M.E.H.L
HOLLYWOOD

Appendix I.4.1

Borehole Logs

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A14.4 Borehole Logs

Boreholes were drilled on at least four occasions prior to the work undertaken at the MEHL facility in the spring of 2010. As part of the hydrogeological site investigation at MEHL in 2010, several new boreholes were constructed on the site. Of these, BH15a, BH16, BH18, BH19 and BH20 were completed as monitoring boreholes and BH17 was completed as a pumping well.

Both the new and pre-existing installations were utilised in hydraulic testing of the aquifer beneath the site and to gather groundwater level information.

As part of the geotechnical investigation of the site, several cable percussive boreholes were drilled by IGSL but these were not utilised in the hydrogeological site investigation. Information pertaining to these cable percussive boreholes is available in **Appendix 14.1.1**.

The geological information obtained during the drilling and installation of the new boreholes was combined with the well log records of the monitoring boreholes already in existence to build a picture of the complex geology and hydrogeological conditions of the site.

Existing monitoring wells

The wells BH4a, BH5, BH6, BH8, BH9, BH10a, BH11a, BH12 and BH13 were drilled and installed between 1998 and 2008 to fulfil a requirement of the EPA license for the MEHL facility (EPA waste license number W0129-02). They are situated on the site perimeter (see **Figure 14.1.1**) and are used regularly to sample groundwater and monitor groundwater levels. The well logs for each of these monitoring boreholes are available in **Appendix 14.4.1**.

Another borehole, BH7 was drilled on site in 1998 but was backfilled on completion as the subsurface material was unsuitable for the installation of a monitoring well. The well log for this borehole is also contained within **Appendix 14.4.1**. Boreholes BH4, BH10 and BH11 existed on the site prior to 2003 as they were monitored for groundwater quality up until that time. However, no well logs for these three boreholes are available.

Borehole ID	Date Drilled	Type of Borehole	Drilling supervised by
BH4A	18/11/2008	Monitoring Well	Patel Tonra
BH5	03/09/1998	Monitoring Well	KT Cullen & Co.
BH6	03/09/1998	Monitoring Well	KT Cullen & Co.
BH7	07/09/1998	NA	KT Cullen & Co.
BH8	17/08/2001	Monitoring Well	KT Cullen & Co.
BH9	03/08/2001	N/A	KT Cullen & Co.
BH10	04/08/2001	Monitoring Well	Golder Associates
BH10a	05/03/2007	Monitoring Well	Golder Associates
B11a	02/05/2007	Monitoring Well	Golder Associates
BH12	01/05/2007	Monitoring Well	Golder Associates
BH13	15/04/2007	Monitoring Well	Golder Associates
BH14	02/03/2007	Monitoring Well	Golder Associates
BH15	06/04/2010	Core: backfilled	Arup
BH15a		Monitoring Well	Arup
BH16	12/04/2010	Core: finished as monitoring well	Arup
BH17	05/05/2010	Pumping well	Arup
BH18	20/04/2010	Core: finished as monitoring well	Arup
BH19	21/04/2010	Monitoring Well	Arup
BH20	22/04/2010	Monitoring Well	Arup

Table 14.4.1: Details of drilling programmes undertaken at the MEHL site, Hollywood, The Naul, Count Dublin.

New monitoring wells

Figure 14.4.2 below shows the initial locations for the new monitoring boreholes proposed prior to the commencement of works on site. **Table 14.4.2** outlines the reasons behind the initial location for each borehole and details of any changes between the proposed and final locations. The locations were initially chosen by taking into account the location of the major faults picked up by the geophysics survey carried out on the site by Apex Geoservices Ltd. in 2010 (see **Appendix 14.9** for more information and geological and hydrogeological considerations and access to the site).

The final locations of all new monitoring boreholes on site are shown below in **Figure 14.3.3**. These positions were influenced by the accessibility of the locations by the drill rig (stability of the ground was important).

