abstraction Well Details

6.3 PHYSICAL CHARACTERISTICS OF THE AREA RELATIVE TO ABSTRACTION WELL

An overview of the relevant information on rainfall, land use, topography, hydrology and hydrogeology for the area around the borehole is provided in Table 6.1.

	Description/Comments
Topography	The borehole is located at a height of approximately 32 m O.D. in a low-lying area. The topography is gently undulating, with an east north-east, west south-west lineation. It falls towards the coast c. 9 km to the west. Cashlaundrumlahan (358 m OD) 16 km southeast, is the closest significant topographic height.
Land use	Land use is the area is dominated by grassland for cattle rearing and some dairy farming. Land spreading and silage production and occur. Unsewered domestic houses and farmyards occur in the area.
Surface Hydrology	There are no natural surface watercourses draining run-off in the region, with the exception of one spring fed surface watercourse arising 2.3 km east northeast of the site. Surface water percolates rapidly to become groundwater, including via discrete points at swallow holes and enclosed depressions. All bodies of water are an emergence of the groundwater at the surface. This occurs seasonally to form turloughs, which are numerous in the surrounding area and include Kiltiernan Turlough (SAC 001285) 2.5 km northwest, Ardrahan Grasslands and turloughs (SAC 002244) 0.8km to the east and two turloughs in Lackan townland 1.4 km and 1.8 km to the southeast and northeast respectively. Flood waters from Ardrahan grassland are drained north westwards, via OPW arterial drainage and piping to Kiltiernan turlough. At high flood levels, water flows in a pipe from Kiltiernan to Tullynafrankagh and westwards to Lough Fingall via open channel and pipework. During extreme flood events, such as 2009, flood waters extended from Ardrahan grasslands, to Kiltiernan Turlough (OPW 2010).
Topsoil	Deep, well drained soils are mapped as occurring at and around the site, with areas of shallow, well drained soils also occurring in the surrounding areas. The well drained soils are mostly lithosols occurring where karstified bedrock is close to or exposed at, the surface.
Subsoil	'Moderately' permeable limestone tills ('boulder clays') are mapped as occuring at and surrounding the site. Karstified bedrock outcrop and subcrop comprise a significant proportion of the surrounding area.
Groundwater Vulnerability	Vulnerability is mapped as high at the site, where limestone tills are mapped. Extreme vulnerability occurs at 0.4 km from the site, in all directions where karst rock is exposed or close to the surface, except towards the northeast. Subsoils recorded in MW1 to MW3 vary from 2 to 8 m in depth. These depths coupled with the subsoil characteristics, would result in vulnerability classifications varying from extreme to moderate according to DELG/EPA/GSI (1999).
Geology	The mapped bedrock comprises Dinantian Pure Bedded Limestones (Burren formation), which are underlain by Dinantian Upper Impure Limestones Tubber formation), which outcrop c. 3 km to the northeast. Numerous karst features (turloughs, swallow holes, enclosed depressions etc.) occur in these karstified limestones. Monitoring boreholes MW1, MW2 and MW3 all encounter Dinantian Pure Bedded Limestone (Burren formation) bedrock to end of hole at depths from 23 to 33 mbgl. MW1 encountered a shallow zone of weather rock at the top of bedrock profile. MW2 encountered 1.5 m of infilled void space in the top 7.5 m of the bedrock profile. Void space was encountered at 9.8 to 11 m and from 13.5 to 19.0 m from the top of the bedrock profile. MW3 encountered a shallow zone of weathered rock at the top of the bedrock

	profile, then infilled voids at depths from 10.8 to 12.2 m and from 12.7 to 14.5 m. These voids are karst features with potential for significant flows, if connected to a regional karst flow system. Infilled voids in a supply well can potentially be cleared during developed of the well, to increase flow to the well. The absence of voids in MW1, in contrast with significant voids in MW2 and MW3 is typical of the heterogeneity that occurs in karstified limestone over short distances (80 m from MW1 to MW2).	
Aquifershttp://www.gsi.ie/mapping	The karstified pure bedded limestones are classified as a Regionally Important Karst Aquifer dominated by conduit flow (Rk_c). The impure limestones are classified as Locally Important Aquifers which is moderately productive only in local zones (Ll).	
Groundwater Body (GWB)	The borehole is located in the Clarinbridge GWB. www.gsi.ie/Programmes/Groundwater/Projects/Groundwater+Body+Descriptions	
Recharge Coefficient (%)	60-85	A rate of 60% is mapped as occurring where well drained soil and 'moderately' permeable subsoils overly the Rk_c aquifer. High recharge rates (85%) occur where bedrock outcrop and subcrop occur.
Recharge (mm)	386-634	
Water Quality		See Section 5.11

Table 6.1 Physical Characteristics for the Area of Interest

6.4 CONCEPTUAL SITE MODEL FOR ZOC

The current understanding of the geological and hydrogeological setting is given as follows

- Rainfall amounts are high in the area. Across a significant proportion of the surrounding area Dinantian Pure Bedded Limestone rock occurs at or very close to the surface, with the balance being overlain by till subsoils. In the areas rock occurs at or very close to the surface, the majority of effective rainfall (up to 85%) will recharge the upper zone of the karst aquifer. Very little rainfall therefore becomes surface water run-off, resulting in no significant surface water drainage courses. Groundwater emerges seasonally to form surface water features, usually within enclosed areas of topography.

- In the upper part of the karst aquifer (from the bedrock surface to approximately 20 m below) a zone of epikarst occurs, in which fissures and fractures are numerous and well connected with one another and with the surface. This zone is highly transmissive of groundwater flow and groundwater flowing in this zone has a high degree of connectivity with the surface. The presence of an epikarst zone adjacent to the abstraction borehole for the housing development is recorded in the monitoring boreholes drilled in the form of shallow weathered zone at the surface of the bedrock and as karst voids to depths of 20 m below the top of bedrock. The increased hydraulic conductivity of this epikarst zone is reflected in groundwater levels shown in Figure 5.3. At water levels above circa 14 mOD, which is the lowest level at which voids appear in the monitoring well boreholes, water levels converge. This reduced gradient between the borehole water levels is indicative of increased hydraulic conductivity in this zone.

- Recharge rate of the upper epikarst zone of the pure limestones is discontinuously across the surface, being highest where subsoils are thin and at any discrete point recharge locations (swallow holes, enclosed depressions). Deeper in the aquifer profile, beneath the epikarst, karst conduits and fissures occur. These are less well connected and may, or may not be, connected with and recharged from the overlying epikarst. Recharge typically enters these fissures and conduits at discrete point recharge locations at the surface and groundwater flow thereafter is constrained within them.

- The abstraction borehole is likely to intersect an upper epikarst layer similar to that recorded in the adjacent monitoring boreholes. It is not known whether it intercepts any underlying conduit system over its estimated 50 m depth.

- Groundwater flow directions are regionally westwards to the coast (OPW, 1998). In the area surrounding Kiltiernan, circa 3 km to the north of the abstraction borehole, groundwater contours indicate seasonal variability, but are predominantly southwesterly flow (Coxon and Drew, 1986). However, individual flow pathways are frequently constrained by the geometry and direction of karst conduits and so actual flow directions do not necessarily follow the regional groundwater flow direction. Groundwater tracing from Tullnafrankagh turlough, located circa 4 km northwest of the housing development abstraction borehole, indicates groundwater flow directions to the southwest towards Kinvara and to the northwest towards Kilcolgan (GSI Tracer Database www.gsi.ie/mapping). Tracing from Garanagh swallow hole, located 4 km east-southeast of the abstraction borehole, indicates flow directions west-southwest towards to the sea at Kinvarra and southwest towards a spring at Coole Demesne (GSI Tracer Database www.gsi.ie/mapping). These traces identify conduit type flow paths, extending over distances ranging from 3.5 to 12 km. Groundwater gradients adjacent to the supply borehole were estimated from water levels in the monitoring boreholes during summer 2020. The gradients indicated flow direction ranging from southwestward to southwards, during summer flow conditions. This indicates that flow directions in the upper epikarst zone, which the monitoring boreholes intersect, are consistent with regional groundwater flow directions. Groundwater flow direction in the area of the abstraction borehole is likely to be consistent with this local epikarst and regional flow directions.

- Groundwater vulnerability is extreme where karstified limestone bedrock underlies thin or absent subsoils. Vulnerability reduces to high, in areas where deeper till subsoils occur. Vulnerability changes quickly over short distances within the area of the monitoring boreholes, ranging from extreme to moderate.

6.4.1 Recharge and water balance

Average annual recharge and water balance calculations are used to support the hydrogeological mapping and to confirm that the preliminary ZOC delineated is big enough to supply the quantity of water being abstracted by the supply. In accordance with best practise, ZOC water balance calculations are undertaken for 150% of the abstraction rate at the supply borehole. This is to account for seasonal variations in recharge amounts and therefore the potentially increased area required to supply recharge to the constant abstraction. 150% of the proposed abstraction rate (15 m^3/d) is circa. 23 m^3/d.

The area directly surrounding the abstraction borehole which is required to support an annual average abstraction of 23 m^3/day is 0.022 km^2 based on mapped annual average recharge rates. This average annual figure assumes that the flow system can store and transmit this volume of water throughout the year. However, in karst systems, if storage is limited to the shallow epikarst zone or poorly connected conduits at depth, this storage may not in fact exist during periods of low water level. During periods when water levels drop below the storage zone, the area required to provide sufficient recharge to support the borehole supply is potentially much greater than that indicated by the 150% seasonal factor.

6.4.2 Boundaries

The preliminary Zone of Contribution (ZOC) delineated for the housing development abstraction borehole is based on a combination of hydrogeological mapping and inferences. The very unpredictable nature of actual flow paths in karst limestone results in a high degree of uncertainty in the delineated ZOC boundaries.

The Ardrahan area, in which the abstraction borehole is located, is bounded to the northwest and southeast by preliminary ZOCs delineated for the Kiltiernan GWS and the Ardrahan GWSs (mapped at www.gsi.ie). The abstraction boreholes for these group water schemes are 52 and 61 m deep and supply 500 and 306 m^3/day respectively. The Adrahan GWS ZOC boundary is located 0.45 km southeast of the housing development abstraction borehole and the closest part of the Kiltiernan ZOC boundary at 0.67 km to the north. These ZOCs assume a regional groundwater flow direction from northeast to southwest and east-northeast to west-southwest. The areas of both ZOCs are significantly greater than the minimum areas required to support the supplies based on their respective water balance calculations. In the case of the Kiltiernan, the ZOC is extended 7 km towards the northeast, in order to account for potential supply to the well, during low flow periods, by water entering the karst flow system via point recharge at the northeastern boundary, (Tynan Environmental and Hydro-G Ltd., 2017).

The minimum preliminary ZOC is based on an assumption of broadly diffuse groundwater recharge occurring in the area surrounding the supply borehole, infiltrating into an epikarst zone, which provides groundwater flow to the supply borehole. The ZOC boundaries are therefore delineated as follows:

- The ZOC downgradient boundary distance and ZOC half-width is calculated to be 5 m. The calculation is carried out using the maximum hydraulic conductivity (K m/d) value recorded in the monitoring boreholes and assuming the lowest hydraulic gradient recorded. See Appendix E. In accordance with best practise, for calculated downgradient distances of < 10 m, a minimum downgradient distance of 10 m is applied.

- The maximum ZOC half width is estimated using the same parameters, to be 16 m. See Appendix E. There is significant uncertainty in both the down gradient and maximum half-width estimates since the hydraulic conductivity of the supply borehole itself is not known and assumptions are therefore made. Additionally, there is uncertainty associated with the validity of using these equations in a heterogeneous karst environment. The half width distance estimate is considered to be an underestimate, based on the likely width to length proportions groundwater ZOCs. It has therefore been increased.

- The upgradient boundary is the boundary required to enclose the minimum recharge area of 0.022 km^2 required to support the supply at the estate supply borehole, based on the water balance calculation. There is no topographic or groundwater divide on which to base this upgradient boundary.

- The northwestern boundary and south south-eastern boundaries are based on two sets of groundwater flow lines, one set parallel to the assumed groundwater flow direction from northeast to southwest and a set parallel to an east-northeast to west-southwest groundwater flow direction. This is in line with best practise for ZOC delineation in areas where there are low groundwater gradients and uncertainty in flow direction, in which case the ZOC is rotated to include the range of potential groundwater flow directions.

- The total area of the minimum preliminary ZOC is 0.03 km^2. The ZOC is shown on Figure 6.2.

It is noted that:

a) The delineated of the ZOC is a preliminary assessment only based on limited data.

b) The preliminary ZOC does not take into account the possibility that the supply borehole intercepts a very thin epikarst zone at the surface of the bedrock and instead is fed by a deeper karst conduit flow, with a point recharge source at a distance from the supply well.

c) During periods of low flow, the preliminary ZOC delineated, could potentially extend significantly further northeastwards and or eastwards, depending on the nature of the epikarst zone at the abstraction borehole and whether the borehole intercepts any conduit flow at depth. If storage is limited to the shallow epikarst zone and/or poorly connected conduits at depth, sufficient storage and transmissivity may not exist during periods of low water level. During periods when water levels drop below the storage zone, the area required to provide sufficient recharge to support the borehole supply is potentially much greater.

d) A swallow hole, in a turlough, is located at 1.8 km due east-northeast of the supply borehole at Cregaclar in Lackan townland. This swallow hole is likely to recharge a deeper conduit type flow system (see Figure 4.2). It is not impossible that the abstraction borehole could intersect such a deep karst flow system, in which case the ZOC would extent to include the recharge entering the system at the swallow hole. There is no specific evidence to support this, without further information on the abstraction borehole characteristics and/or groundwater tracing. Two spring discharges 0.3 km and 0.7 km to the to the north and northeast of this swallow hole may represent a groundwater flow divide which could form the up-gradient boundary of a ZOC extending into this area.

Figure 6.2 Preliminary Minimum Zone of Contribution

7 WASTEWATER DISCHARGE IMPACT ASSESSMENT

The results of the 2019 and 2020 site investigation activities and the local area walkover were used to develop a CSM and are discussed below:

7.1 SOIL PERCOLATION

1. Infiltration tests undertaken within trial pits in proximity to the filter and its general environs recorded very low permeabilities within the overburden above the bedrock. This is consistent with the percolation testing within the overburden undertaken in 2019 at the site entrance.
2. Bedrock permeability ranged between 0.00024 and 6.2 metres/day with higher permeability possibility within the shallow bedrock zone.
3. No groundwater was encountered in the subsoils.
4. No surface water features are present in the general vicinity of the site indicating vertical infiltration of rainfall is occurring on the site.

Based on the site investigation data recorded to-date, the subsoils present at the site are insufficiently permeable to facilitate the discharge of treated wastewater to ground. However, it is acknowledged that the lack of any surface water features in proximity to the site, the lack of any ponding of disposed wastewater to ground and the moderate permeability mapped by the GSI in the area suggests that some form of infiltration is occurring at the site, most likely via preferential pathways or localised permeable zone(s) within the overburden. These pathways have not been identified to-date at the site.

7.2 DEPTH TO BEDROCK

Depth of bedrock was recorded ranging between 2.1 and 8.1 metres within the boreholes drilled. Depth to bedrock in close proximity to the filter was recorded within MW2 at a depth of 5.3 mbgl. Bedrock was not encountered in the trial pits.

7.3 HYDRAULIC FEASIBILITY

1. Proposed Daily Discharge = 13.77 m^3/day
2. Proposed Filter Percolation Area = 850 m^2
3. Rainfall through Percolation area = 682 mm/yr (effective recharge by the GSI)
4. TOTAL calculated Hydraulic Loading = 14.43 m^3/day
5. Loading Rate to subsoil underlying percolation area = 0.025 (m^3/m^2/d or m/d)
6. Based on the poor permeabilities of the overburden at the site, both the current and proposed increased discharge are not hydraulically feasible within the overburden across the areas of the site investigated. However, the lack of any surface water features in proximity to the site and the lack of any ponding of disposed wastewater to ground suggests that some form of infiltration is occurring at the site, most likely via preferential pathways or localised permeable zone(s) within the overburden not identified to-date.
7. The average hydraulic conductivity of the underlying limestone bedrock across the site is $2.6x10^{-5}$ m/s (i.e. 2.24 m/day) which equates to 90 times the loading rate of 0.025 m/d as the anticipated discharge percolation from the filter zone. Therefore, the bedrock has adequate hydraulic capacity to handle the existing and proposed additional loading.

7.4 WASTEWATER TREATMENT PLANT & ENVIRONMENTAL LOADINGS

BREL understands that the existing wastewater treatment plant (pre soil filter) is designed to treat the effluent to the following standard with an expected final effluent quality of the following:

- pH: 7-7.5
- BOD: <20 mg/l
- Suspended Solids: <30 mg/l
- ORP: <5 mg/l
- Ammonium (NH4-N) <10 mg/l

With a suitably constructed and installed Tertiary treatment, the predicted discharge quality is outlined in Table 7.1 below:

	Treated Effluent Characteristic		
Hydraulic Loading to percolation area	**WWTP**	**Secondary Effluent Concentration (mg/l)**	**Tertiary Effluent Concentration (mg/l)**
Hydraulic Loading 13.77 m^3/day	Biochemical Oxygen Demand	20	20
	Suspended Solids	30	10
	Total Nitrogen as N	15	15
	Nitrate-N	5	5
	Ammonium N	10	10
	Total Phosphorus as P	5	2

Table 7.1 Resultant Loads discharged

Gill et al. (2009) recommended attenuation factors of 10 and 90% for both nitrogen and phosphorus, respectively. It is reasonable in this scenario to apply the 90% reduction in orthophosphate quoted as occurring in 1.0 m unsaturated subsoils by Gill et al. The reduction factor has not been included for ammonia as it is unclear if the data supports nitrate in ammoniacal form to be constant throughout the year.

A water sample was collected by BREL from the outlet of the WWTP on the 15th March 2022. All parameters recorded were considered to be suitably reduced and in accordance with safe groundwater quality thresholds with the exception of Ammonia as N (21.17 mg/l).

7.5 GROUNDWATER ASSIMILATIVE CAPACITY CALCULATIONS

The following assimilative capacity calculations are provided to assess the impact on groundwater quality within the aquifer from the existing and proposed additional properties. They are based on discharge to the bedrock aquifer to provide an indication of the ability of the bedrock aquifer to cater for the existing and proposed additional hydraulic and chemical loadings.

As the overburden across the site comprises very low permeability subsoils, where investigated, these calculations are based on the theoretical assumption that the discharge is to the more permeable zones under the existing low permeability subsoils.

7.5.1 Effluent Discharge Rate

The discharge rate of 15.75 m^3/d (including rainfall recharge) is regarded as a conservative maximum and based on the EPA & Irish Water recommended design loads for the development. The boundary width at the end of the discharge zone is 26 m. Maximising the discharge area width increases the exposure to background groundwater, and thus greater potential for dilution.