BH type	BH name	Proposed location	Reasons	Final location	Monitoring installation	Comments
Cored holes	BH15	SE portion of site, 20m east of N-S fault	Prove Loughshinny Fm. (LS). Assess thickness of weathered rock	Same. Fault closer to BH15 than anticipated	No	Backfilled. Alternative rotary BH15a drilled 4m east of BH15
	BH16	N end of proposed cells, west of central bund.	Prove LS. Establish thickness of Namurian rock.	Same	Yes	Extended to 60m depth to confirm geology
	BH17	NE corner of proposed cells, E of N-S fault	Prove geology on other side of major fault	Abandoned due to importance of going deeper on other boreholes	-	-
	BH18	S of BH16 and E-W fault, on ramp	Locate LS	Same	Yes	
Rotary drilled	BH19	50m N of pumping well, in centre of proposed cell	Confirm geology and downthrow on N side of E-W fault	Same, fault closer to BH19 than anticipated. Almost in fault zone.	Yes	
	BH20a, BH20b	Two possible locations were proposed : a) Ne of pumping well across intersection of major faults, b) E of pumping well across N-S fault	Obtain intermediate geology between BH15 and BH17 (E of N-S fault)	Moved to 50m NW of BH19 in centre of proposed cell	Yes	
Pumping wells	PW1	Adjacent to intersection of N-S and E-W faults, on S side where LS should be shallow	Pump LS and fault during pumping tests	Moved to ~150m SW of BH19 to avoid fault zones and drilled deeper than originally expected.	Yes (pumping well)	Now called BH17
	PW2	Far N of site, 50m from stream (adjacent to settlement pond)	Target aquitard overlying LS during pumping test. Also use as a monitoring well when pumping PW1	Abandoned due to importance of going deeper on PW1	-	-

Table 14.4.2: Details of proposed and final locations of all new monitoring and pumping wells on the MEHL site.

The second pumping well, PW2, and the monitoring installation BH17 were sacrificed to allow other boreholes such as BH16 to be drilled to greater depths. The final pumping well was renamed BH17 and its location was moved from the initial location in order to avoid some minor faults visible in an outcrop of rock immediately to the south.

BH15 and BH15a were drilled in the same location on the site (approximately 4 m apart) using different drilling methods as outlined below. This exercise was undertaken to allow a site specific comparison of the quality and composition of the arisings from each different drilling method. It was intended that this information could then be used to allow a more accurate description of the geological profile across the site in locations where no cores were obtained.

The new monitoring boreholes constructed as part of this investigation were drilled by two different contractors using three different methods of drilling. BH15, BH16 and BH18 were drilled by Petersen Drilling Services (PDS) using a Geobore ‘S’ drill rig. This rig uses a double core-barrel system and polymer fluid to produce very high quality cores of the subsurface material, which is known to be highly weathered and broken. A geotechnical log of these cores was made by a representative from IGSL. BH15 was backfilled on completion and BH16 and BH18 were completed as monitoring boreholes.

BH15a, BH19 and BH20 were drilled and installed by Patrick Briody and Sons Ltd. (PBS). These boreholes were drilled using a standard rotary percussive rig and the subsurface material was returned to the surface as a slurry of gravel sized chips and mud. These chippings were sampled and logged on site by representatives of Arup and IGSL. As outlined previously the exercise conducted at BH15 and BH15a aided in the interpretation of the lithologies.

The pumping well, BH17, was drilled by PBS using a reverse circulation rotary rig. This rig was used as difficult drilling conditions had been encountered in BH19 and BH20 and the reverse circulation of a high viscosity polymer mud was necessary for borehole stability and well completion. A more powerful rig was also necessary to obtain the large depth (50 m) and diameter (12” open hole) needed for the installation of a well with a significant pumping capacity. The bedrock samples were returned to the surface as rock chips within the circulating polymer mud and allowed to settle out before being logged and sampled by a hydrogeologist from Arup.

The drillers’ logs for all new boreholes drilled at MEHL are presented in **Appendix 14.4.2**.