7.5.2 Natural Recharge from Rainfall

Groundwater vulnerability = High (from site specific investigation).
Soil type = Deep well drained mineral soil
Effective Recharge = 682 mm/yr (GSI)

Estimated recharge from rainfall to sand filter = 950m^2 x 0.682 m/yr = 426 m^3/yr = 0.93 m^3/day

Total hydraulic loading = 13.77 m^3/d + 0.682 m^3/d = 14.52 m^3/d

The areal loading rate of **0.025 $m^3/d.m^2$** is **below** the average hydraulic conductivities of the site bedrock and confirms that the bedrock conditions are hydraulically suitable for the existing load from the WWTP.

7.5.3 Horizontal Migration of Effluent in Groundwater

Darcy's Law: $Q = KiA$

where Q = groundwater flow rate in aquifer, m^3/d
K = average hydraulic conductivity in bedrock = 0.546 m/d
I = hydraulic gradient = 0.01 m/m (conservative)
A = cross-sectional area of part of the aquifer, m^2 = (1m width by 10m depth) = 130.0 m^2
Q = 0.546 x 0.01 x 130.0 = 0.71 m^3/d per m width of aquifer

7.5.4 Time of Travel

The permeability values can be used to provide an assessment of the area of the aquifer that could potentially be impacted upon by the proposed percolation area by calculating the 100-day time of travel (TOT). The 100-day TOT is typically used to define source protection areas, with one hundred days considered to be the maximum possible lifespan of microbial contaminants of water.

- The 100-day TOT is calculated as follows:
- 100-day TOT = (100 x K x i)/n where: n = effective porosity = 0.35 and K = hydraulic conductivity
- 100-day TOT = (100 x 0.546 x 0.01)/0.35 = 1.56 m

This value indicates that microbial contamination is not expected to migrate significantly downgradient as a result of the WWTP discharge.

7.5.5 Mixing Equations

$$C_{gw} = [(C_{in} \times Q_{in}) + (C_{gwu} \times Q_{gw})] / (Q_{in} + Q_{gw})$$

where:
C_{gw} = resulting concentration in groundwater
C_{in} = concentration in the infiltrating water
Q_{in} = volumetric rate of infiltrating water
C_{gwu} = concentration in the aquifer from upgradient areas
Q_{gw} = groundwater flow rate through the aquifer

All mixing equations are provided in Appendix F which also presents the output of the above mixing equation for each of the primary chemical parameters of concern. A summary of the table is provided in Table 6.2.

Inflow concentrations to groundwater are taken as being the effluent from the combined proposed package treatment plant and tertiary filter treatment system.

7.6 ESTIMATED RESULTANT GROUNDWATER CONCENTRATIONS

The risk of deterioration in the quality of groundwater was assessed by calculation based on adopting EPA (2011) Guidance on the Authorisation of Discharges to Groundwater. Recharge volume, effluent flow rate, groundwater flow rate, background groundwater concentrations and the concentrations in the final effluent are simulation inputs.

The calculations are based on the assumption that the existing discharge bed has not been constructed in line with the EPA Code of Practice, does not operate as a tertiary treatment filter and a new filter bed will be constructed by the local authority.

Based on the calculated annual effective rainfall of 682 mm, an effective effluent hydraulic load of 14.58 m^3/day and a discharge to a new soil polishing filter zone of 850 m^2, resultant simulation data, calculated adopting EPA (2011) guidance on the Authorisation of Discharges to Groundwater, are presented in Table 6.2: The detailed calculations determining these predicted calculations are provided in Appendix F.

		Groundwater Regulations 2010	Background Baseline Quality Cgw	Influent Quality Cin	Reduction Factor from Soil Filter	Predicted Resultant Cgw (mg/l)	% of Threshold Value allocation used directly under discharge zone
BOD	mg/l		**2.0**	**20**	-	**2.01**	0
SS	mg/l		**2.0**	**30**	-	**2.0**	0
Temp	^{o}C		**11.0**	**10**	-	**11.0**	0
pH	-		**7.0**	**7**	-	**7.0**	0
Total Ammonia	mg/l N	**0.175**	**<0.03**	**20**	50%	**0.039**	21%
Nitrate	mg/l NO_3	**37.50**	**7.2**	**10**	10%	**7.2**	0%
Total Phosphorus	mg/l P		**<0.05**	**3**		**0.051**	2%
Ortho-P as P	mg/l P	**0.035**	**<0.05**	**2**	90%	**0.05**	0%

Table 7.2 Assimilative Capacity & Mixing Equations

These predicted resulting values in the aquifer from the WWTP demonstrate compliance with the Groundwater Regulations (2010) Threshold Values using the bedrock hydraulic capacity parameters. Based on the simulated levels recorded using the bedrock hydraulic capacity parameters only and the proposed loading discharges to ground, no evidence of a current or future deterioration of groundwater quality is identified in the immediate area.

7.7 PROPOSED EMISSION LIMIT VALUES FOR THE DISCHARGE LICENCE

The results of the assimilation capacity simulations were used to define proposed Emission Limit Values for the discharge licence, as presented in Table 7.3. As a precautionary measure to provide further protection to the Caislean Raitlin water supply, the proposed ELV for Ammonia has been reduced further to 5 mg/l.

	Units	Proposed ELVs
Daily Hydraulic Loading	m^3/d	16
BOD	mg/l	25
COD	mg/l	150
SS	mg/l	35
Temperature	oC	Ambient
pH	pH units	6 to 9 pH
Total Ammonia	mg/l N	5
Nitrate	mg/l NO^3	20
Ortho-P as P	mg/l MRP-P	1

Table 7.3 Proposed Emission Limit Values

7.8 SEPARATION DISTANCES

Vertical separation distance of unsaturated subsoil above bedrock underlying the proposed discharge zone is maintained.

The current WWTP infrastructure adheres to the required horizontal separation distances for boundaries. Appendix F (Table F3) of EPA (2011) guidance on the authorisation of discharges to groundwater most stringent separation distance is 60m from a public water supply which is adhered to be the proposed development. The existing abstraction well for the housing development is located approximately 215 metres to the southwest of the WWTP.

7.9 IMPACT ON GROUNDWATER AS A DRINKING WATER RESOURCE

The ‘prevent or limit’ core groundwater quality objective addressed by EPA (2011) Guidance on the Authorisation of Discharges to Groundwater is the “first line of defence in restricting inputs of pollutants to groundwater and thereby avoiding or reducing pollution”. The proposal adheres to the objective of the Guidance. The ‘prevent’ objective relates to hazardous substances: With respect to the proposed discharge from the site, it is domestic characteristic wastewater and the discharge is not envisaged to contain hazardous substances as defined by the EPA (2010). The ‘limit’ objective relates to non-hazardous substances.

With respect to the current discharge from the WWTP, it has a domestic characteristic wastewater with low level tertiary level of treatment (i.e. the filter unit has not been constructed in line with the EPA Code of Practice). The assimilative capacity assessment of the system on the underlying aquifer, in addition to groundwater analysis, indicates that the system does not appear to be impacting on groundwater quality downgradient of the WWTP. The available capacity of the groundwater aquifer to assimilate ammonia and ORP from the current system and the proposed increased loadings from the proposed development appears sufficient based on the background quality of the aquifer and the loading from the wastewater being discharged.

8 CONCEPTUAL SITE MODEL & RISK ASSESSMENT

8.1 POLLUTANT LINKAGE CONCEPT

In the context of land contamination, there are three essential elements to any risk:

- A **source** – a substance that is in, on or under the land and has the potential to cause harm or to cause pollution of groundwater and surface waters.
- A **receptor** – in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property, or a water body.
- A **pathway** – a route or means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist independently, but they create a risk only where they are linked together, so that a particular contaminant affects a particular receptor through a particular pathway. This kind of linked combination of contaminant source–pathway–receptor (SPR) is described as a pollutant linkage. The conceptual model was developed to describe viable SPR linkages for the site. By considering the sources, pathways and receptors (pollutant linkages), an assessment of the human health and environmental risks is made with reference to the significance and degree of the risk.

This assessment is based on consideration of whether any source of contamination can reach a receptor, and hence whether the resulting impact is of major or minor significance.

The risk assessment completed for this site is based on consideration of whether a potential source of contamination can reach a receptor, and hence whether it is of major or minor significance. The risk assessment is based on qualitative data and a 'lines-of-evidence' approach; therefore, the identification of potential risk does not necessarily indicate a risk to a receptor, rather that further assessment may be required to investigate assumptions made in the CSM and quantify whether a potential risk actually exists.

8.2 POTENTIAL SOURCES OF CONTAMINATION

The following potential sources of contamination were identified on site:

- Treated wastewater from a packaged wastewater treatment plant discharging to ground. Main contaminant of concern relate to Ammonia and Phosphates.

8.3 POTENTIAL RECEPTORS

The following potential receptors were identified:

- Groundwater Abstraction

The existing drinking water abstraction well located on the Caislean Rathlin development is located approximately 215 metres west/southwest of the existing discharge. The preliminary ZOC estimate suggests that the WWTP will be located within the ZOC on completion of the proposed additional houses for the development. Therefore, contaminants entering the groundwater aquifer have the potential to migrate towards the abstraction borehole.

- Bedrock Groundwater Aquifer

Uncontrolled or inappropriately treatment of wastewater from the WWTP has the potential to impact on the Clarinbridge GWB.

8.4 POTENTIAL PATHWAYS

Given the site's setting, there are considered to be a number of potential exposure pathways for site users and groundwater. The potential pathways to which are considered viable are outlined below in Table 3.1.

Receptor	Pathway
Drinking Water	• Horizontal migration of contaminants within groundwater from the vicinity of the from WWTP
Clarinbridge GWB	• Vertical migration of contaminants to the bedrock aquifer from the WWTP.

Figure 8.1 Potential Pathways

8.5 RISK ASSESSMENT

The proposed additional housing units will increase the hydraulic and organic loading of domestic wastewater to the current WWTP in addition to increase the volume of water to be abstracted from the existing abstraction well.

As detailed in Section 6.4, a preliminary ZOC was mapped based on the increased anticipated abstraction rates and was estimated to encompass the discharge zone of the WWTP. Therefore, the theoretical risk posed to the drinking water supply of Caislean Rathlin development is considered to be high.

However, the following salient points and 'lines-of-evidence' are noted that significantly reduce the risk posed.

1. Based on 2 no. rounds of groundwater monitoring in the vicinity of the WWTP and the abstraction well, no impact to groundwater quality has been identified to-date. This is a very positive consideration given the fact that the WWTP is not functioning as designed and the tertiary treatment has not been appropriately constructed nor is functioning as a tertiary treatment system. This would suggest that there is significant dilution capacity within the groundwater system underlying the discharge zone.
2. Water sampling from the WWTP discharge did not indicate significantly elevated contaminants with slightly elevated levels of Ammonia identified to-date. Phosphate levels appear within the typical range for the WWTP design.
3. Overburden across the site has been confirmed as low permeability thereby facilitating a likely form of filtration of the wastewater posed WWTP.
4. Water from the Caislean Raitlin development abstraction well is treated using chlorination thereby providing an additional layer of protection to human health from the WWTP discharge.

Given the generally good quality groundwater recorded across the site and the lack of any impact to water quality in the vicinity of the WWTP, the risk posed to the Clarinbridge GWB is considered to be low. Reconstruction of the tertiary filter bed in line the EPA Code of Practice in the future will further treat the wastewater before it enters the GWB, thereby further minimising the risk posed.

9 CONCLUSIONS & RECOMMENDATIONS

9.1 CONCLUSIONS

1. BlueRock Environmental Limited (BREL) were requested to undertake an updated Tier 2 Hydrogeological Assessment of an existing housing development (Caislean Rathlin) and associated wastewater treatment plant (WWTP) located on the outskirts of Ardrahan Village, approximately 17 km southeast of Galway city.
2. This 2022 Updated Tier 2 Assessment report provides a more up-to-date assessment of the WWTP and its associated discharge to ground. It includes a more detailed assessment of the housing development abstraction well and supersedes the findings of the 2020 Tier 2 assessment.
3. The existing current housing development comprises 24 no. residential houses, a wastewater treatment plant including soil filter and an abstraction well to supply water to the development only. Based on a current estimated discharge rate of 9.7 m^3/day, a Tier 2 Hydrogeological Assessment was required. GCC are currently considering extending the existing development by an additional 10 no. residential units utilising the existing WWTP and water supply on site. This would further increase the loading to 13.77 m^3/day.
4. A draft Phase 1 Hydrogeological Assessment report (Ref: BRE19015Rp01F01, dated 19th June 2019) was previously issued by BREL based on a site walkover and a desk top data collation exercise. The report indicated that given the uncertainty surrounding background and site-specific aquifer conditions and the quality of wastewater discharging from the WWTP, the preliminary risk posed by the WWTP discharge to sensitive receptors was Moderate to High. A series of recommendations was provided including the completion of a Tier 2 Hydrogeological Assessment.
5. The following scope of works was subsequently undertaken:
    - A hydrogeological site investigation was undertaken in 2020 that comprised borehole drilling, monitoring well installations, trial pitting, inspection pits of filter bed, soil infiltration testing, bedrock hydraulic conductivity testing, groundwater level monitoring and groundwater sampling;
    - Additional site investigation activities were undertaken in 2022 comprising additional groundwater sampling, sampling of the Caislean Rathlin development abstraction well and development of a Preliminary Zone of Contribution (ZOC) for the well; and,
    - Completion of an interpretative updated Tier 2 Hydrogeological Site Assessment Report.
6. The existing treatment system installed is a 100 PE SAF WWTP comprising a 4 no. tank concrete unit system including 2 no. settlement tanks, an aeration tank and a second settlement tank with media, sludge return pump and controls. Based on calculated loadings, the existing treatment plant is considered to be suitably sized to cater for the additional 10 no. dwellings proposed by Galway County Council i.e. calculated PE BOD_5 load of 91.8 g/day for a 100 PE system.
7. Investigation of the tertiary treatment filter confirmed the following:
    - The filter is effectively a gravel distribution bed only and is not a soil or sand filter as originally understood. The filter was also not constructed in line with the EPA Code of Practice, 2009. However, it is noted that it was constructed prior to the 2009 guidance document.
    - Wastewater from the WWTP is currently not being pumped to the gravel bed with all wastewater being discharged into the French drain along the eastern side of distribution bed. This wastewater is seeping into the surrounding soils and eventually into the

bedrock aquifer likely via discontinuities within the low permeability silts and clays that have not been identified to-date.

- A newly constructed filter bed is required to be constructed in line with the Code of Practice.

8. Infiltration testing of the overburden in proximity to filter and its general environs recorded very low permeabilities across the site. This is consistent with the percolation testing within the overburden undertaken in 2019 at the site entrance. The permeabilities do not conform with the EPA Code of Practice and are deemed inappropriate to facilitate the infiltration of treated wastewater to groundwater. However, it is noted that the lack of any surface water features in proximity to the site and the lack of any ponding of disposed wastewater to ground suggests that some form of infiltration is occurring at the site, most likely via preferential pathways or localised permeable zone(s) within the overburden not identified to-date.

9. Hydraulic testing of the bedrock aquifer suggests suitable hydraulic capacity to facilitate infiltration of treated wastewater within the bedrock aquifer.

10. Groundwater quality across the site was found to be of a good quality with no impact on groundwater quality by the existing WWTP identified. All groundwater abstracted from the abstraction well within the Caislean Rathlin development is also of good quality. This water is treated within the treatment building (Chlorine dosing only) also located within the grounds of the development.

11. A preliminary Zone of Contribution (ZOC) Assessment was undertaken for the current abstraction borehole considering the proposed additional houses being considered for development. The ZOC assessment was based on desk study, limited well information and is a preliminary assessment only. The extent of the ZOC was estimated to encompass an area that includes the WWTP and its discharge to ground.

12. Groundwater assimilation capacity has been simulated (using bedrock aquifer data only) with no consideration of overburden conditions and shown to be compliant with the Groundwater Regulations (2010). This simulation provides an indication of the ability of the bedrock aquifer to cater for the existing and proposed additional hydraulic and chemical loadings. As the overburden across the site comprises very low permeability subsoils, where investigated, the simulation calculations are based on the theoretical assumption that the subsoils are sufficiently permeable or will be suitably permeable as part of site redevelopment works and does not represent current site conditions of wastewater discharging to these subsoils.

13. The main identified receptors posed by the WWTP discharge are to the Clarinbridge GWB and the drinking water well supply to Caislean Rathlin development. As the WWTP discharge is located within the preliminary delineated ZOC for the well, the risks to this supply are considerably increased and considered to be high. However, the following salient points and ‘lines-of-evidence’ are noted that significantly reduce the risk posed:

    - Based on 2 no. rounds of groundwater monitoring in the vicinity of the WWTP and the abstraction well, no impact to groundwater quality has been identified to-date. This is a very positive consideration given the fact that the WWTP is not functioning as designed and the tertiary treatment has not been appropriately constructed nor is functioning as a tertiary treatment system. This would suggest that there is significant dilution capacity within the groundwater system underlying the discharge zone.
    - Water quality discharge from the WWTP does not indicate significantly elevated contaminants with slightly elevated levels of Ammonia only identified to-date. Phosphate levels appear within the typical range for the WWTP.
    - Overburden across the site has been confirmed as low permeability thereby facilitating a form of filtration of the wastewater posed WWTP.
    - Water from the abstraction well for drinking water purposes is treated using chlorination thereby providing an additional layer of protection to human health from the WWTP

discharge. Given the lack of any impact to water quality within the bedrock aquifer in the vicinity of the WWTP and the good quality groundwater recorded, the risk posed to the Clarinbridge GWB is considered to be low. Reconstruction of the tertiary filter bed in line the EPA Code of Practice in the future will further treat the wastewater before it enters the GWB, thereby minimising the risk posed.

14. This updated Tier 2 Assessment confirms that the proposed additional 10 no. houses planned for connection to the existing WWTP is unlikely to impact on the Clarinbridge GWB or groundwater quality to the abstraction well of the housing development. In addition, assimilative capacity assessments confirm that there is sufficient capacity within the bedrock aquifer to cater for the proposed additional discharge.

9.2 RECOMMENDATIONS

Based on the findings of this updated Tier 2 Hydrogeological Assessment a number of recommendations have been outlined below that the above conclusions are based on:

1. The existing filter bed is not suitably designed, nor has it been constructed in accordance with the EPA Code of Practice. It is recommended that it be replaced with a suitably constructed sand or soil filter to provide an appropriate level of tertiary treatment to the site.
2. The subsoils underlying the current gravel distribution bed are not sufficiently permeable to facilitate the infiltration of treated wastewater to the underlying bedrock aquifer. Therefore, two alternate mitigation measures are outlined below:
    a. Construct a new tertiary treatment system in an alternative location on the site that has not been previously investigated e.g. to the south of the site. The drawback with this option is that similar ground conditions could be encountered in this area thereby preventing this option from progressing any further. There may also be planning considerations that need consideration.
    b. Excavate the existing gravel distribution bed to a depth of approximately 4 metres below surrounding ground level i.e. to a depth below the low permeability clay subsoils. The excavation would then be backfilled with more permeable engineered fill material and a soil or sand filter constructed above this material. The increased permeability would facilitate the infiltration of the tertiary treated wastewater to the more permeable horizons at depth. The excavation could be a single large excavation or a series of excavated channels.
3. The existing main pipeline from the WWTP to the filter area requires replacing to ensure no future discharge to the french drain occurs with all discharges directed to the filter.
4. An assessment of the functioning of the main WWTP is recommended by a suitably experienced person or company to ensure consistently of treatment over time. The system was observed to be poorly functioning on occasion which is potentially as a result of the system surcharging or the system infrastructure not functioning efficiently.
5. On-going monitoring of the existing groundwater monitoring well network the discharge of wastewater from the WWTP is recommended to demonstrate the system is not impacting, nor likely to impact on the hydrogeological environment or on the housing development well.
6. In the event of a substantial increase in anticipated abstraction rates from the current abstraction well within the Caislean Rathlin housing development, a reassessment of the risks posed to the water supply is recommended by undertaking a more site-specific hydrogeological assessment of this well including pumping tests, recovery tests to more accurately delineate the preliminary ZOC delineated.
7. The results of the assimilation capacity simulations were used to define proposed Emission Limit Values for the discharge licence. As a precautionary measure to provide further protection to the Caislean Raitlin water supply, the proposed ELV for Ammonia was reduced further to 5 mg/l. The list of proposed ELVs is outlined below:

	Units	Proposed ELVs
Daily Hydraulic Loading	m^3/d	16
BOD	mg/l	25
COD	mg/l	150
SS	mg/l	35
Temperature	^oC	Ambient
pH	pH units	6 to 9 pH
Total Ammonia	mg/l N	5
Nitrate	mg/l NO^3	20
Ortho-P as P	mg/l MRP-P	1

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APPENDIX A

Site Investigation Logs

GroundCheck
SITE INVESTIGATION SPECIALISTS

PROPOSED PUBLIC HOUSING DEVELOPMENT,
CAISLEÁN RAITHLÍN,
ARDRAHAN,
COUNTY GALWAY

GROUND INVESTIGATION REPORT

CLIENT: Galway County Council
JOB REF: 20-2384
ISSUED: June 2020




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1.2 Method 1
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3.0 GROUND CONDITIONS 4
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3.3 Groundwater 4

FIGURES

APPENDIX A: BOREHOLE & TRIAL PIT LOGS AND PHOTOGRAPHS

APPENDIX B: GEOTECHNICAL LABORATORY TEST RESULTS

1.0 INTRODUCTION

1.1 Terms of Reference

Ground Check Ltd was commissioned by McKenna Consulting Engineers, to undertake a ground investigation for a proposed public housing development at Caisleán Raithlín, Ardrahan, County Galway. The location of the site is shown by Figure 1.

1.2 Method

The ground investigation was undertaken in accordance with the guidelines set-out in BS5930 Code of Practice for Site Investigations, 4th Edition (2015); UK Specification for Ground Investigation, 2nd edition (2011); BS EN 1997-2 (2007) and BS EN ISO 22475-1 (2006) and related standards. The scope of works comprised of the following elements:

- **Exploratory Holes**

  The locations of exploratory holes are shown by Figure 2 and logs and trial pit photographs are included in Appendix A:

  - ***Trial Pits:*** Five trial pits, IP1-3 & PT1-2, were opened using a 13Tonne tracked mechanical excavator fitted with a 450mm toothed bucket.
  - ***Rotary Drilling:*** Three boreholes, MW1-03, were sunk using a Comacchio MC305 rig equipped with 150mm Symmetrix casing and tools and continued by open-hole drilling with down-hole hammer into the bedrock.

- **Sampling & In-situ Testing**

  - ***Disturbed samples:*** comprising ~1kg of soil sealed in a grip-seal polythene bag were recovered at intervals shown on the exploratory hole logs; generally being taken at 1m depth increments and from each stratum.
  - ***Bulk samples:*** comprising ~10kg of soil sealed in heavy gauge plastic sacks were recovered at intervals shown on the exploratory hole logs.

- **Instrumentation & Monitoring**

  - ***Standpipe Installations:*** Three boreholes were installed with a 50mm HDPE slotted standpipe on completion of drilling operations, where the installation records are attached to the relevant borehole logs, which is presented in Appendix A.

- **Geotechnical Laboratory Testing**

  Selected soil samples were scheduled for the following laboratory tests, which were conducted in accordance with procedures outlined in BS1377. Test results are included in Appendix B:

  - Particle Size Distribution (Wet Sieve)

2.0 SITE DESCRIPTION

The proposed scheme involves the construction of a public housing development on a vacant plot of land that is located at Caisleán Raithlín, Ardrahan, County Galway; and is centred over ITM Grid Co-ordinates E546190 N712548. It is located 500m from the junction with the N18 road and is bounded by a railway line to the north, agricultural grazing lands to the east, and the existing residential properties of Caisleán Raithlín and the R347 to the west and south. Plate 1 provides an aerial overview of the site.

Plate 1: Overview of Site

3.0 GROUND CONDITIONS

3.1 Geology

The geological maps of the area indicate the Site is underlain by the following strata:

- **Glacial Till (Boulder Clay)**
- **Bedrock – Carboniferous Burren Formation Limestone**

3.2 Ground Investigation

The findings of the ground investigation are listed in Table 1 and summarised below:

- **Made Ground:** a superficial layer of made ground was encountered in all holes and ranged in thickness between 0.6 to 1m. The material was mostly composed of reworked glacial subsoils, locally being composed of layers of; grey, fine to medium, sub-angular to sub-rounded gravel; brownish grey, slightly clayey, silty, sandy, fine to coarse, angular gravel containing cobbles; greyish brown, gravelly, very sandy, desiccated, clayey silt; brownish grey, fine to coarse, sub-angular gravel and cobbles in a matrix of sandy, clayey silt; and greyish brown, gravelly, very sandy, clayey silt containing cobbles and occasional boulders.
- **Glacial Deposits:** were encountered below the made ground, and were composed of layers of; greyish brown and brownish grey, gravelly, sandy, silty clay containing cobbles; light grey, mottled brown/light brownish grey, gravelly, sandy, fissured, silty clay containing cobbles and occasional boulders; and dark brownish grey, silty fine to medium sand.
- **Bedrock:** Strata characteristic of the Carboniferous Burren Limestone Formation occurred below the glacial deposits at depths ranging between 2.3 and 9.0m in boreholes MW1-3, where the rock was described from drill cuttings as being composed of, light grey, fine grained limestone with voids and infilled voids, typical of karst limestone geology.

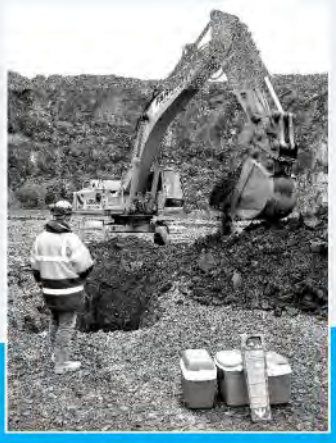
3.3 Groundwater

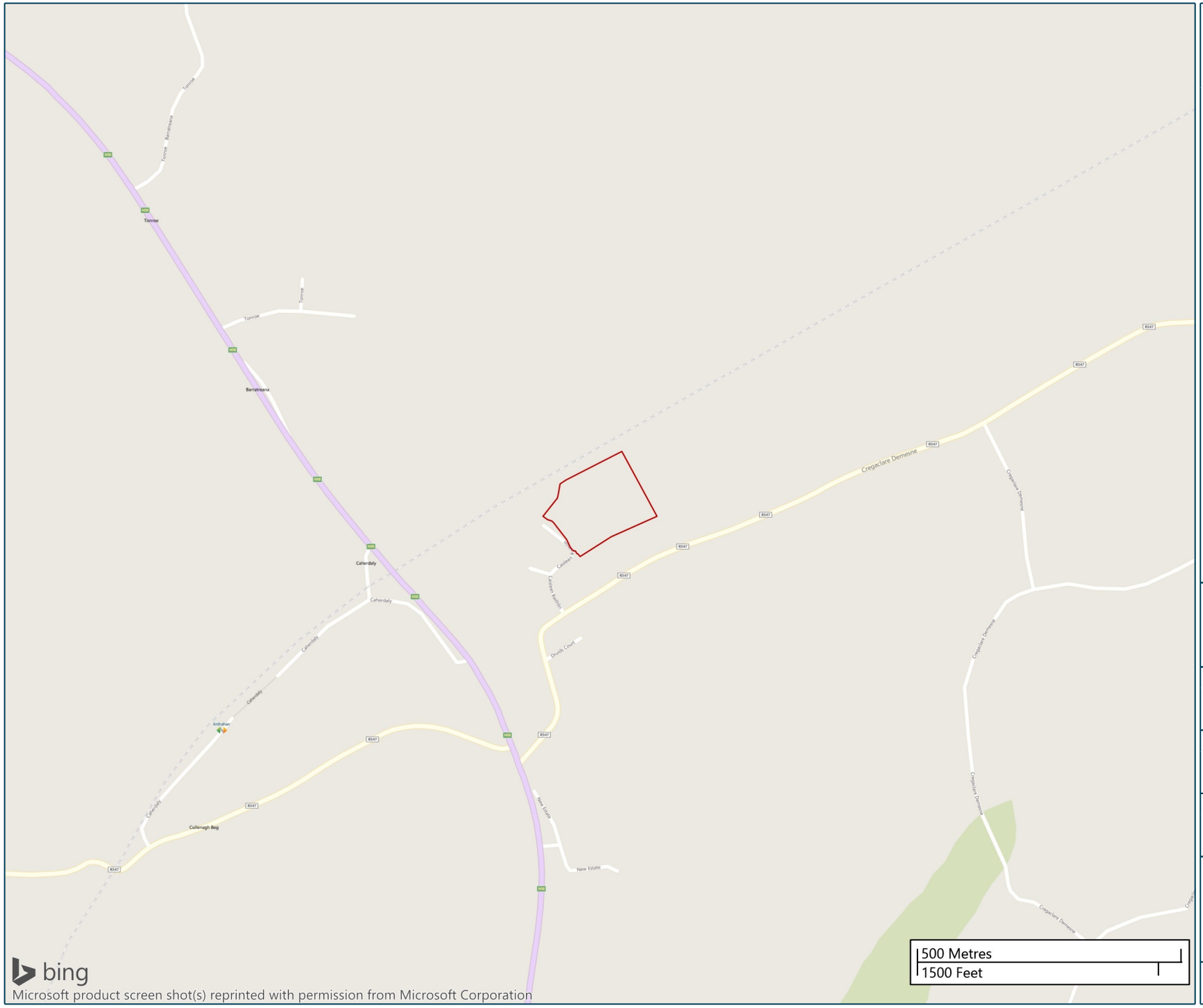
Seepages of groundwater were encountered in boreholes MW1 and MW3 at depths ranging from 14.5 to 28.0m below ground level within the bedrock, where standing water levels rose to a depth of 16.78, 17.19 and 22.21mbc respectively upon termination of drilling operations. No groundwater strikes were encountered within the superficial deposits, where all trial pits were recorded as dry on completion. It should be noted, however, that as groundwater levels and inflow rates may possibly vary seasonally and relative to rainfall intensity, the reported short-term observations should be verified by the excavation of inspection pits prior to commencement of construction work. It is also possible that discreet flows of groundwater could have been masked by driving of casing during rotary drilling.

Table 1: Ground Conditions Summary

Exploratory Hole Reference	Completion Depth (m)	Stratum Base Depth (m)			Bedrock Top (m)
		Made Ground	Recent Deposits	Glacial Deposits	
MW1	23.0	0.7	-	2.3	2.3
MW2	23.0	0.9	-	5.3	5.3
MW3	33.0	1.0	-	9.0	9.0
IP1	1.3	0.7	-	>1.3	(not proven)
IP2	1.3	0.6	-	>1.3	(not proven)
IP3	1.2	0.9	-	>1.2	(not proven)
PT1	2.2	1.0	-	>2.2	(not proven)
PT2	2.2	0.9	-	>2.2	(not proven)

Figures



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Drawing Title

Figure 1 - Site Overview

Project ID

20-2384

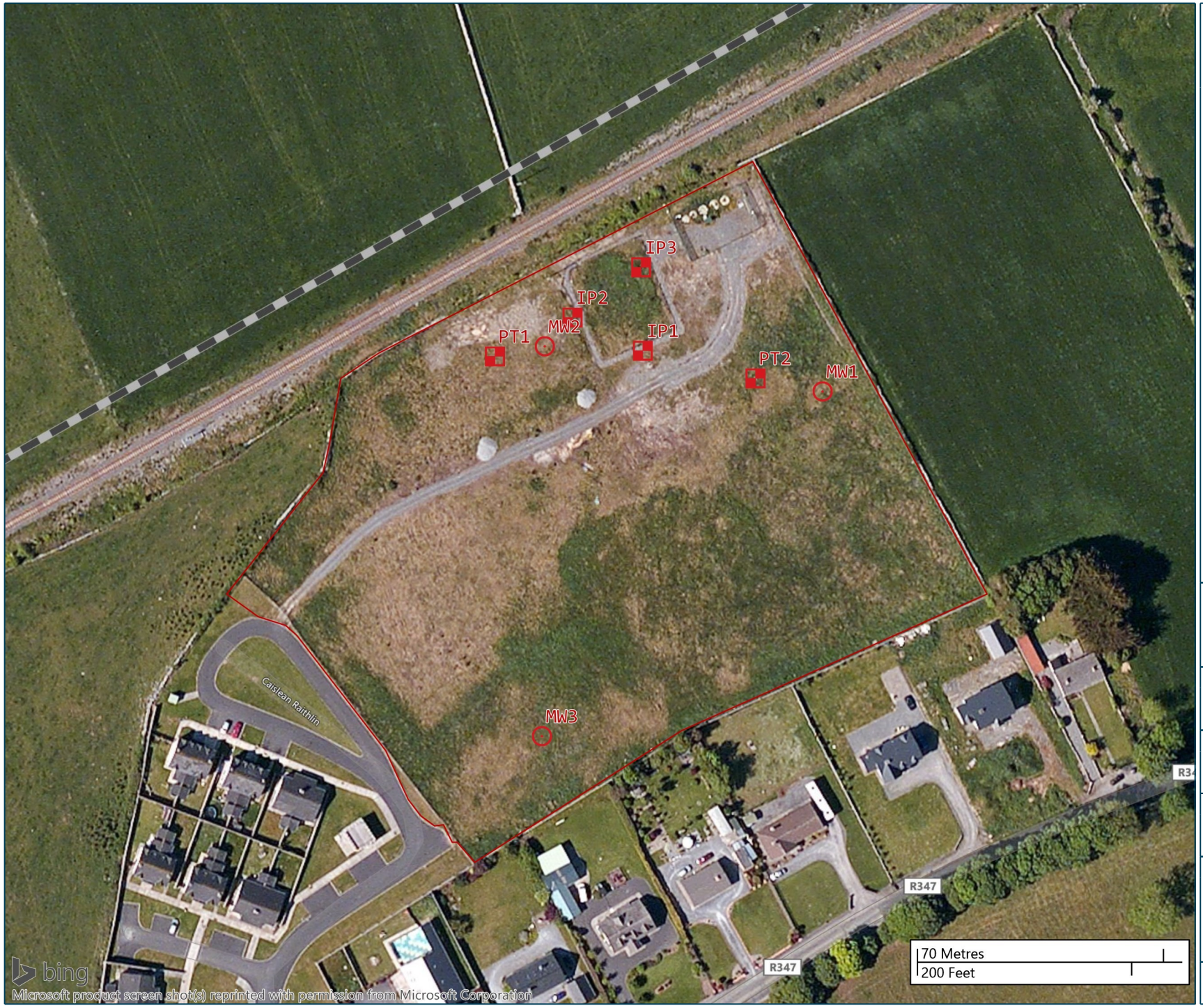
Project Title

Proposed Public Housing Development

Project Location

Caisleán Raithlín, Ardrahan, County Galway

Scale: 1:10000



N

Legend Key

- Locations By Type - RO
- Locations By Type - TP
- Project Bounds - Project Bounds

GroundCheck
SITE INVESTIGATION SPECIALISTS

Drawing Title

Figure 2 - Site Plan

Project ID

20-2384

Project Title

Proposed Public Housing Development

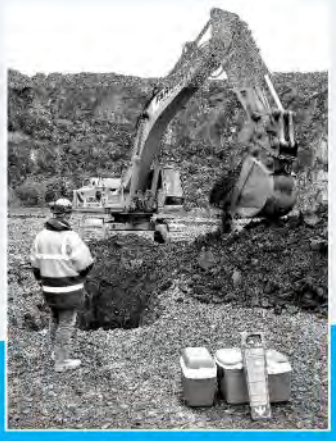
Project Location

Caisleán Raithlín, Ardrahan, County Galway

Scale: 1:1500

Appendix A:

Borehole & Trial Pit Logs and Photographs




GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID: **MW1**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546317	712620

Date Finish:	Logged By:	Site Location:	Elevation:
02/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	28.91(m) OD

Samples & In-situ Testing Type	Samples & In-situ Testing Depth (m)	Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
D	0.50		W			Greyish brown, gravelly, very sandy, clayey SILT containing cobbles and occasional boulders. Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. MADE GROUND		0.70	28.21
D	1.00					Light grey, mottled brown, gravelly, sandy, fissured, silty CLAY containing cobbles and occasional boulders. Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL	1.0		
D	1.70								
D	2.00						2.0		
						WEATHERED ROCK?		2.10	26.81
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE		2.30	26.61
D	3.00						3.0		
D	4.00						4.0		
							5.0		
							6.0		
							7.0		
							8.0		
							9.0		

Continued on Next Page

Water Monitoring

Depth	Date
16.78mbtoc	18-06-2020

Water Strikes

Struck	Date	Flow
14.50m	02/06	Seepage

Shift Information

Depth	Water	Remarks	Date Time
0.00			02/06/2020 10:20
23.45	17.71		02/06/2020 17:00

Depth Related Remarks

Top	Base	Remarks
0.00	1.20	Obstruction time - Hand dug inspection pit.