Borehole and well logging

The logging of boreholes to geotechnical standards and for hydrogeological purposes is differentiated in this report. A geotechnical borehole log describes the physical properties of the rock types encountered while a hydrogeological well log is a summary of the geology encountered during drilling, the installation details and any water strikes encountered.

A representative from IGSL undertook a geotechnical logging exercise in line with standards described in BS5930 for the cored holes BH15, BH16 and BH18 and for the cable percussive boreholes BH21 to BH23. These logs are presented in **Appendix 14.4.3**. Summary well logs were also prepared by IGSL for all boreholes which had an installation constructed in them (BH15a, BH16, BH17, BH18, BH19 and BH20). These are presented in **Appendix 14.4.4**

An interpretive hydrogeological well log was compiled by Arup for each of the new monitoring boreholes installed on site and for the pumping well, BH17. These logs include information from the driller’s notes, the site hydrogeologist’s observations, groundwater level monitoring rounds and a lithological interpretation of the subsurface material encountered. These interpretive logs are presented in **Appendix 14.4.5**. For the lithological interpretation, in some boreholes it was not possible to distinguish between the Balrickard and Donore Formations. These have been grouped together on some logs to be presented as Namurian deposits.

Monitoring installations

All boreholes on site were grouted by PBS as their equipment includes a grouting plant that can be used to mix grout at the site of each borehole. It was critical that the boreholes were grouted to a high standard as otherwise they may have had the potential to act as pathways for contamination in the future. Samples were taken of the grout used for each borehole and these were retained by MEHL for testing in the future if required.

Each monitoring installation was designed by a hydrogeologist after the borehole had been drilled and an initial draft log of the geological profile had been compiled on site. In this way, each monitoring installation was tailored to target areas of specific hydrogeological interest. A summary of the installation configurations for each borehole is laid out in **Table 14.4.3** below.

BH name	Slotted casing		Plain casing		Gravel pack		Fine sand		Bentonite	
	Depth (mbgl)	**Length (m)**	**Depth (mbgl)**	**Length (m)**	**Depth (mbgl)**	**Length (m)**	**Depth (mbgl)**	**Length (m)**	**Depth (mbgl)**	**Length (m)**
BH15a	29-28	1	30-29	1	30-26	4	26-25	1	25-0	25
			28-0	28						
BH16	22-20	2	24-22	2	23-19	4	24-23	1	60-24	36
			20-0	20			19-18	1	18-0	18
BH17	48-42	6	53-48	5	54-23	31	23-22	1	22-0	22
	37-32	5	42-37	5						
	27-25	2	32-27	5						
			25-0	25						
BH18	19-17	2	21-19	2	20-16	4	21-20	1	15-0	15
			17-0	17			16-15	1		
BH19	17-16	1	18-17	1	18-14	4	14-13	1	13-0	13
			16-0	16						
BH20	42-40	2	43-42	1	43-38	5	38-37	1	37-0	37
			40-0	40						

Table 14.4.3: Summary of monitoring well installation at the MEHL site in 2010.

Table 14.4.4 summarises hydrogeological information gathered from each borehole including the bedrock geology, any water strikes, the static water level and the amount of water removed during the development of each monitoring well before sampling for laboratory analysis.