Backfill

Top	Base	Type
0.00	0.20	
0.20	10.00	
10.00	23.45	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.54magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW1

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546317	712620

Date Finish:	Logged By:	Site Location:	Elevation:
02/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	28.91(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
		Water Strike 14.50m				Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0		14.41

Continued on Next Page

Water Monitoring

Depth	Date
16.78mbtoc	18-06-2020

Water Strikes

Struck	Date	Flow
14.50m	02/06	Seepage

Shift Information

Depth	Water	Remarks	Date Time
0.00			02/06/2020 10:20
23.45	17.71		02/06/2020 17:00

Depth Related Remarks

Top	Base	Remarks

Backfill

Top	Base	Type
0.00	0.20	
0.20	10.00	
10.00	23.45	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.54magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW1

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546317	712620

Date Finish:	Logged By:	Site Location:	Elevation:
02/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	28.91(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE			
						End of Borehole at 23.45m	21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0	23.45	5.46

Water Monitoring		Water Strikes			Shift Information				Depth Related Remarks			Backfill		
Depth	Date	Struck	Date	Flow	Depth	Water	Remarks	Date Time	Top	Base	Remarks	Top	Base	Type
16.78mbtoc	18-06-2020	14.50m	02/06	Seepage	0.00 23.45	17.71		02/06/2020 10:20 02/06/2020 17:00				0.00 0.20 10.00	0.20 10.00 23.45	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.54magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID: **MW2**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546237	712634

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.69(m) OD

Samples & In-situ Testing Type	Samples & In-situ Testing Depth (m)	Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
D	0.50					Greyish brown, gravelly, very sandy, clayey SILT containing cobbles and occasional boulders. Sand is fine to coarse. Gravel is fine to coarse, sub-angular. MADE GROUND			
D	1.00					Light grey mottled greyish brown, gravelly, sandy, fissured, silty CLAY containing cobbles and boulders. Sand is fine to medium. Gravel is fine to coarse, sub-angular. GLACIAL	1.0	0.90	28.79
D	2.00						2.0		
D	3.00						3.0		
D	4.00						4.0		
						POSSIBLE BEDROCK/BOULDER?		4.10	25.59
						Light greyish brown, slightly gravelly, sandy, clayey SILT. Sand is fine to medium. Gravel is fine to medium, sub-rounded. GLACIAL?		4.50	25.19
D	5.00						5.0		
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE		5.30	24.39
D	6.00					VOID	6.0	6.00	23.69
						Karst void infilled with brown, slightly gravelly, sandy, silty CLAY.			
D	7.00						7.0		
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE		7.50	22.19
							8.0		
							9.0		
D	~~10.00~~					VOID		9.80	19.89

Continued on Next Page

Water Monitoring

Depth	Date
17.19mbtoc	18-06-2020

Water Strikes

Struck	Date	Flow

Shift Information

Depth	Water	Remarks	Date Time
0.00			02/06/2020 17:00
19.00			02/06/2020 18:30
19.00	13.1	Damp	03/06/2020 08:40
23.00			03/06/2020 10:20

Depth Related Remarks

Top	Base	Remarks
0.00	1.20	Obstruction time - Hand dug inspection pit.

Backfill

Top	Base	Type
0.00	0.20	
0.20	10.50	
10.50	22.27	
22.27	23.00	

Termination Reason:

Terminated on instructions of engineer.

General Remarks:

Raised well head cover is 0.71magl.
No samples were recovered below 9.8m due to loss of compressed air into voids in the Karst Geology.

AGS

Scale: 1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW2

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546237	712634

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.69(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						VOID *Karst void infilled. No sample recovery.*			
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	11.0	11.00	18.69
							12.0		
							13.0		
						VOID *Karst void infilled. No sample recovery.*		13.50	16.19
							14.0		
							15.0		
							16.0		
							17.0		
							18.0		
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE *No sample recovery.*	19.0	19.10	10.59

Continued on Next Page

Water Monitoring

Depth	Date
17.19mbtoc	18-06-2020

Water Strikes

Struck	Date	Flow

Shift Information

Depth	Water	Remarks	Date Time
0.00			02/06/2020 17:00
19.00			02/06/2020 18:30
19.00	13.1	Damp	03/06/2020 08:40
23.00			03/06/2020 10:20

Depth Related Remarks

Top	Base	Remarks
13.10	19.00	Hole collapsed below 13.1m overnight.

Backfill

Top	Base	Type
0.00	0.20	
0.20	10.50	
10.50	22.27	
22.27	23.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.71magl.
No samples were recovered below 9.8m due to loss of compressed air into voids in the Karst Geology.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW2

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
02/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546237	712634

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.69(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	21.0		
						VOID *Karst void infilled. No sample recovery.*	22.0	22.00	7.69
						End of Borehole at 23.00m	23.0	23.00	6.69
							24.0		
							25.0		
							26.0		
							27.0		
							28.0		
							29.0		

Water Monitoring

Depth	Date
17.19mbtoc	18-06-2020

Water Strikes

Struck	Date	Flow

Shift Information

Depth	Water	Remarks	Date Time
0.00			02/06/2020 17:00
19.00			02/06/2020 18:30
19.00	13.1	Damp	03/06/2020 08:40
23.00			03/06/2020 10:20

Depth Related Remarks

Top	Base	Remarks

Backfill

Top	Base	Type
0.00	0.20	
0.20	10.50	
10.50	22.27	
22.27	23.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.71magl.
No samples were recovered below 9.8m due to loss of compressed air into voids in the Karst Geology.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID: **MW3**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546235	712523

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	31.87(m) OD

Samples & In-situ Testing Type	Samples & In-situ Testing Depth (m)	Results & Information	Stratum Description	Scale	Depth (m)	Reduced Level (m)
			TOPSOIL		0.30	31.57
D	0.50		Brown, gravelly, sandy, silty CLAY containing cobbles. Sand is fine to medium. Gravel is fine to coarse, sub-angular. MADE GROUND?			
D	1.00		Light grey to light brownish grey, gravelly, very sandy, silty CLAY containing cobbles and boulders. Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL	1.0	1.00	30.87
D	2.00			2.0		
D	3.00			3.0		
D	4.00			4.0		
D	5.00			5.0		
D	6.00			6.0		
D	7.00			7.0		
D	8.00		Dark brownish grey, silty fine to medium SAND. GLACIAL WEATHERED ROCK?	8.0	7.90 8.10	23.97 23.77
D	9.00		Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	9.0	9.00	22.87

Continued on Next Page

Water Monitoring

Depth	Date
22.21mbtoc	18-07-2020

Water Strikes

Struck	Date	Flow
28.00m	03/06	Seepage

Shift Information

Depth	Water	Remarks
0.00		
33.00	29.1	

Depth Related Remarks

Date Time	Top	Base	Remarks
03/06/2020 10:30	0.00	1.20	Obstruction time - Hand dug inspection pit.
03/06/2020 17:00			

Backfill

Top	Base	Type
0.00	0.20	
0.20	9.00	
9.00	33.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.64magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW3

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546235	712523

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	31.87(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE			
								10.80	21.07
D	11.00					VOID *Karst void infilled with light brown, silty, fine to medium SAND with bands of sandy, silty clay.*	11.0		
D	12.00						12.0		
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE		12.20	19.67
						VOID *Karst void infilled with greyish brown, sandy, clayey SILT with bands of silty, fine to medium sand.*		12.70	19.17
D	13.00						13.0		
D	14.00						14.0		
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE		14.50	17.37
							15.0		
							16.0		
							17.0		
							18.0		
							19.0		

Continued on Next Page

Water Monitoring		Water Strikes			Shift Information				Depth Related Remarks			Backfill		
Depth	Date	Struck	Date	Flow	Depth	Water	Remarks	Date Time	Top	Base	Remarks	Top	Base	Type
22.21mbtoc	18-07-2020	28.00m	03/06	Seepage	0.00			03/06/2020 10:30				0.00	0.20	
					33.00	29.1		03/06/2020 17:00				0.20	9.00	
												9.00	33.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.64magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID: **MW3**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546235	712523

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	31.87(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0		
		Water Strike 28.00m							3.87

Continued on Next Page

Water Monitoring

Depth	Date
22.21mbtoc	18-07-2020

Water Strikes

Struck	Date	Flow
28.00m	03/06	Seepage

Shift Information

Depth	Water	Remarks	Date Time
0.00			03/06/2020 10:30
33.00	29.1		03/06/2020 17:00

Depth Related Remarks

Top	Base	Remarks

Backfill

Top	Base	Type
0.00	0.20	
0.20	9.00	
9.00	33.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.64magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Borehole Log

Location ID:
MW3

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Rotary open hole	20-2384	Proposed Public Housing Development	546235	712523

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	31.87(m) OD

Samples & In-situ Testing		Results & Information	Wells	Water	Legend	Stratum Description	Scale	Depth (m)	Reduced Level (m)
Type	Depth (m)								
						Light grey, fine grained LIMESTONE. CARBONIFEROUS BURREN FORMATION LIMESTONE	31.0 32.0		
						End of Borehole at 33.00m	33.0 34.0 35.0 36.0 37.0 38.0 39.0	33.00	-1.13

Water Monitoring

Depth	Date
22.21mbtoc	18-07-2020

Water Strikes

Struck	Date	Flow
28.00m	03/06	Seepage

Shift Information

Depth	Water	Remarks	Date Time
0.00			03/06/2020 10:30
33.00	29.1		03/06/2020 17:00

Depth Related Remarks

Top	Base	Remarks

Backfill

Top	Base	Type
0.00	0.20	
0.20	9.00	
9.00	33.00	

Termination Reason:
Terminated on instructions of engineer.

General Remarks:
Raised well head cover is 0.64magl.

AGS

Scale:
1:55

GroundCheck
SITE INVESTIGATION SPECIALISTS

Trial Pit Log

Location ID: **IP1**

Page1/1

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Trial Pit	20-2384	Proposed Public Housing Development	546265	712632

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	28.90(m) OD

Samples & In-situ Testing		Results & Information	Water	Scale	Legend	Stratum Description	Depth (m)	Reduced Level (m)
Type	Depth (m)							
						Geotextile membrane at base of strata. TOPSOIL		
						Grey, fine to medium, sub-angular GRAVEL. MADE GROUND	0.20	28.70
						Brownish grey, slightly clayey, silty, sandy, fine to coarse, angular GRAVEL containing cobbles. Sand is fine to coarse. MADE GROUND	0.40	28.50
						Greyish brown and brownish grey, gravelly, sandy, silty CLAY containing cobbles. Sand is fine to coarse. Gravel is fine to coarse, sub-angular. GLACIAL?	0.70	28.20
				1.0				
						Light grey, mottled brown, gravelly, sandy, fissured, silty CLAY containing cobbles . Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL	1.20	27.70
						End of Trial Pit at 1.30m	1.30	27.60
				2.0				
				3.0				

Trial Pit Dimensions

Length - 2.8m

Width - 0.5m

Shift Information

Depth	Water	Remarks	Date Time
1.30		DRY	03/05/2020 15:30

Depth Related Remarks

Top	Base	Remarks

Water Strikes

Depth Strike	Flow

Termination:
Terminated on instructions of engineer.

Pit Stabilty:
Trial pit sidewalls spalling between 0.2 and 0.4m as excavated.

Scale: 1:20

General Remarks:
Trial pit excavated using a 13tonne excavator fitted with a 300mm toothed bucket.

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Trial Pit Photographs

IP1

GroundCheck
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Trial Pit Photographs

IP1

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Trial Pit Photographs

IP1

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Trial Pit Log

Location ID: **IP2**

Page1/1

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Trial Pit	20-2384	Proposed Public Housing Development	546245	712642

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.01(m) OD

Samples & In-situ Testing		Results & Information	Water	Scale	Legend	Stratum Description	Depth (m)	Reduced Level (m)
Type	Depth (m)							
						Greyish brown, gravelly, very sandy, desicated, clayey SILT. Sand is fine to medium. Gravel is fine to coarse, sub-angular. MADE GROUND		
						Grey, fine to medium, sub-angular to sub-rounded GRAVEL. MADE GROUND	0.50	28.51
						Greyish brown and brownish grey, gravelly, very sandy, fissured, silty CLAY containing cobbles. Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL?	0.60	28.41
				1.0				
				2.0				
				3.0		End of Trial Pit at 1.30m	1.30	27.71

Trial Pit Dimensions

Length - 2.9m

Width - 0.5m

Shift Information

Depth	Water	Remarks	Date Time
1.30		DR	03/06/2020 15:55

Depth Related Remarks

Top	Base	Remarks

Water Strikes

Depth Strike	Flow

Termination:
Terminated on instructions of engineer.

Pit Stabilty:
Trial pit sidewalls spalling between 0.5 and 0.6m as excavated.

Scale: 1:20

General Remarks:
Trial pit excavated using a 13tonne excavator fitted with a 300mm toothed bucket.

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Trial Pit Photographs

IP2

GroundCheck
SITE INVESTIGATION SPECIALISTS

Trial Pit Photographs

IP2

GroundCheck
SITE INVESTIGATION SPECIALISTS

Trial Pit Photographs

IP2

GroundCheck
SITE INVESTIGATION SPECIALISTS

Trial Pit Log

Location ID: **IP3**

Page1/1

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Trial Pit	20-2384	Proposed Public Housing Development	546265	712656

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	28.78(m) OD

Samples & In-situ Testing		Results & Information	Water	Scale	Legend	Stratum Description	Depth (m)	Reduced Level (m)
Type	Depth (m)							
						Geotextile membrane at base of strata.	0.05	28.73
						TOPSOIL Grey, fine to medium, sub-rounded GRAVEL. MADE GROUND *1" HDPE Pipe capped off at 0.1m below the geotextile membrane.*	0.30	28.48
						Brownish grey, fine to coarse, sub-angular GRAVEL and COBBLES in a matrix of sandy, clayey silt. Sand is fine to coarse. MADE GROUND		
				1.0		Light grey, mottled brown, gravelly, sandy, fissured, silty CLAY containing cobbles . Sand is fine to medium. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL	0.90	27.88
						End of Trial Pit at 1.20m	1.20	27.58
				2.0				
				3.0				

Trial Pit Dimensions

Length - 2.8m

Width - 0.5m

Shift Information

Depth	Water	Remarks	Date Time
1.20		DRY	03/06/2020 16:30

Depth Related Remarks

Top	Base	Remarks

Water Strikes

Depth Strike	Flow

Termination:
Terminated on instructions of engineer.

Pit Stabilty:
Trial pit sidewalls spalling between 0.5 and 0.6m as excavated.

Scale: 1:20

General Remarks:
Trial pit excavated using a 13tonne excavator fitted with a 300mm toothed bucket.

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Trial Pit Photographs

IP3

GroundCheck
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Trial Pit Photographs

IP3

Trial Pit Photographs

IP3

GroundCheck
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Trial Pit Log

Location ID: **PT1**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Trial Pit	20-2384	Proposed Public Housing Development	546223	712631

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.51(m) OD

Samples & In-situ Testing		Results & Information	Water	Scale	Legend	Stratum Description	Depth (m)	Reduced Level (m)
Type	Depth (m)							
						Greyish brown, gravelly, very sandy, clayey SILT with medium cobble and boulder content. Sand is fine to coarse. Gravel is fine to coarse, sub-angular. MADE GROUND		
				1.0			1.00	28.51
B	1.50					Firm to stiff, light brownish grey, gravelly, sandy, fissured, silty CLAY containing cobbles. Sand is fine to coarse. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL		
				2.0				
						End of Trial Pit at 2.20m	2.20	27.31
				3.0				

Trial Pit Dimensions

Length - 3.4m

Width - 1.2m

Shift Information

Depth	Water	Remarks	Date Time
2.20		DRY	03/06/2020 14:15

Depth Related Remarks

Top	Base	Remarks

Water Strikes

Depth Strike	Flow

Termination: Terminated on instructions of engineer.

Pit Stabilty: Trial pit sidewalls stable on completion of excavation.

Scale: 1:20

General Remarks:

Trial pit excavated using a 13tonne excavator fitted with a 300mm toothed bucket.
Percolation test carried out in base of pit.

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Trial Pit Photographs

PT1

GroundCheck
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Trial Pit Photographs

PT1

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Trial Pit Photographs

PT1

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Trial Pit Log

Location ID: **PT2**

Date Start:	Location Type:	Project ID:	Project Name:	Easting:	Northing:
03/06/2020	Trial Pit	20-2384	Proposed Public Housing Development	546297	712624

Date Finish:	Logged By:	Site Location:	Elevation:
03/06/2020	S. Thompson	Caisleán Raithlín, Ardrahan, County Galway	29.01(m) OD

Samples & In-situ Testing		Results & Information	Water	Scale	Legend	Stratum Description	Depth (m)	Reduced Level (m)
Type	Depth (m)							
						Light greyish brown, gravelly, very sandy, clayey SILT containing cobbles, boulders and broken brick. Sand is fine to medium. Gravel is fine to coarse, sub-angular. MADE GROUND		
				1.0		Firm, light greyish brown, mottled brownish grey, gravelly, sandy, fissured, silty CLAY containing cobbles. Sand is fine to coarse. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL?	0.90	28.11
B	1.50			2.0		Firm to stiff, light brownish grey, gravelly, sandy, fissured, silty CLAY containing cobbles. Sand is fine to coarse. Gravel is fine to coarse, sub-angular to sub-rounded. GLACIAL	1.40	27.61
						End of Trial Pit at 2.20m	2.20	26.81
				3.0				

Trial Pit Dimensions

Length - 3.8m

Width - 1.4m

Shift Information

Depth	Water	Remarks	Date Time
2.20		DRY	03/06/2020 15:05

Depth Related Remarks

Top	Base	Remarks

Water Strikes

Depth Strike	Flow

Termination:
Terminated on instructions of engineer.

Pit Stabilty:
Trial pit sidewalls stable on completion of excavation.

Scale: 1:20

General Remarks:
Trial pit excavated using a 13tonne excavator fitted with a 300mm toothed bucket.
Percolation test carried out in base of pit.

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Trial Pit Photographs

PT2

GroundCheck
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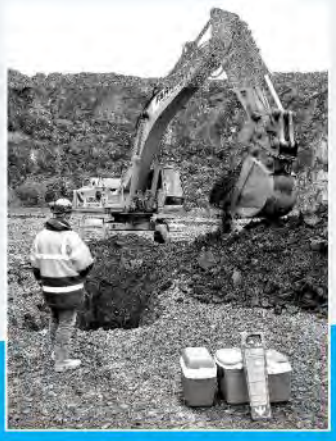
Trial Pit Photographs

PT2


HITACHI

Appendix B:

Geotechnical Laboratory Test Results




Ground Check Ltd

Laboratory Test Results

Site : CAISLEAN RAITHLIN

Client :

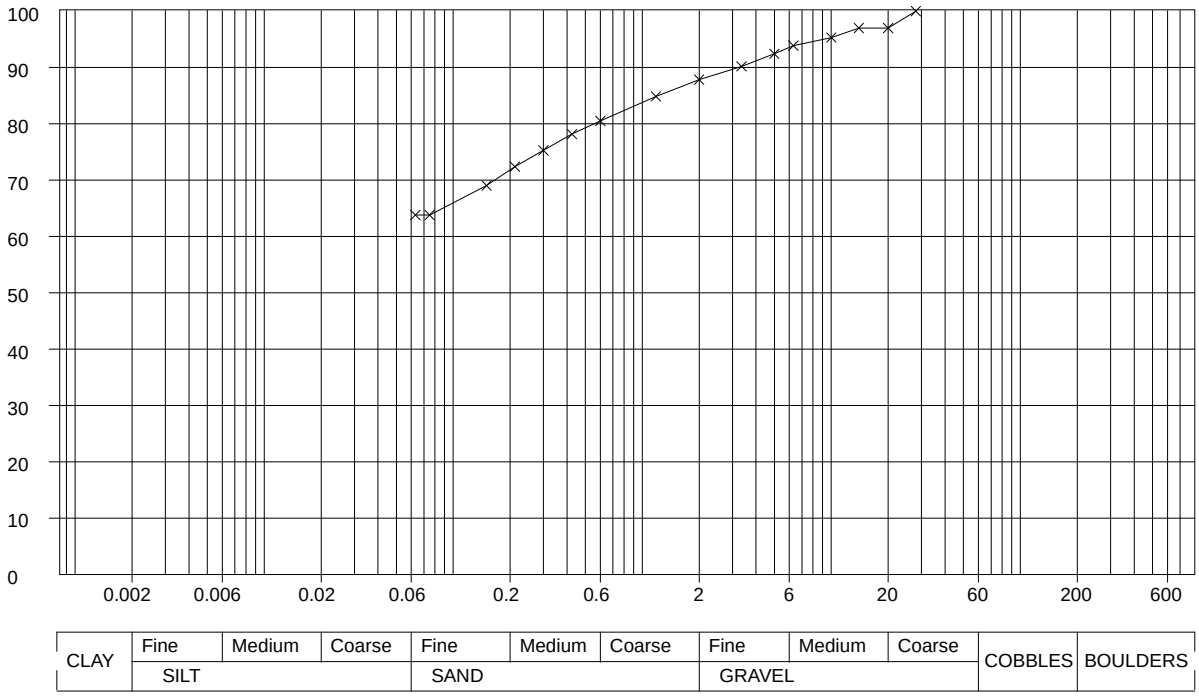
Engineer :

Job Number 20-2384

Sheet 1/2

DETERMINATION OF PARTICLE SIZE DISTRIBUTION

Borehole / Trial Pit	Depth (m)	Sample	Laboratory Description
TP01	1.50	B1	



Sieve / Particle Size	% Passing
28 mm	100.0
20 mm	97.0
14 mm	97.0
10 mm	95.3
6.3 mm	93.9
5 mm	92.4
3.35 mm	90.2
2 mm	87.9
1.18 mm	84.9
600 µm	80.5
425 µm	78.2
300 µm	75.3
212 µm	72.4
150 µm	69.0
75 µm	63.8
63 µm	63.8

Grading Analysis	
D85	1.2 mm
D60	-
D10	<63.0 µm
Uniformity Coefficient	-

Particle Proportions	
Cobbles + Boulders	-
Gravel	12.1%
Sand	24.1%
Silt	-
Clay	-

Method of Preparation : BS 1377:PART 1:1990:7.3 Initial preparation 1990:7.4.5 Particle size tests

Method of Test : BS 1377:PART 2:1990:9 Determination of particle size distribution

Remarks :

Ground Check Ltd

Laboratory Test Results

Site : CAISLEAN RAITHLIN

Client :

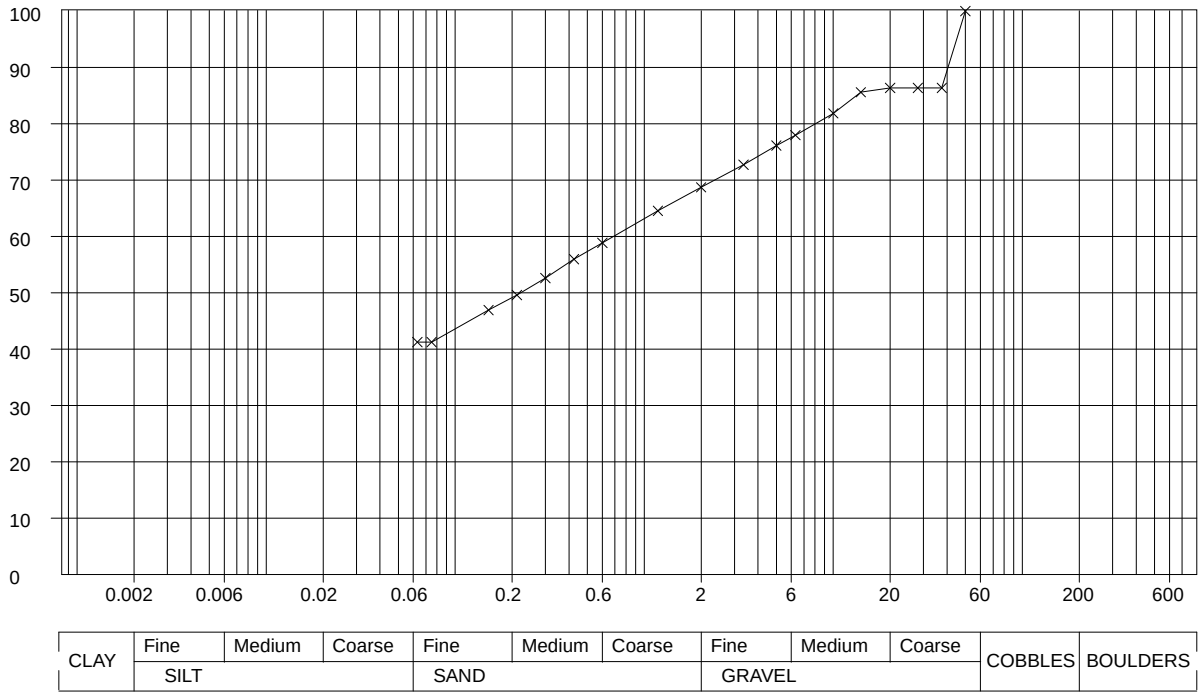
Engineer :

Job Number 20-2384

Sheet 2/2

DETERMINATION OF PARTICLE SIZE DISTRIBUTION

Borehole / Trial Pit	Depth (m)	Sample	Laboratory Description
TP02	1.50	B1	



Sieve / Particle Size	% Passing
50 mm	100.0
37.5 mm	86.4
28 mm	86.4
20 mm	86.4
14 mm	85.6
10 mm	81.9
6.3 mm	78.0
5 mm	76.2
3.35 mm	72.7
2 mm	68.7
1.18 mm	64.6
600 µm	58.9
425 µm	56.0
300 µm	52.6
212 µm	49.6
150 µm	46.9
75 µm	41.3
63 µm	41.3

Grading Analysis	
D85	13.4 mm
D60	716.2 µm
D10	<63.0 µm
Uniformity Coefficient	-

Particle Proportions	
Cobbles + Boulders	-
Gravel	31.3%
Sand	27.5%
Silt	-
Clay	-

Method of Preparation : BS 1377:PART 1:1990:7.3 Initial preparation 1990:7.4.5 Particle size tests

Method of Test : BS 1377:PART 2:1990:9 Determination of particle size distribution

Remarks :

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APPENDIX B

Percolation Testing 2019 Brendan Reddan

Ennis Road,
Miltown Malbay,
Co. Clare,
Ireland.
18th Feb 2019

McKenna Consulting Engineers,
Bank Place,
Milltown Malbay,
Co. Clare.s

Re: Proposed Soakaways,
For Social Housing in Ardrahan,
Co Galway.

To whom it may concern.
With reference to your request for a soakaway trial pit report, regarding the proposed Social Housing development in Ardrahan Co Galway, a site survey was carried out and the following is my report.

Proposed New Soakawys.

The ground area to the east of the Proposed Housing Development where the proposed soakways are to be located is generally overgrown with bushes and shrub.
A Trial hole and T-Test were excavated, and the following are the results.

T-Test Results.

T-Test 1
Time for Water to drain away from 75% to 25% = 425 Min
T-Test 2
Time for Water to drain away from 75% to 25% = 420 Min.
T-Test 3
Time for Water to drain away from 75% to 25% = 455 Min.

Size of Soakage trial pit No 1. L= 1400. W= 800 Dpt = 800

Size of Soakage trial pit No2. L= 1500. W=900 Dpt = 900

Size of Soakage trial pit No 3. L= 1400. W= 750 Dpt = 800

Trial Hole .

The Trial Hole was excavated in the same general area as the Soakage trial pit area. (See enclosed drawing).

Dept of Trial hole. = 2.3m. See results and photographs attached

See Photographs of Soakaway trial pits and Trial Hole attached.

Hoping this information is to your satisfaction.
Yours sincerely,

Brendan Reddan.
EPA Approved site Assessor.

3.2 Trial Hole (should be a minimum of 2.1m deep (3m for regionally important aquifers))

To avoid any accidental damage, a trial hole assessment or percolation tests should not be undertaken in areas, which are at or adjacent to significant sites (e.g. NHAs, SACs, SPAs, and/or Archaeological etc.), without prior advice from National Parks and Wildlife Service or the Heritage Service.

Depth of trial hole (m): 2.30

Depth from ground surface to bedrock (m) (if present):

Depth from ground surface to water table (m) (if present):

Depth of water ingress:

Rock type (if present): None Encountered.

Date and time of excavation: 13/02/2019 11:00

Date and time of examination:

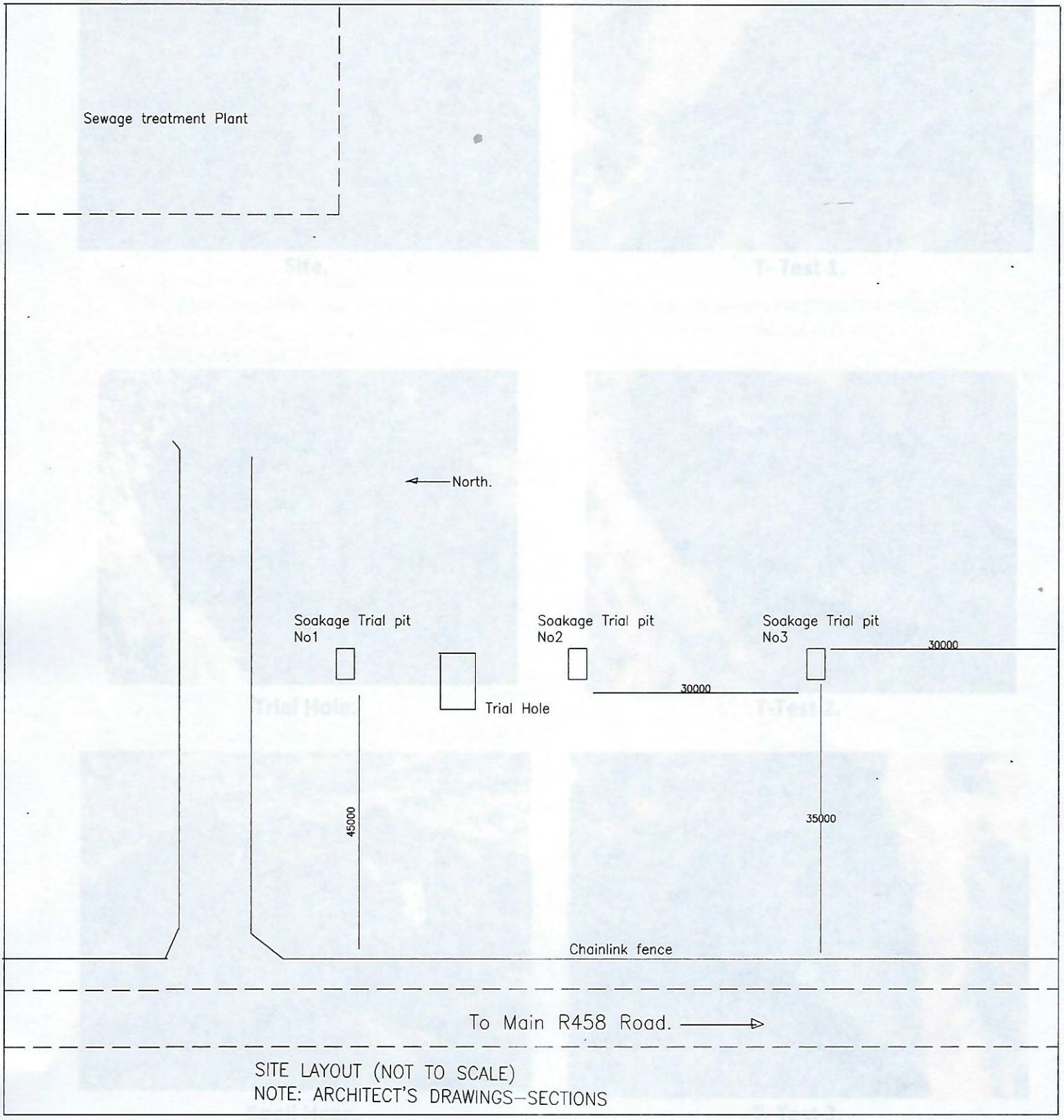
	Depth of P/T Test*	Soil/Subsoil Texture & Classification**	Plasticity and dilatancy***	Soil Structure	Density/ Compactness	Colour****	Preferential flowpaths
0.1 m		Loamy.		Crumb	Low	Brown	Vertical grass roots.
0.2 m							
0.3 m							
0.4 m		.....	.....	.....	.....	.....	.....
0.5 m							
0.6 m							
0.7 m							
0.8 m		Mixture of White Sand and Clay and Cobbles Boulders.		Granular	High.	Light Grey.	
0.9 m							
1.0 m							
1.1 m							
1.2 m							
1.3 m							
1.4 m							
1.5 m		.....	.....	.....	.....	.....	
1.6 m							
1.7 m		Mixture of White Sand and Clay and Cobbles Boulders.		Massive	High	Dark Brown.	
1.8 m							
1.9 m							
2.0 m							
2.1 m							
2.2 m							
2.3 m		.....	.....	.....	.....	.....	
2.4 m		Dept of Trial Hole					
2.5 m							
2.6 m							
2.7 m							
2.8 m							
2.9 m							
3.0 m							

Evaluation:

There are no signs of mottling.
The trial hole was excavated at the rear of the site. The Mixture of Clay and Boulders from 0.3m level to 2.3m level seems to be very stiff and is impermeable.

Likely T value:

Note: *Depth of percolation test holes should be indicated on log above. (Enter P or T at depts as appropriate).
** See Appendix E for BS 5930 classification.
*** 3 samples to be tested for each horizon and results should be entered above for each horizon.
**** All signs of mottling should be recorded.



SITE LAYOUT (NOT TO SCALE)
NOTE: ARCHITECT'S DRAWINGS–SECTIONS

Site.

T- Test 1.

Trial Hole.

T-Test 2.

Spoil Heap.

T- Test 3.

APPENDIX C

Infiltration & Hydraulic Conductivity Test Results

Soakaway Infiltration Test

Project No: BRE19015
Site: Ardrahan Housing Development
Test Location: PT1
Test Date: 3rd June 2020

Analysis using method as described in BRE Digest 365 and CIRA Report C697 - SUDS Manual

	width (m)	length (m)
test pit top dimensions	**1.2**	**3.4**
test pit base dimensions	**0.4**	**2**
test pit depth (m)	**2.1**	

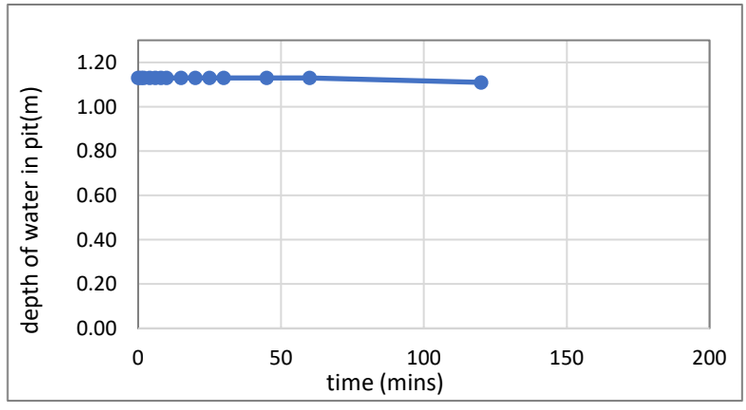
depth to groundwater before adding water (m)= **DRY**

time (mins)	depth to water surface (m)	depth of water in pit (m)
0	0.97	1.13
1	0.97	1.13
2	0.97	1.13
4	0.97	1.13
6	0.97	1.13
8	0.97	1.13
10	0.97	1.13
15	0.97	1.13
20	0.97	1.13
25	0.97	1.13
30	0.97	1.13
45	0.97	1.13
60	0.97	1.13
120	0.99	1.11
180	-	

From graph below:
test start - 75% depth at 0.73m water depth
time is not determined

test end - 25% depth at 0.24 m water depth
time is not determined

time (mins)	depth to water surface (m)	depth of water in pit (m)	time elapsed (mins)	volume of water lost (m3)	area of walls and base at 50% drop (m2)	q (m/min)	q (m/h)



Soakaway Infiltration Test

Project No: BRE19015
Site: Ardrahan Housing Development
Test Location: PT2
Test Date: 3rd June 2020

Analysis using method as described in BRE Digest 365 and CIRA Report C697 - SUDS Manual

	width (m)	length (m)
test pit top dimensions	**1.4**	**3.8**
test pit base dimensions	**0.4**	**2.5**
test pit depth (m)	**2**	

depth to groundwater before adding water (m)= **DRY**

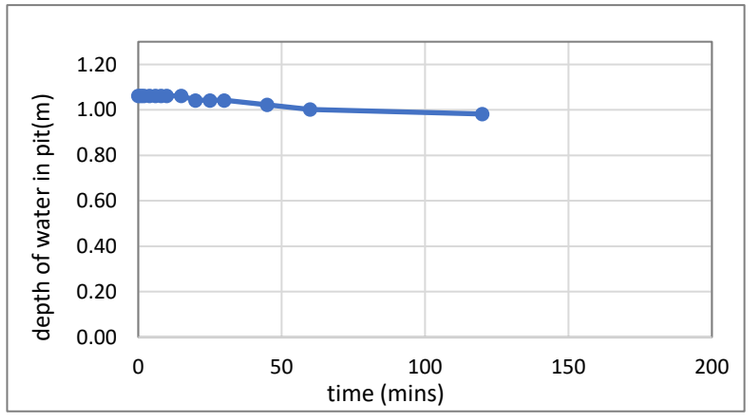
time (mins)	depth to water surface (m)	depth of water in pit (m)
0	0.938	1.062
1	0.938	1.062
2	0.938	1.062
4	0.938	1.062
6	0.938	1.062
8	0.938	1.062
10	0.938	1.062
15	0.938	1.062
20	0.958	1.042
25	0.958	1.042
30	0.958	1.042
45	0.978	1.022
60	0.998	1.002
120	1.018	0.982
180	-	