BH name	Geology		Water strike		Flush losses (Geobore 'S')		Static level (May 2010 ave.)	Total volume removed during well development	Water removed during hydraulic tests in May	Water removed during pumping tests	Water removed before GW sampling in June	Total water removed from borehole
	Depth (mbgl)	Lithology	Depth (mbgl)	Estimated flow (g/h)	Depth (mbgl)	% loss	Depth (mbgl)	Approximate volume (l)	Approximate volume (l)	Approximate volume (l)	Approximate volume (l)	Volume (l)
BH15a	0-6	Balrickard Fm.	7	200	-	-	6.65	300	25		150	475
	6-17	Balrickard Fm.	15	300	-	-						
	17-24	Poss. Donore Fm	18	3000								
	24-30	Loughshinny Fm.	28	8000	-	-						
BH16	0-58	Walshestown Fm.	-	-	12.2-19.6	30	3.48	200	30		120	350
			-	-	19.6-24.6	20						
	58-60	Balrickard Fm. (poss. graded contact)	-	-	48-55.5	10						
BH17	0.-22	Poss. Balrickard Fm.	15	500	-	-	4.91	9350		1658268	50	1667668
	22-33	Namurian Deposits	24	5000								
	33-54	Poss. Loughshinny Fm.	33	>15000	-	-						
BH18	0-5	Balrickard Fm.	-	-	14.8-21	100	10.08	15	170		120	305
	5-16	Namurian Deposits	-	-								
	16-21	Poss. Loughshinny Fm.	-	-								
BH19	0-14	Balrickard Fm.	7	100	-	-	3.47	1335	50		120	1505
	14-18	Namurian Deposits.			-	-						
BH20	0-6	Poss. Balrickard Fm.	6	100	-	-	3.96	900	30		240	1170
	6-43	Namurian Deposits	16	500	-	-						
	43-48	Poss. Loughshinny Fm.	30	3500	-	-						
			42	>10,000	-	-						

Table 14.4.4: Hydrogeological summary for each borehole drilled at the MEHL site in 2010.

Table 14.4.5 summarises the details of the targeted zones of all existing wells.

BH name	Geology		Slotted casing		Gravel pack	
	Depth (mbgl)	Lithology	Depth (mbgl)	Length (m)	Depth (mbgl)	Length (m)
BH15a	0-6	Balrickard Fm.	29-28	1	30-26	4
	6-17	Balrickard Fm.				
	17-24	Poss. Donore Fm				
	24-30	Loughshinny Fm.				
BH16	0-58	Walshestown Fm.	22-20	2	23-19	4
	58-60	Balrickard Fm. (poss. graded contact)				
BH17	0.-22	Poss. Balrickard Fm.	48-42	6	54-23	31
	22-33	Namurian Deposits	37-32	5		
	33-54	Poss. Loughshinny Fm.	27-25	2		
BH18	0-5	Balrickard Fm.	19-17	2	20-16	4
	5-16	Namurian Deposits				
	16-21	Poss. Loughshinny Fm.				
BH19	0-14	Balrickard Fm.	17-16	1	18-14	4
	14-18	Namurian Deposits.				
BH20	0-6	Poss. Balrickard Fm.	42-40	2	43-38	5
	6-43	Namurian Deposits				
	43-48	Poss. Loughshinny Fm.				

Table 14.4.5: Hydrogeological summary for each borehole, highlighting targeted zones.

Site notes

The following section contains a detailed summary of the drilling and installation process for each monitoring borehole and the pumping well. This information was collated from a combination of driller's logs and site notes from the supervising hydrogeologist. All monitoring installations were designed by Eugene Daly (Eugene Daly Associates), Catherine Buckley (Arup) or Marie Fleming (Arup) and were communicated to the driller in person or by telephone. A site hydrogeologist was present for the drilling and development of BH15a, BH16, BH18, BH19, BH20 and BH17. **Table 14.4.6** below summarises the response zones of the well screens in each monitoring installation.

BH name	Status	Depth to top and bottom of well screen (mbgl)	Geology of response zone	Reason for screen depth
BH15a	New, monitoring well	28 - 29	Loughshinny Fm.	Screened in LS
BH16	New, monitoring well	20 - 22	Walshestown Fm.	To target water-bearing zone
BH18	New, monitoring well	17 - 19	Poss. Loughshinny Fm.	To target large fracture
BH19	New, monitoring well	16 - 17	Namurian deposits	To target high yield zone
BH20	New, monitoring well	40 - 42	Namurian deposits	To target area of v. large ingress
BH17	New, pumping well	25 - 27	Namurian deposits	To target area of high mud loss to fm.
		32 - 37	Poss. Loughshinny Fm.	To target area of high mud loss to fm.
		42 - 48	Poss. Loughshinny Fm.	To target area of high mud loss to fm.