From graph below:
test start - 75% depth at 0.7m water depth
time is not determined

test end - 25% depth at 0.23 m water depth
time is not determined

0.08

time (mins)	depth to water surface (m)	depth of water in pit (m)	time elapsed (mins)	volume of water lost (m3)	area of walls and base at 50% drop (m2)	q (m/min)	q (m/h)



Soakaway Infiltration Test

Project No: BRE19015
Site: Ardrahan Housing Development
Test Location: PT5
Test Date: 19-Nov-20

Analysis using method as described in BRE Digest 365 and CIRA Report C697 - SUDS Manual

	width (m)	length (m)
test pit top dimensions	**1.2**	**5.0**
test pit base dimensions	**1.2**	**3.8**
test pit depth (m)	**2.1**	

depth to groundwater before adding water (m)= 1.175

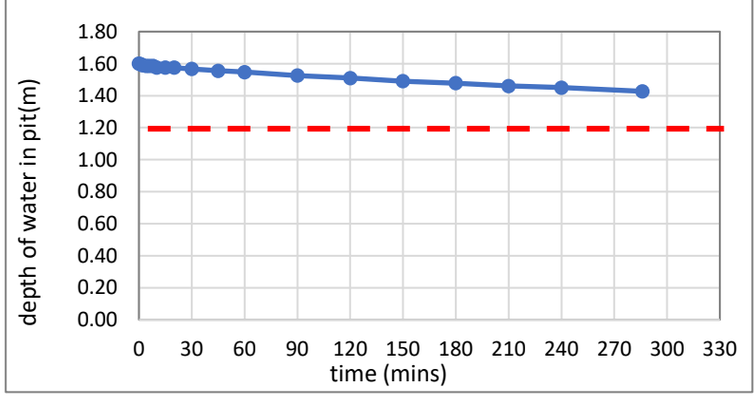
time (mins)	depth to water surface (m)	depth of water in pit (m)
0	0.5	1.6
1	0.505	1.595
2	0.51	1.59
4	0.515	1.585
6	0.515	1.585
8	0.515	1.585
10	0.525	1.575
15	0.525	1.575
20	0.525	1.575
30	0.533	1.567
45	0.545	1.555
60	0.553	1.547
90	0.575	1.525
120	0.59	1.51
150	0.61	1.49
180	0.622	1.478
210	0.64	1.46
240	0.65	1.45
286	0.673	1.427

From graph below:
test start - 75% depth at 1.2m water depth
time is not determined

test end - 25% depth at 0.4m water depth
time is not determined

Pit was pre soaked for 17 hours, water level dropped from 0.6 to 1.2 mbgl.

time (mins)	depth to water surface (m)	depth of water in pit (m)	time elapsed (mins)	volume of water lost (m3)	area of walls and base at 50% drop (m2)	q (m/min)	q (m/h)
		1.2					
		0.4					



Soakaway Infiltration Test

Project No: BRE19015
Site: Ardrahan Housing Development
Test Location: PT7
Test Date: 19-Nov-20

Analysis using method as described in BRE Digest 365 and CIRA Report C697 - SUDS Manual

	width (m)	length (m)
test pit top dimensions		
test pit base dimensions	**1.2**	**3.5**
test pit depth (m)	**2.5**	

depth to groundwater before adding water (m)= Dry

time (mins)	depth to water surface (m)	depth of water in pit (m)
0	1.09	1.41
1	1.105	1.395
2	1.11	1.39
4	1.15	1.35
6	1.155	1.345
8	1.165	1.335
10	1.19	1.31
15	1.22	1.28
20	1.245	1.255
30	1.29	1.21
45	1.345	1.155
60	1.39	1.11
90	1.45	1.05
120	1.52	0.98
150	1.56	0.94
180	1.6	0.9
210	1.64	0.86
240	1.665	0.835

From graph below:
test start - 75% depth at 1.0575m water depth
time is 90 mins

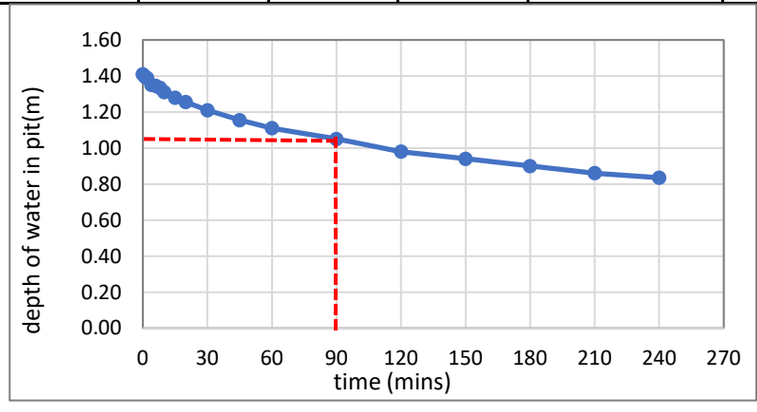
test end - 25% depth at 0.35m water depth
time is not determined

Pit was not pre soaked before test

vol outflowing from T0 to T240	2.415	m3
mean surface area at 50%	10.827	m2
time taken	240	min

infiltration rate 1.55E-05

time (mins)	depth to water surface (m)	depth of water in pit (m)	time elapsed (mins)	volume of water lost (m3)	area of walls and base at 50% drop (m2)	q (m/min)	q (m/h)
	1.45	1.0575	90	1.512	10.827	0.002395833	0.14375
		0.35					



VARIABLE HEAD PERMEABILITY TEST (BOREHOLE)

CONTRACT Ardrahan Development Tier 2 BOREHOLE No.: **MW01** TEST No.: 1
TYPE OF TEST: FALLING HEAD DATE: 04/06/2020

Diameter of casing (D):	*150*	(mm)		0.15	(m)
Height of TOP of casing above ground level:	*0.54*	(m)			
Depth to bottom of casing below ground level (m):	*0.00*	(m)			
Depth to bottom of borehole below ground level before test:	*23.36*	(m)			
Depth to bottom of borehole below ground level after test:	*23.36*	(m)			
Standing ground water level (mbgl):	*11.24*	(m)	on	04/06/2020	

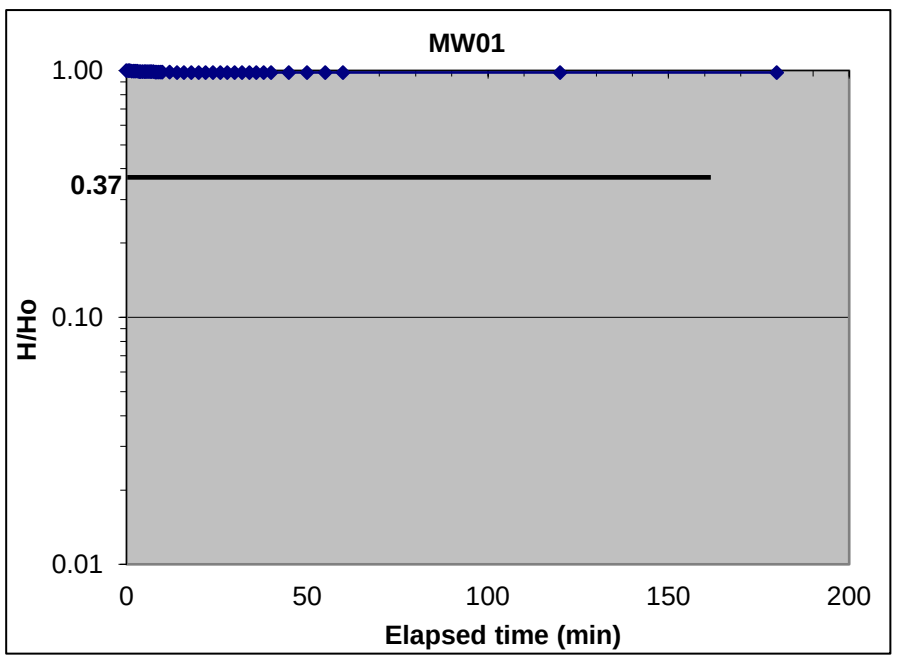
DATUM:All depths to water level measured from top of casing. i.e.SWL 11.78 m below datum.

TIME ELAPSED (mins)	WATER LEVEL* (m)	HEAD H (m)	HEAD RATIO H/Ho
0	10.76	1.02	1.0000
0.5	10.76	1.02	1.0000
1	10.76	1.02	1.0000
1.5	10.765	1.02	0.9951
2	10.765	1.02	0.9951
2.5	10.765	1.02	0.9951
3	10.765	1.02	0.9951
3.5	10.766	1.01	0.9941
4	10.766	1.01	0.9941
4.5	10.767	1.01	0.9931
5	10.768	1.01	0.9922
5.5	10.768	1.01	0.9922
6	10.768	1.01	0.9922
6.5	10.769	1.01	0.9912
7	10.77	1.01	0.9902
7.5	10.77	1.01	0.9902
8	10.771	1.01	0.9892
8.5	10.771	1.01	0.9892
9	10.771	1.01	0.9892
9.5	10.772	1.01	0.9882
10	10.773	1.01	0.9873
12	10.774	1.01	0.9863
14	10.775	1.01	0.9853
16	10.775	1.01	0.9853
18	10.776	1.00	0.9843
20	10.777	1.00	0.9833
22	10.778	1.00	0.9824
24	10.779	1.00	0.9814
26	10.778	1.00	0.9824
28	10.778	1.00	0.9824
30	10.778	1.00	0.9824
32	10.778	1.00	0.9824
34	10.778	1.00	0.9824
36	10.778	1.00	0.9824
38	10.778	1.00	0.9824
40	10.778	1.00	0.9824
45	10.778	1.00	0.9824
50	10.778	1.00	0.9824
55	10.778	1.00	0.9824
60	10.778	1.00	0.9824
120	10.778	1.00	0.9824
180	10.778	1.00	0.9824

T - basic time lag N/A min
area of borehole 0.0314 m2
F - intake factor 0.912868
BS:5930 Figure 6(d)

k=(A/FT) #VALUE! #VALUE!
failed to establish time lag at t =0.37
or

k=(A/F(t2-t1))ln(H1/H2) (general approach)
3.4024E-06 **3.40E-06**
2.04E-04 m/day
5.67E-08 m/sec



VARIABLE HEAD PERMEABILITY TEST (BOREHOLE)

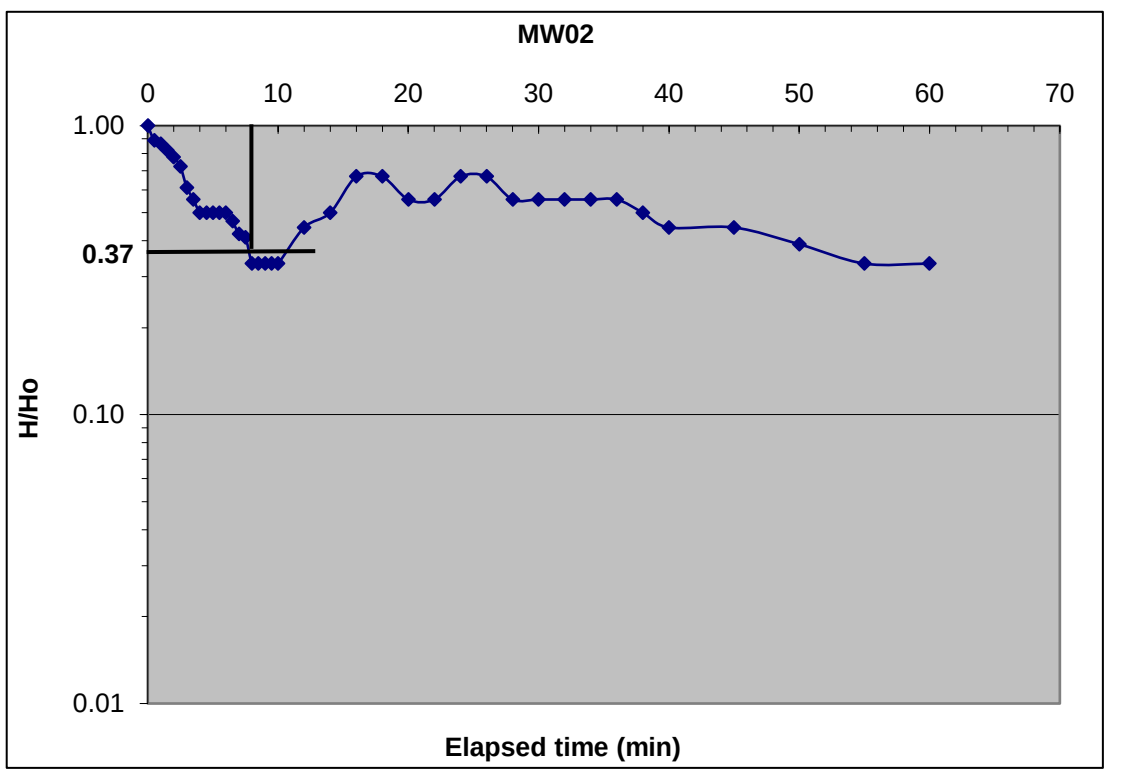
CONTRACT Ardrahan Development Tier 2 BOREHOLE No.: **MW02** TEST No.: 1
TYPE OF TEST: FALLING HEAD DATE: 04/06/2020

Diameter of casing (D):	*150*	(mm)		0.15	(m)
Height of TOP of casing above ground level:	*0.71*	(m)			
Depth to bottom of casing below ground level (m):	*0.00*	(m)			
Depth to bottom of borehole below ground level before test:	*22.60*	(m)			
Depth to bottom of borehole below ground level after test:	*22.60*	(m)			
Standing ground water level (mbgl):	*16.28*	(m)	on	04/06/2020	

DATUM:All depths to water level measured from top of casing. i.e.SWL 16.99 m below datum.

TIME ELAPSED (mins)	WATER LEVEL* (m)	HEAD H (m)	HEAD RATIO H/Ho
0	16.9	0.09	1.0000
0.5	16.91	0.08	0.8889
1	16.912	0.08	0.8667
1.5	16.916	0.07	0.8222
2	16.92	0.07	0.7778
2.5	16.925	0.06	0.7222
3	16.935	0.05	0.6111
3.5	16.94	0.05	0.5556
4	16.945	0.04	0.5000
4.5	16.945	0.04	0.5000
5	16.945	0.04	0.5000
5.5	16.945	0.04	0.5000
6	16.945	0.04	0.5000
6.5	16.948	0.04	0.4667
7	16.952	0.04	0.4222
7.5	16.953	0.04	0.4111
8	16.96	0.03	0.3333
8.5	16.96	0.03	0.3333
9	16.96	0.03	0.3333
9.5	16.96	0.03	0.3333
10	16.96	0.03	0.3333
12	16.95	0.04	0.4444
14	16.945	0.04	0.5000
16	16.93	0.06	0.6667
18	16.93	0.06	0.6667
20	16.94	0.05	0.5556
22	16.94	0.05	0.5556
24	16.93	0.06	0.6667
26	16.93	0.06	0.6667
28	16.94	0.05	0.5556
30	16.94	0.05	0.5556
32	16.94	0.05	0.5556
34	16.94	0.05	0.5556
36	16.94	0.05	0.5556
38	16.945	0.04	0.5000
40	16.95	0.04	0.4444
45	16.95	0.04	0.4444
50	16.955	0.04	0.3889
55	16.96	0.03	0.3333
60	16.96	0.03	0.3333

T - basic time lag	8	min				
area of borehole	0.0314	m2	k=(A/FT)	0.00430327	**4.30E-03**	
F - intake factor	0.912098				6.20E+00	m/day
BS:5930 Figure 6(d)					7.17E-05	m/sec



VARIABLE HEAD PERMEABILITY TEST (BOREHOLE)

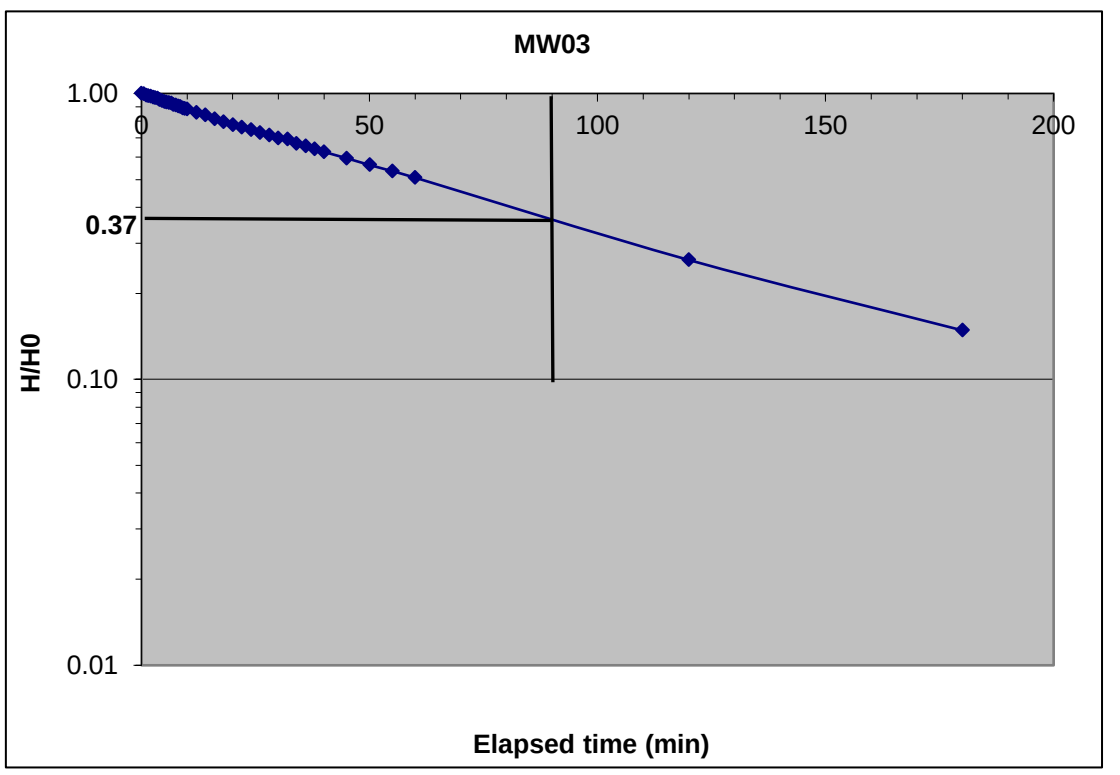
CONTRACT Ardrahan Development Tier 2 BOREHOLE No.: **MW03** TEST No.: 1
TYPE OF TEST: FALLING HEAD DATE: 04/06/2020

Diameter of casing (D):	*150*	(mm)		0.15	(m)
Height of TOP of casing above ground level:	*0.64*	(m)			
Depth to bottom of casing below ground level (m):	*0.00*	(m)			
Depth to bottom of borehole below ground level before test:	*33.00*	(m)			
Depth to bottom of borehole below ground level after test:	*33.00*	(m)			
Standing ground water level (mbgl):	*21.26*	(m)	on	04/06/2020	

DATUM:All depths to water level measured from top of casing. i.e.SWL 21.90 m below datum.

TIME ELAPSED (mins)	WATER LEVEL* (m)	HEAD H (m)	HEAD RATIO H/Ho
0	20.62	1.28	1.0000
0.5	20.63	1.28	0.9961
1	20.64	1.26	0.9844
1.5	20.65	1.26	0.9805
2	20.65	1.25	0.9766
2.5	20.66	1.24	0.9688
3	20.67	1.24	0.9648
3.5	20.67	1.23	0.9609
4	20.68	1.22	0.9531
4.5	20.69	1.21	0.9453
5	20.70	1.20	0.9375
5.5	20.71	1.20	0.9336
6	20.71	1.19	0.9297
6.5	20.72	1.19	0.9258
7	20.73	1.17	0.9141
7.5	20.74	1.17	0.9102
8	20.75	1.16	0.9023
8.5	20.75	1.15	0.8984
9	20.76	1.14	0.8906
9.5	20.77	1.14	0.8867
10	20.77	1.13	0.8828
12	20.80	1.10	0.8594
14	20.83	1.08	0.8398
16	20.86	1.05	0.8164
18	20.88	1.02	0.7969
20	20.91	0.99	0.7773
22	20.93	0.97	0.7617
24	20.95	0.95	0.7461
26	20.97	0.93	0.7305
28	20.99	0.91	0.7148
30	21.01	0.90	0.6992
32	21.02	0.88	0.6914
34	21.05	0.85	0.6680
36	21.06	0.84	0.6563
38	21.08	0.82	0.6406
40	21.10	0.80	0.6250
45	21.14	0.76	0.5938
50	21.18	0.72	0.5625
55	21.22	0.68	0.5352
60	21.25	0.65	0.5078
120	21.57	0.33	0.2617
180	21.71	0.19	0.1484

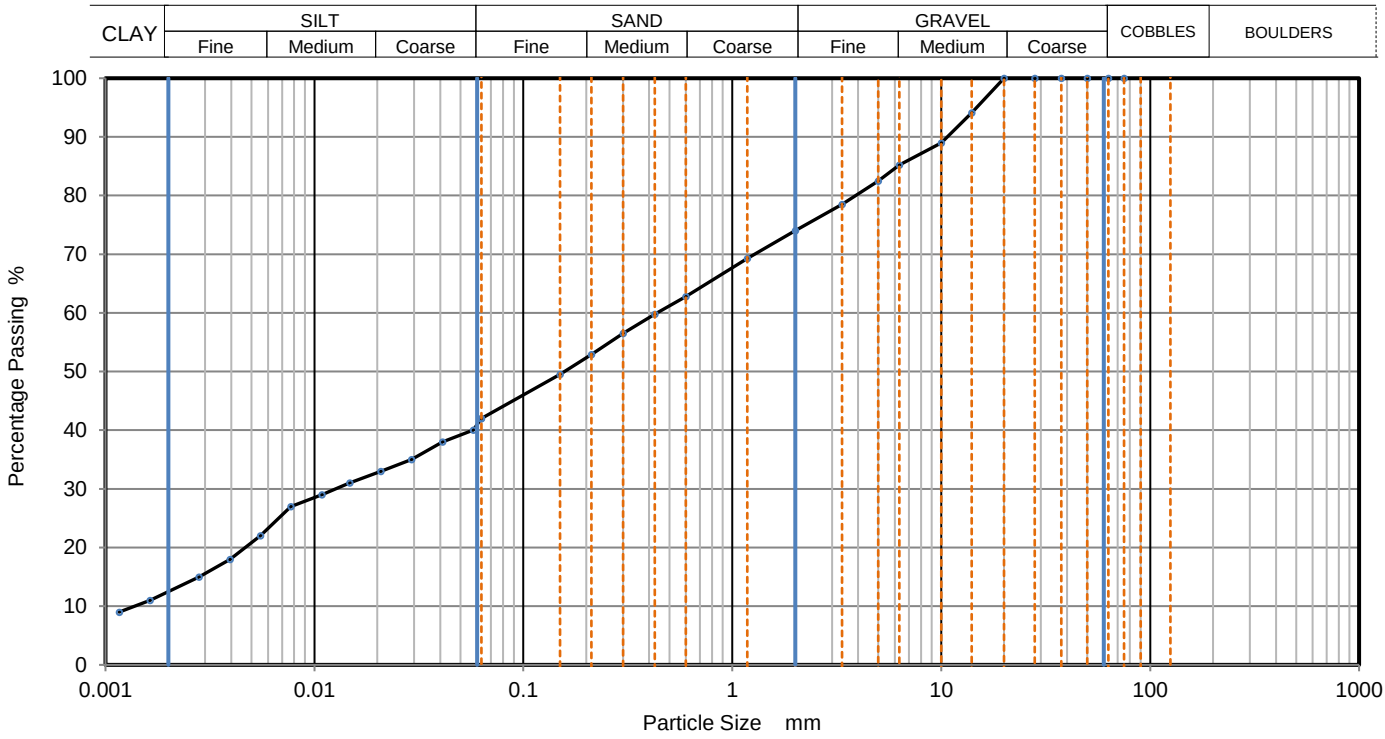
T - basic time lag	90	min				
area of borehole	0.0314	m2	k=(A/FT)	0.000379	**3.79E-04**	m/min
F - intake factor	0.919915				5.46E-01	m/day
BS:5930 Figure 6(d)					6.32E-06	m/sec



APPENDIX D

Particle Size Distribution (PSD)

IRISH DRILLING LIMITED	**PARTICLE SIZE DISTRIBUTION**			Job Ref	**2020Lab105**
				Borehole/Pit No.	Ardrahan.IP4
Site Name	Blue Rock Env			Sample No.	1
Soil Description	Light brown slightly gravelly slightly sandy SILT.			Depth, m	0.40
Specimen Reference		Specimen Depth	m	Sample Type	B
Test Method	BS1377:Part 2:1990, clauses 9.2 and 9.5			KeyLAB ID	IDL1202011265



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
		0.0630	42
		0.0577	40
75	100	0.0410	38
63	100	0.0292	35
50	100	0.0208	33
37.5	100	0.0148	31
28	100	0.0108	29
20	100	0.0077	27
14	94	0.0055	22
10	89	0.0039	18
6.3	85	0.0028	15
5	83	0.0016	11
3.35	79	0.0012	9
2	74		
1.18	69		
0.6	63	Particle density (assumed)	
0.425	60	2.65 Mg/m3	
0.3	57		
0.212	53		
0.15	50		
0.063	42		

Dry Mass of sample, g	1058

Sample Proportions	% dry mass
Very coarse	0
Gravel	26
Sand	32
Silt	29
Clay	13

Grading Analysis		
D100	mm	
D60	mm	0.433
D30	mm	0.0129
D10	mm	0.00139
Uniformity Coefficient		310
Curvature Coefficient		0.28

Remarks

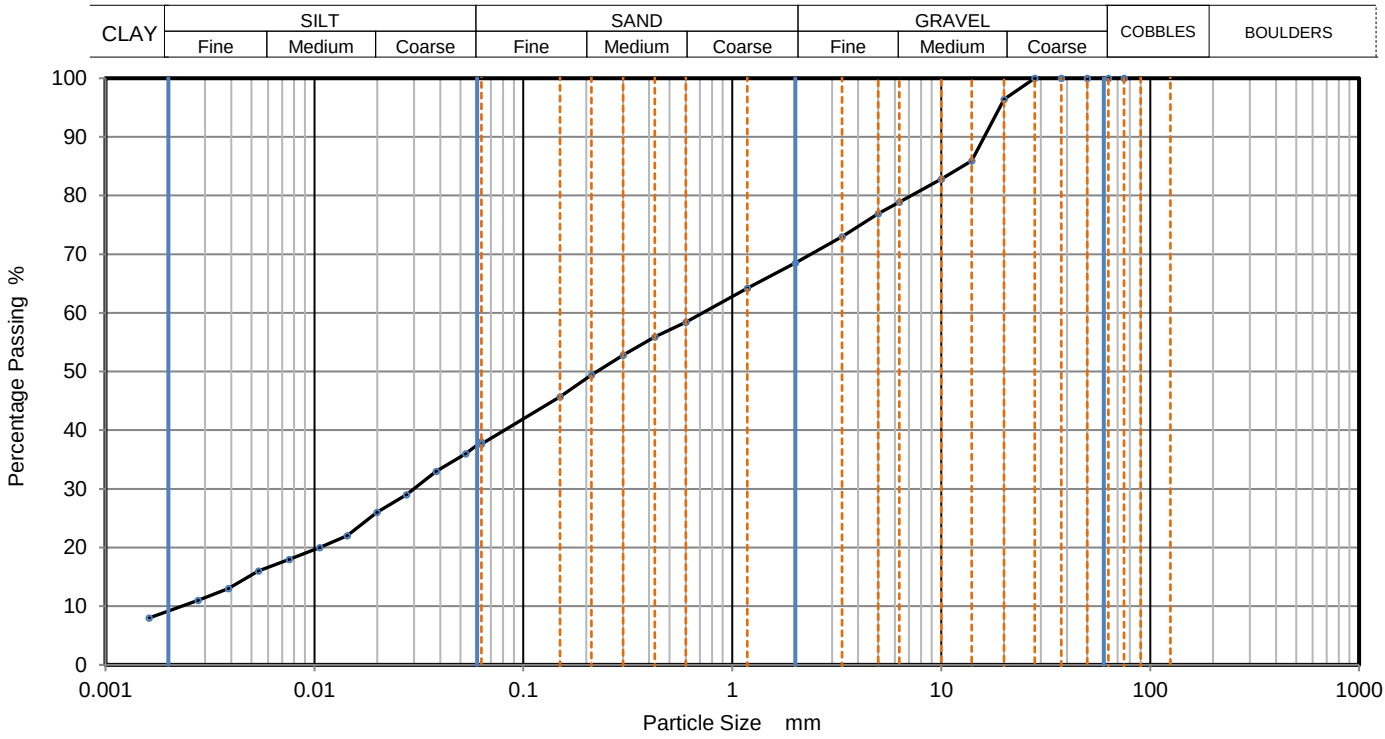
Preparation and testing in accordance with BS1377 unless noted below

Operator	Checked	Approved	Sheet printed	
		Dympna Darcy B.Sc.	01/12/2020 10:07	**1** QC From No:R2

Tested in: Irish Drilling Ltd.(IDL), Old Galway Road, Loughrea, Co. Galway, Ireland. H62VX39

Approved Signatures: Dympna Darcy (DCD) Lab Manager, Declan Joyce (DJ) Chartered Geotechnical Engineer, Ronan Killeen (RK) Quality Manager.

IRISH DRILLING LIMITED	**PARTICLE SIZE DISTRIBUTION**			Job Ref	**2020Lab105**
				Borehole/Pit No.	Ardrahan.PT3
Site Name	Blue Rock Env			Sample No.	
Soil Description	Light brown slightly sandy slightly gravelly SILT.			Depth, m	1.50
Specimen Reference		Specimen Depth	m	Sample Type	B
Test Method	BS1377:Part 2:1990, clauses 9.2 and 9.5			KeyLAB ID	IDL1202011261



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
		0.0630	38
		0.0529	36
75	100	0.0382	33
63	100	0.0276	29
50	100	0.0199	26
37.5	100	0.0143	22
28	100	0.0106	20
20	96	0.0076	18
14	86	0.0054	16
10	83	0.0039	13
6.3	79	0.0028	11
5	77	0.0016	8
3.35	73		
2	69		
1.18	64		
0.6	58	Particle density (assumed)	
0.425	56	2.65 Mg/m3	
0.3	53		
0.212	49		
0.15	46		
0.063	38		

Dry Mass of sample, g	828

Sample Proportions	% dry mass
Very coarse	0
Gravel	32
Sand	31
Silt	28
Clay	9

Grading Analysis		
D100	mm	
D60	mm	0.724
D30	mm	0.0292
D10	mm	0.00243
Uniformity Coefficient		300
Curvature Coefficient		0.49

Remarks

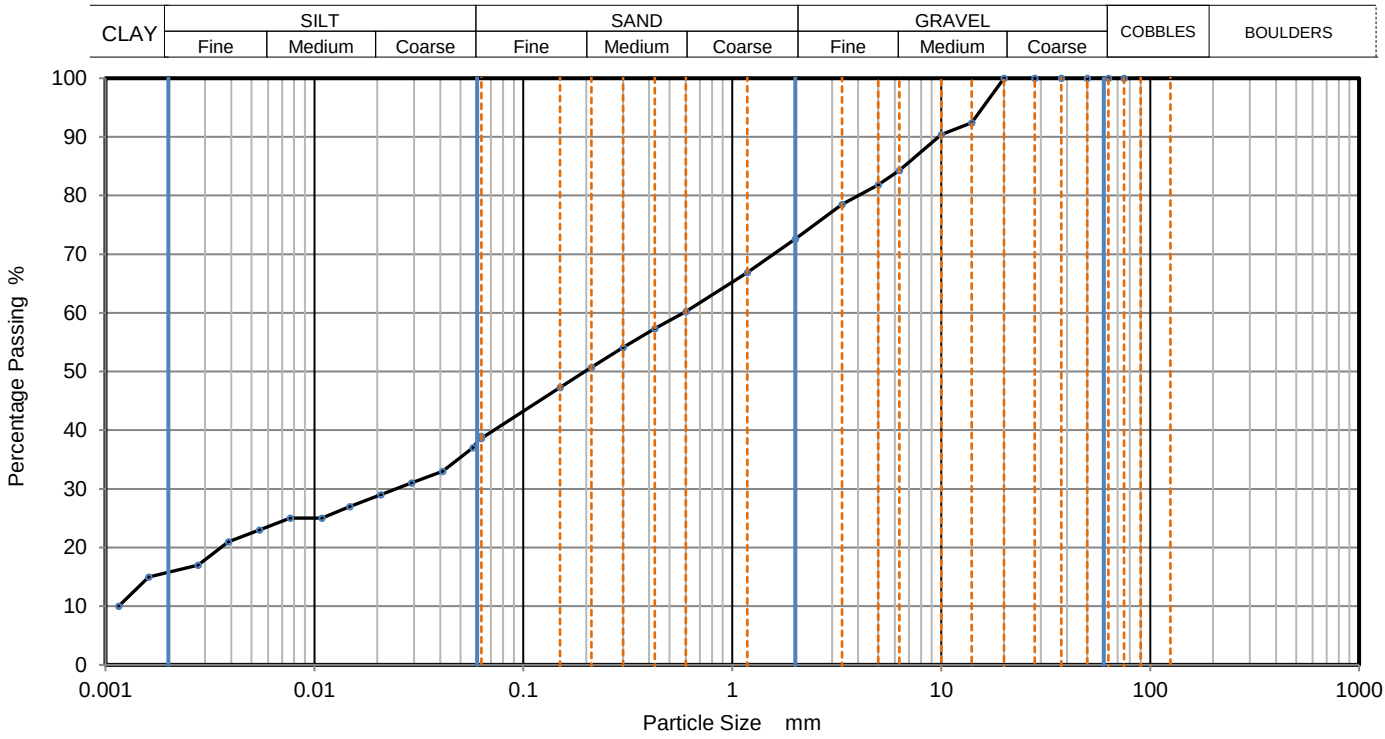
Preparation and testing in accordance with BS1377 unless noted below

Operator	Checked	Approved	Sheet printed	
		Dympna Darcy B.Sc.	01/12/2020 10:07	**1** QC From No:R2

Tested in: Irish Drilling Ltd.(IDL), Old Galway Road, Loughrea, Co. Galway, Ireland. H62VX39

Approved Signatures: Dympna Darcy (DCD) Lab Manager, Declan Joyce (DJ) Chartered Geotechnical Engineer, Ronan Killeen (RK) Quality Manager.