Table 14.4.6: Summary of details of the well installation undertaken at the MEHL site in 2010.

BH15 and BH15a

The location for BH15a was chosen 4 m to the east of BH15. This was to ensure that BH15a would be situated away from the fault zone on the main N-S oriented fault. It was located 'up-dip' of the limestone bedrock from BH15 to ensure that grout used in BH15 would not be encountered in BH15a. Since BH15a and BH15 are close to each other, it was expected that the same lithologies would be encountered in each.

BH15 was drilled by PDS using the Geobore 'S' rig between the 9th and the 12th of April 2010. An 8" diameter open hole was drilled down to 0.8 m and cores were taken from 0.8 mbgl to 31.1 mbgl. Drilling flush losses (which indicate the presence of fractures) are summarised below:

- 100% flush losses were experienced between 25.3 and 29 mbgl.
- 10% return of flush from 29 - 31.9 mbgl
- 100% flush losses were experienced from 31.9 mbgl to the end of the borehole

Packer tests (where pressurised water is forced down the borehole and into the bedrock formation in a specific section which is defined by the use of inflatable 'packers') were carried out on a single horizon. PDS were unable to pressurize the test section indicating the presence of an open fracture.

Following testing the borehole was grouted back to the surface by PBS. The cores from this borehole were photographed and logged by Dafydd O'Shea of IGSL. The logs from this borehole and the monitoring borehole BH15a were later compared and combined to form the interpretive log for BH15a in Appendix 14.B.5.

Based upon the lithologies encountered in the Geobore 'S' hole, a location for the monitoring borehole BH15a was chosen by Eugene Daly 4 m away and across the main N-S oriented fault on the site. BH15a was drilled by PBS between the 16th and the 22nd April 2010 using a standard rotary drill rig with a button bit. The chippings were sampled every metre and logged on site by Sarah Blake (Arup). The sample chippings were also logged by Dafydd O'Shea (IGSL). The results of both logging exercises were used to compile the interpretative log in Appendix 14.B.5.

BH15a was drilled as a 10" diameter open hole from 0-12 mbgl. The first water strike was at 7 mbgl and this section of the borehole was developed by airlifting for 60 minutes which resulted in a yield of 200 gallons per hour. 12 m of 8" steel casing was installed and drilling continued down as far as 18 mbgl. The water yield increased between 15 mbgl and 18 mbgl to 300 g/h (0.38 lps litres per second/ 32.73 m^3d meters cubed per day) and another 6 m of 8" casing was installed. Between 18 and 21 m a high volume of water (estimated at approximately 3000 g/h (3.8lps/ 327.3m^3d)) was produced.

At 24 mbgl calcite chips were returned possibly indicating the start of the Loughshinny Formation (Fm). 45 minutes of surging and well development gave a yield of 8000 g/hr (10.1 lps/ 872.7 m^3d at this horizon. Another 6 m of 8" casing was installed. Between 24 mbgl and 29 mbgl the open section of the hole collapsed during drilling. The well was developed by surging for another 60 minutes. Another 6 m of casing was installed to bring the total casing string length to 30 mbgl. The yield rapidly decreased to nothing once the borehole had been cased down to 30 mbgl.