IRISH DRILLING LIMITED	**PARTICLE SIZE DISTRIBUTION**			Job Ref	**2020Lab105**
				Borehole/Pit No.	Ardrahan.PT5
Site Name	Blue Rock Env			Sample No.	
Soil Description	Light brown slightly gravelly sandy SILT.			Depth, m	1.50
Specimen Reference		Specimen Depth	m	Sample Type	B
Test Method	BS1377:Part 2:1990, clauses 9.2 and 9.5			KeyLAB ID	IDL1202011262



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
		0.0630	39
		0.0573	37
75	100	0.0410	33
63	100	0.0292	31
50	100	0.0208	29
37.5	100	0.0148	27
28	100	0.0108	25
20	100	0.0077	25
14	92	0.0055	23
10	90	0.0039	21
6.3	84	0.0028	17
5	82	0.0016	15
3.35	79	0.0012	10
2	73		
1.18	67		
0.6	60	Particle density (assumed)	
0.425	57	2.65 Mg/m3	
0.3	54		
0.212	51		
0.15	47		
0.063	39		

Dry Mass of sample, g	741

Sample Proportions	% dry mass
Very coarse	0
Gravel	27
Sand	34
Silt	22
Clay	16

Grading Analysis		
D100	mm	
D60	mm	0.586
D30	mm	0.025
D10	mm	0.00118
Uniformity Coefficient		500
Curvature Coefficient		0.9

Remarks

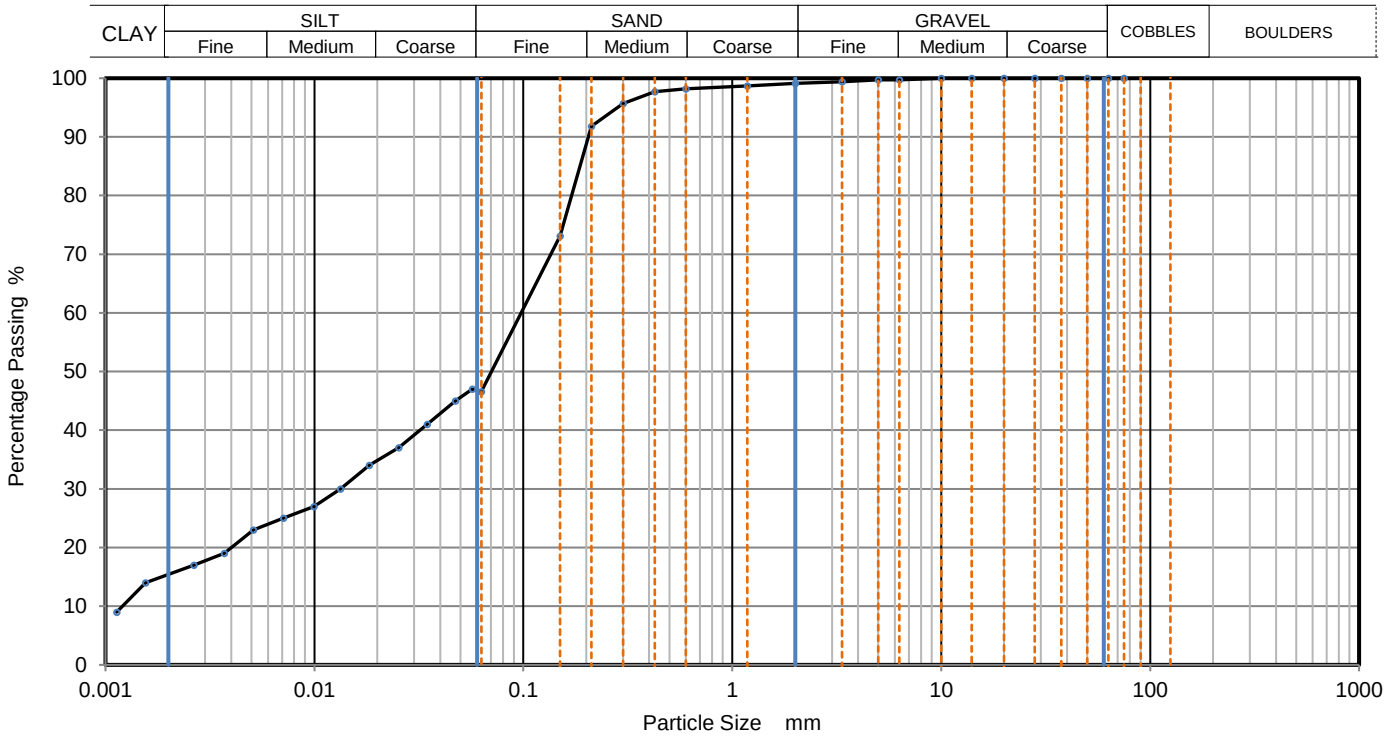
Preparation and testing in accordance with BS1377 unless noted below

Operator	Checked	Approved	Sheet printed	
		Dympna Darcy B.Sc.	01/12/2020 10:07	**1** QC From No:R2

Tested in: Irish Drilling Ltd.(IDL), Old Galway Road, Loughrea, Co. Galway, Ireland. H62VX39

Approved Signatures: Dympna Darcy (DCD) Lab Manager, Declan Joyce (DJ) Chartered Geotechnical Engineer, Ronan Killeen (RK) Quality Manager.

IRISH DRILLING LIMITED	**PARTICLE SIZE DISTRIBUTION**			Job Ref	**2020Lab105**
				Borehole/Pit No.	Ardrahan.PT7
Site Name	Blue Rock Env			Sample No.	1
Soil Description	Orange-brown slightly gravelly sandy SILT. Sand is fine.			Depth, m	1.10
Specimen Reference		Specimen Depth	m	Sample Type	B
Test Method	BS1377:Part 2:1990, clauses 9.2 and 9.5			KeyLAB ID	IDL1202011263



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
		0.0570	47
		0.0473	45
75	100	0.0346	41
63	100	0.0253	37
50	100	0.0183	34
37.5	100	0.0133	30
28	100	0.0099	27
20	100	0.0071	25
14	100	0.0051	23
10	100	0.0037	19
6.3	100	0.0026	17
5	100	0.0016	14
3.35	99	0.0011	9
2	99		
1.18	99		
0.6	98	Particle density (assumed)	
0.425	98	2.65 Mg/m3	
0.3	96		
0.212	92		
0.15	73		
0.063	47		

Dry Mass of sample, g	495

Sample Proportions	% dry mass
Very coarse	0
Gravel	1
Sand	53
Silt	31
Clay	15

Grading Analysis		
D100	mm	
D60	mm	0.0976
D30	mm	0.0136
D10	mm	0.00121
Uniformity Coefficient		80
Curvature Coefficient		1.6

Remarks

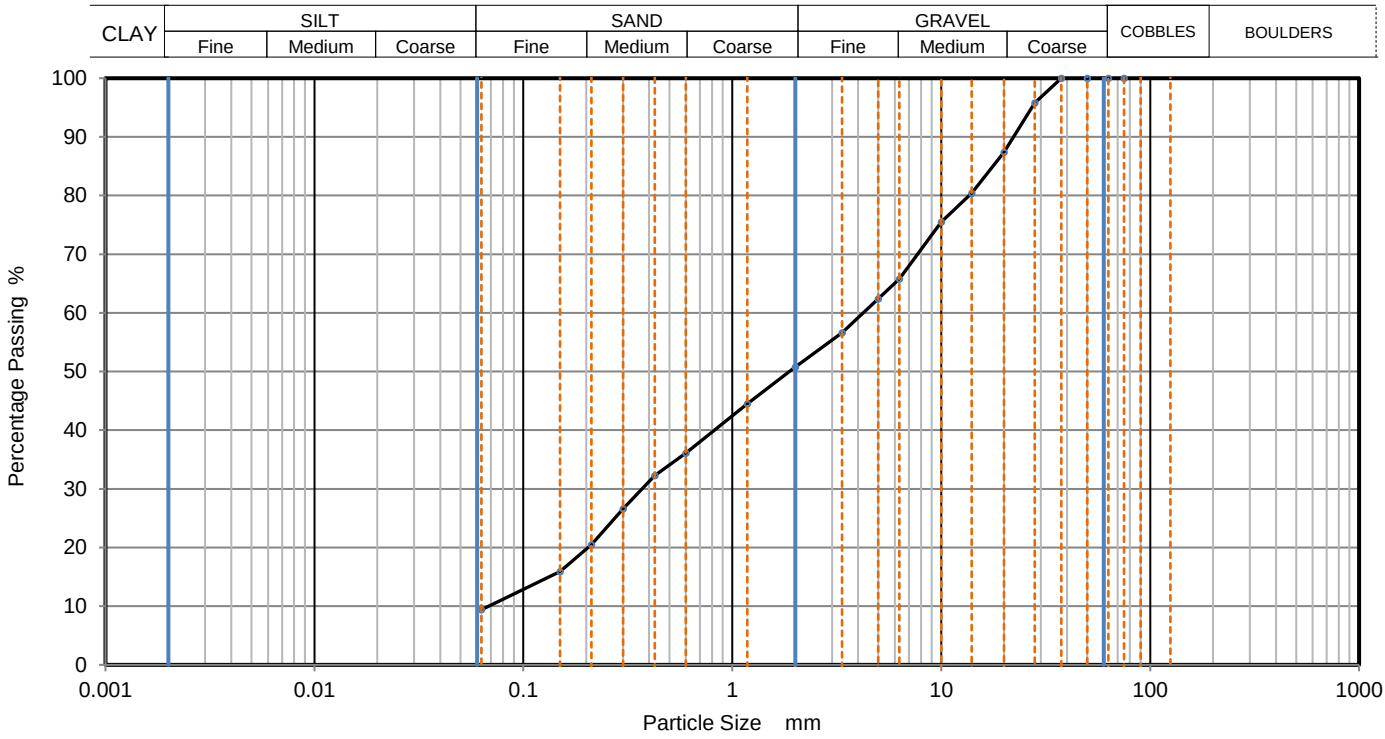
Preparation and testing in accordance with BS1377 unless noted below

Operator	Checked	Approved	Sheet printed	
		Dympna Darcy B.Sc.	01/12/2020 10:07	**1** QC From No:R2

Tested in: Irish Drilling Ltd.(IDL), Old Galway Road, Loughrea, Co. Galway, Ireland. H62VX39

Approved Signatures: Dympna Darcy (DCD) Lab Manager, Declan Joyce (DJ) Chartered Geotechnical Engineer, Ronan Killeen (RK) Quality Manager.

IRISH DRILLING LIMITED	**PARTICLE SIZE DISTRIBUTION**			Job Ref	**2020Lab105**
				Borehole/Pit No.	Ardrahan.PT7
Site Name	Blue Rock Env			Sample No.	2
Soil Description	Dark grey silty SAND and GRAVEL.			Depth, m	1.60
Specimen Reference		Specimen Depth	m	Sample Type	B
Test Method	BS1377:Part 2:1990, clause 9.2			KeyLAB ID	IDL1202011264



Sieving		Sedimentation	
Particle Size mm	% Passing	Particle Size mm	% Passing
75	100		
63	100		
50	100		
37.5	100		
28	96		
20	87		
14	80		
10	76		
6.3	66		
5	62		
3.35	57		
2	51		
1.18	45		
0.6	36		
0.425	32		
0.3	27		
0.212	21		
0.15	16		
0.063	9		

Dry Mass of sample, g	736

Sample Proportions	% dry mass
Very coarse	0
Gravel	49
Sand	41
Fines <0.063mm	9

Grading Analysis		
D100	mm	
D60	mm	4.23
D30	mm	0.369
D10	mm	0.0679
Uniformity Coefficient		62
Curvature Coefficient		0.47

Remarks

Preparation and testing in accordance with BS1377 unless noted below

Operator	Checked	Approved	Sheet printed	
		Dympna Darcy B.Sc.	01/12/2020 10:07	**1** QC From No:R2

Tested in: Irish Drilling Ltd.(IDL), Old Galway Road, Loughrea, Co. Galway, Ireland. H62VX39

Approved Signatures: Dympna Darcy (DCD) Lab Manager, Declan Joyce (DJ) Chartered Geotechnical Engineer, Ronan Killeen (RK) Quality Manager.

APPENDIX E

Zone of Contribution Estimates

Zone of Contribution Downgradient and Half-width Estimates

Uniform Flow Eqn (confined) Downgradient Distance (Todd D.K., 1980 Groundwater Hydrology)

Distance = Q/2πKbi

Borehole	Q (m^3/d)	T (m^2/d)	i	Downgradient Distance (m)
Abstraction Borehole	15	93	0.005	5

Uniform Flow Eqn (confined) Maximum Half Width calculation (Todd D.K., 1980 Groundwater Hydrology)

Distance = +/- Q/2Kbi Unconfined conditions met.

Table	Q (m3/d)	T (m2/d)	i	Max Half Width (m)
PW1	15	93	0.005	16

Groundwater gradient (i) estimated from minimum gradient recorded in Tier 2 Assessment monitoring boreholes estimated between MW02 to MW03 i.e. 0.5 m/120 m = 0.005 This gradient is consistent with generalised Rk_c aquifer values.

Transmissivity (T) most conservative estimate derived from maximum recorded K value of 6.2 m/day. Assumption that 15 m of borehole depth provides T.

APPENDIX F

Mixing Calculations

Resultant Groundwater Concentrations leaving site

EPA (2011) Part 2:
Cgw = [(Cin x Qin) + (Cgwu x Qgw)] / (Qin + Qgw)
where
Cgw = resulting concentration in groundwater
Cin = concentration in the infiltrating water
Qin = volumetric rate of infiltrating water
Cgwu = concentration in the aquifer from upgradient areas
Qgw = groundwater flow rate through the aquifer

Resultant Groundwater Concentrations Beneath Discharge Area (95%tiles)

Calculations for Daily Discharge of 8.04 m3/d		BOD	SS	Temp	pH	Total Ammonia	Nitrate	Total Phosphorus	Ortho-P as P
	units	mg/l	mg/l	oC	-	mg/l N	mg/l NO3	mg/l P	mg/l P
Concentration from WWTP (Cin mg/l)		20	30	10	7	20.0	10	3	2
Reduction Factors							0.9		0.1
Concentration from WWTP at Delivery to GW (Cin mg/l)		15	10	10	7	10.0	9	1.5	0.2
Influents	WW Q (l/d)	13770	13770	13770	13770	13770	13770	13770	13770
	eff Recharge (l/d)	682	682	682	682	682	682	682	682
	WW & RF to Percolation Area Qin (l/d)	14452	14452	14452	14452	14452	14452	14452	14452
	Filter Area (m2)	850	850	850	850	850	850	850	850
	site southern boundary length (m)	30	30	30	30	30	30	30	30
Groundwater Flow 15.4 km2 catchment contributing GW to under dischagre zone = (9400000 m2 x 0.409m GW recharge (GSI/yr)/365*1000)) l/d	Q GW (l/d)	15400000	15400000	########	15400000	15400000	15400000	15400000	15400000
Groundwater Baseline Quality (Lab Analysis & BREL monitoring)		2	2	11	7	0.03	7.2	0.05	0.05
Simulation Constituents	Cin * Qin (mg/d)	216780	144520			144520	130068	21678	2890
	Cgw * Qgw (mg/d)	30800000	30800000			462000	110880000	770000	770000
	Qin + Qgw (l/d)	15414452	15414452	########	15414452	15414452	15414452	15414452	15414452
Simulation Output: Beneath Percolation Area	Resultant Cgw (mg/l)	2.01	2.008			0.039	7.20	0.051	0.050
	Change in GW Conc as a result of discharge	0.01	0.01			0.009	0.00		0.00
Groundwater Regulations 2010	GW Regs 2010 Threshold Value (TV)					0.175	37.50		0.035
	Trend Reversal Point Value of GW Regs 2010 (ie. 75% of TV)					0.131	28.125		0.026
Evaluation	% of TV Allocation used at Site DIRECTLY under Discharge Zone					22.5	0		143
Parameter						Total Ammonia	Nitrate		Ortho - P
Comment		Minimal change	Minimal change			Increase from 0.03 to 0.0039 = used only 21% of theoretical available capacity for GW Ammonia. Also within drinking water Regs for Ammonia (0.3 mg/l)	No change		increase of 0.0001 = not significant in the context o f the site's baseline MRP-P being low. Rwesulatn concentration will not cause change in status.

REFERENCES: CLASSIFICATION OF HAZARDOUS AND NON-HAZARDOUS SUBSTANCES IN GROUNDWATER (EPA, 2010), EPA (2011) Guidance on discharge to GW, Groundwater Regs SI 9 of 2010

APPENDIX G

Laboratory Results

Element Materials Technology
Unit 3 Deeside Point
Zone 3
Deeside Industrial Park
Deeside
CH5 2UA

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W: www.element.com

Bluerock Environmental Limited
48 Lower Salthill
Galway

Attention :	Niall Mitchell
Date :	30th June, 2020
Your reference :	Ardrahan
Our reference :	Test Report 20/7916 Batch 1
Location :	Ardrahan
Date samples received :	19th June, 2020
Status :	Final report
Issue :	1

Three samples were received for analysis on 19th June, 2020 of which three were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Authorised By:

Bruce Leslie
Project Manager

Element Materials Technology

Client Name: Bluerock Environmental Limited
Reference: Ardrahan
Location: Ardrahan
Contact: Niall Mitchell
EMT Job No: 20/7916

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	1-4	5-8	9-12									
Sample ID	MW01	MW02	MW03									
Depth												
COC No / misc												
Containers	V P G	V P G	V P G									
Sample Date	18/06/2020	18/06/2020	18/06/2020									
Sample Type	Ground Water	Ground Water	Ground Water									
Batch Number	1	1	1									
Date of Receipt	19/06/2020	19/06/2020	19/06/2020									

Please see attached notes for all abbreviations and acronyms

											LOD/LOR	Units	Method No.
Dissolved Aluminium #	<20	<20	<20								<20	ug/l	TM30/PM14
Dissolved Calcium #	92.6	120.9	115.6								<0.2	mg/l	TM30/PM14
Dissolved Manganese #	19	3	95								<2	ug/l	TM30/PM14
Dissolved Potassium #	1.0	1.5	1.2								<0.1	mg/l	TM30/PM14
Dissolved Sodium #	9.8	21.4	12.4								<0.1	mg/l	TM30/PM14
Total Hardness Dissolved (as CaCO3)	378	360	388								<1	mg/l	TM30/PM14
Sulphate as SO4 #	23.9	16.8	21.4								<0.5	mg/l	TM38/PM0
Chloride #	19.7	31.2	20.2								<0.3	mg/l	TM38/PM0
Nitrate as NO3 #	<0.2	5.2	3.4								<0.2	mg/l	TM38/PM0
Nitrite as NO2 #	<0.02	<0.02	0.03								<0.02	mg/l	TM38/PM0
Ortho Phosphate as P #	<0.03	<0.03	<0.03								<0.03	mg/l	TM38/PM0
Ammoniacal Nitrogen as N #	<0.03	<0.03	<0.03								<0.03	mg/l	TM38/PM0
Ammoniacal Nitrogen as NH4 #	<0.03	<0.03	<0.03								<0.03	mg/l	TM38/PM0
Electrical Conductivity @25C #	736	742	600								<2	uS/cm	TM76/PM0
Kjeldahl Nitrogen	0.8	3.1	0.7								<0.5	mg/l	TM125/PM0
pH #	7.74	7.51	7.58								<0.01	pH units	TM73/PM0
Total Organic Carbon #	<2	<2	<2								<2	mg/l	TM60/PM0
Total Dissolved Solids #	424	461	476								<35	mg/l	TM20/PM0

All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Bluerock Environmental Limited
Reference: Ardrahan
Location: Ardrahan
Contact: Niall Mitchell

EMT Job No.	Batch	Sample ID	Depth	EMT Sample No.	Analysis	Reason
No deviating sample report results for job 20/7916						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

EMT Job No.: 20/7916

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

Measurement Uncertainty

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above calibration range, the result should be considered the minimum value. The actual result could be significantly higher, this result is not accredited.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range

EMT Job No: 20/7916

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM20	Modified BS 1377-3:1990/USEPA 160.1/3 (TDS/TS: 1971) Gravimetric determination of Total Dissolved Solids/Total Solids	PM0	No preparation is required.	Yes			
TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry): WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009: SOILS by Modified USEP	PM14	Preparation of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for Dissolved metals, and remain unfiltered for Total metals then acidified				
TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry): WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009: SOILS by Modified USEP	PM14	Preparation of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for Dissolved metals, and remain unfiltered for Total metals then acidified	Yes			
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993 (comparabl	PM0	No preparation is required.	Yes			
TM60	TC/TOC analysis of Waters by High Temperature Combustion followed by NDIR detection. Based on the following modified standard methods: USEPA 9060A (2002), APHA SMEWW 5310B:1999 22nd Edition, ASTM D 7573, and USEPA 415.1.	PM0	No preparation is required.	Yes			
TM73	Modified US EPA methods 150.1 (1982) and 9045D Rev. 4 - 2004) and BS1377-3:1990. Determination of pH by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM76	Modified US EPA method 120.1 (1982). Determination of Specific Conductance by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM125	Modified AOAC EPA 973.48 (2011). Kjeldahl Nitrogen by application of a strong acid digestion, distillation and titration.	PM0	No preparation is required.				