A 50 mm standpipe with an end cap was installed from 30 mbgl on the instructions of Eugene Daly (relayed to PBS with a drawing). 1 m of slotted 50 mm UPVC well screen was installed from 29 mbgl to 28 mbgl in order to target the limestone bearing formation (possibly the Loughshinny Fm.) and a formation stabiliser (pea gravel of grade 10 mm) was installed from 30 mbgl to 26 mbgl. The gravel was followed by a 1 m layer of fine sand to 25 mbgl. The casing was pulled back to 28 mbgl and left overnight. The following afternoon the casing was pulled back to 24 mbgl and grout was pumped into the annular space until returns of grout were seen at the surface. The casing was then pulled back to 21 mbgl and grout pumped into the borehole but no returns were seen. The casing was pulled back to 18 mbgl and 66 bags of grout were added to the borehole without returns at the surface. The borehole was left overnight and grouting recommenced the following morning. A further 24 bags of bentonite were added to the borehole bringing the level of grout to 12.4 mbgl. Grout was pumped into the boreholehole with 12 m of casing remaining in the hole. Grout returns were seen at the surface. The casing was pulled back to 9 mbgl and grout was lost again. A further 20 bags of bentonite combined with 40 bags of cement were put into the borehole in a combined grout mix. Grout was seen to rise again and BH15a was grouted to the surface, around the plain standpipe, using a total of 129 bags of cement and 49 bags of bentonite.

BH16

The location for BH16 was chosen to establish the depth to the top of the Loughshinny Fm. in the northern portion of the site and to establish the thickness of Namurian rock overlying the Loughshinny Fm. aquifer.

This borehole was drilled by PDS between the 12th and the 20th April 2010 using the Geobore 'S' rig. The borehole was drilled as an open hole with a diameter of 8" from ground level down to 0.8 mbgl and cores were extracted from 0.8 mbgl to 59 mbgl. Flush losses to the formation occurred between 12.2 mbgl and 24.6 mbgl and again between 48 mbgl and 55.5 mbgl.

Packer tests were carried out between 54-56 mbgl and 18-21 mbgl on the 19th April. The results of these tests can be found in **Appendix A14.5**. Between 15-25 mbgl the core returns were observed to be rounded and oxidised indicating the presence of significant water movement at that depth. The packer test undertaken in this zone indicated that it had an approximate permeability of $2.22\text{x}10^{-6}$m/s (22.2 Lugeon). The material between 54-56 mbgl was composed of fine grained weathered siltstone grading into more weathered sandy bedrock. The packer test undertaken in this zone indicated that it had an approximate permeability of $3.29\text{x}10^{-6}$m/s (32.9 Lugeon).

PBS grouted the hole from 60 mbgl to 30 mbgl on the 19th of April. On the 20th April, Catherine Buckley (Arup) provided installation instructions to PDS on site (in the form of a drawing). The hole was backfilled to 24 mbgl with bentonite pellets and a 50 mm casing was installed. A well screen consisting of 2 m of 50 mm slotted PVC pipe with a filter sock and end cap was installed from 22 mbgl to 20 mbgl. The aim of this design was to target the shallow water-bearing zone from 15-25 mbgl as discussed above. The well screen was surrounded by a formation stabiliser (pea gravel of grade 10 mm) from 23 mbgl to 19 mbgl. A layer of fine sand was added at the top and bottom of the gravel pack from 24 mbgl to 23 mbgl and from 19 mbgl to 18 mbgl. The hole was then grouted from 18 m to the surface by PBS. The cores from BH16 were photographed and logged by Dafydd O'Shea (IGSL).

BH17

BH17 is the pumping well that was installed by PBS between the 5th and the 13th of May 2010. The location for BH17 was chosen so as to avoid the fault zone and to attempt to pump water from the competent Loughshinny Fm. during subsequent pumping tests. As PBS had encountered difficulty when drilling BH20 (see below), a large reverse circulation rotary rig was brought in to drill the pumping well. It was initially expected that the pumping well would be drilled to 50 mbgl and that competent Loughshinny Fm. rock would be encountered at this depth.

As the rock near the surface was very weathered, 6 m of 300 mm steel casing was installed prior to drilling in order to stabilise the hole. The chippings were sampled and logged every metre by Catherine Buckley (Arup). The hole was drilled to 25 mbgl using water flush only but polymer mud was added from 25 mbgl as losses to the formation began occurring at a depth of 20 mbgl. A non-ballistic drill bit was used from 0 to 27 mbgl until a ballistic drill bit became necessary for progress.

Water was struck at 15 mbgl at a volume of approximately 500 g/h (0.63 lps/ 54.54 m^{3}d). The water volume was increased between 24 and 27 mbgl to approximately 5000 g/h (6.3 lps/ 545.4 m^{3}d). Polymer mud was added from 24 to 27 mbgl. There were large mud losses to the formation between 33-35 mbgl and 37-40 mbgl. The drill bit was blocked at 40 mbgl due to the volumes of large chippings entering the bit. The hole was drilled to 55 mbgl and developed by airlifting and surging for two hours.

Installation details were provided on site by Catherine Buckley (Arup) in the form of a drawing. A 125 mm casing was installed in the borehole with screened sections from 48 to 42 mbgl, 37 to 32 mbgl and 27 to 25 mbgl. These screened sections were chosen to target those sections of the borehole where there had been either a large ingress of water or a large loss of fluid to the formation. The screened sections were surrounded by a formation stabiliser (pea gravel of grade 10 mm) from 54 to 23 mbgl and a 1 m layer of fine sand was added from 23 to 22 mbgl. Large losses were experienced at 27 mbgl indicating the presence of a large fracture in the bedrock. The borehole was developed by airlifting for a whole working day on May 12th (seven hours). 125 bags of cement/bentonite grout mix were then used to grout to ground level by PBS.

BH18

The location for BH18 was chosen to locate the Loughshinny Fm. on the south side of the E-W fault where it was estimated to be located at shallow depths. This hole was drilled by PDS between the 20th and the 22nd April 2010. The hole was drilled as an 8” open hole to 0.6 mbgl and then cored with the Geobore ‘S’ rig until 21.2 mbgl. 100% flush losses to the formation were encountered from 14.8 mbgl which would suggest the presence of a very large fracture at this depth. Unsuccessful packer tests were carried out on two different horizons as PDS could not obtain a good seal downhole.

Catherine Buckley (Arup) instructed PDS on site to install a 50 mm casing in the borehole. A slotted UPVC well screen was installed between 19 and 17 mbgl to target the large fracture. A formation stabiliser (pea gravel of grade 10 mm) was installed from 20 mbgl to 16 mbgl with a 1 m layer of sand on the top and bottom of the gravel (from 21 to 20 mbgl and from 16 to 15 mbgl).

The borehole was grouted from 15 mbgl to the surface by PBS. BH18 was developed by PBS on the 13th May using a bailer. The cores from BH18 were photographed and logged by Dafydd O’Shea (IGSL).

BH19

The location for BH19 was chosen to confirm the geology and the downthrow on the north side of the E-W trending fault. BH19 was drilled on the 21st and 22nd of April 2010 by PBS. The chippings were sampled and logged every metre by Sarah Blake (Arup).

The hole was drilled as a 10” diameter open hole to 6 mbgl. 8” steel casing was installed and the drilling continued to 9 mbgl. Water was struck at 7 mbgl; developing and surging gave a yield of 100 g/h (0.13 lps/ 10.9 m^3d). Due to the material in the chippings, Eugene Daly and Catherine Buckley were concerned that the borehole was in the wrong location relative to the main N-S fault for the purposes of this investigation. As a result the decision was made to terminate the borehole at 18 mbgl but still retain it as a shallow monitoring well. On the 22nd April, the borehole was drilled as far as 18 mbgl. At 18 mbgl, the borehole was surged for 60 minutes to develop it; this increased the yield to 150 g/h (0.19 lps/ 16.36 m^3d).

The monitoring installation was designed by Catherine Buckley (Arup) and instruction was given to the driller on site by Sarah Blake (Arup). A 50 mm uPVC standpipe was installed in the hole containing a 1 m well screen of slotted uPVC pipe from 17 to 16 mbgl. This well screen depth was chosen to target the zone of a slightly higher yield towards the base of the borehole. The annular space was filled with a formation stabiliser (pea gravel of grade 10 mm) to 14 mbgl followed by a layer of fine sand to 13 mbgl. The hole was then grouted to ground level by PBS.

BH20

The location for BH20 was chosen to try and obtain a depth to the top of the Loughshinny Fm. at an intermediate distance between the pumping well (BH17) and BH16. This borehole was drilled by standard rotary method between the 22nd and the 28th of April 2010 by PBS. The chippings were sampled and logged every metre by Sarah Blake (Arup).

A 10” diameter borehole was drilled to 6 mbgl before 8” casing was installed. Drilling continued at 8” diameter until 30 mbgl. At 11 mbgl water was struck at a volume of 100 g/h (0.13 lps/ 10.91 m^{3}d). This volume increased to 500 g/h (0.63 lps/ 54.54 m^{3}d). from 16 mbgl to 21 mbgl and this horizon was developed for 30 minutes, during which time the flow remained consistent. At 30 mbgl the hole was left open overnight and on the drillers’ return the next morning, the hole had collapsed below 12 mbgl. A significant increase in water yield was encountered once drilling had recommenced. This yield was further increased from 3000 to 3500 g/h (3.79 lps/ 327.26 m^{3}d to 4.42 lps/ 381.8 m^{3}d). after 60 minutes of well development by airlifting and surging. 30 m of 6” steel casing was added to the borehole in order to allow drilling to proceed as the collapsing walls were impeding progress beyond 12 mbgl. Drilling continued with difficulty to 52 mbgl. At 42 mbgl there was a large water strike with volumes in excess of 10,000 g/h (12.63 lps/ 1090.87 m^{3}d). High viscosity foam mix was added to the borehole and 90 minutes of airlifting and surging followed to clean the section from 42 to 48 mbgl. The volume of water was seriously impeding the hammer bit and chippings were not representative of the formation as the large volumes of water were washing away the direct returns. The hole was still collapsing after surging. The hole was developed and cleaned down to 46 mbgl for 90 minutes.

The driller was instructed by Marie Fleming (Arup) to install a 50 mm UPVC casing from 43 mbgl. 2 m of slotted uPVC well screen was installed from 42 to 40 mbgl to target the area of extremely large ingress of water. A formation stabiliser was installed around the well screen from 43 to 38mbgl followed by a 1 m layer of fine sand from 38 to 37mbgl. The drillers encountered difficulties when trying to remove the 36 m string of steel casing from the hole. As a solution to this problem, it was decided by Eugene Daly and Marie Fleming (Arup) that the 6” casing was to be grouted in place and the 8” casing would be removed. After consultation with Padraig Briody (PBS) it was agreed that a larger reverse circulation rotary drill rig would be required if a pumping well was to be drilled to 50m in similar subsurface material to BH20. This larger rig was eventually used to remove the steel casing from BH20 so that no metal casing was left downhole. The borehole was grouted from 37 mbgl to ground level by PBS.

Appendix A14.4.1

Well logs for pre-existing wells

DUNNES
DRILLING

No: 5668

DRILLERS LOG

WELL DRILLING AND HORIZONTAL DRILLING ENGINEERS

Dublin Road, Dromiskin, Dundalk, Co. Louth.
E-Mail: info@dunnesdrilling.com website: www.dunnesdrilling.com
Tel: +353 42 9372188 Fax: +353 42 9372714

Borehole for: Murphy Environmental Hollywood Ltd
at Hollywood Quarry

8" Monitoring Well

Date	Depth ft	Diam	Conditions
18.11.08	0 - 3	8"	Clay & stones
	3 - 14	8"	Sticky clay
	14 - 17	8"	Grey rock
	17 - 25	8"	Black rock - water at 25ft
	25 - 30	8"	Black rock
	30 - 40	8"	Black rock - water at 35ft

Total depth of well	40ft (12.19m)
Estimated yield	1000 gallons per hour
Depth to rock	14ft (4.27m)
Steel casing installed	17ft (5.18m) of 8" steel casing
PVC casing installed	7m of 2" PVC
Well screen	6m of 2" Screen
Other remarks	Install gravel pack from 40ft to 18ft. 6 bags of bentonite seal from 18ft to 3ft above ground level

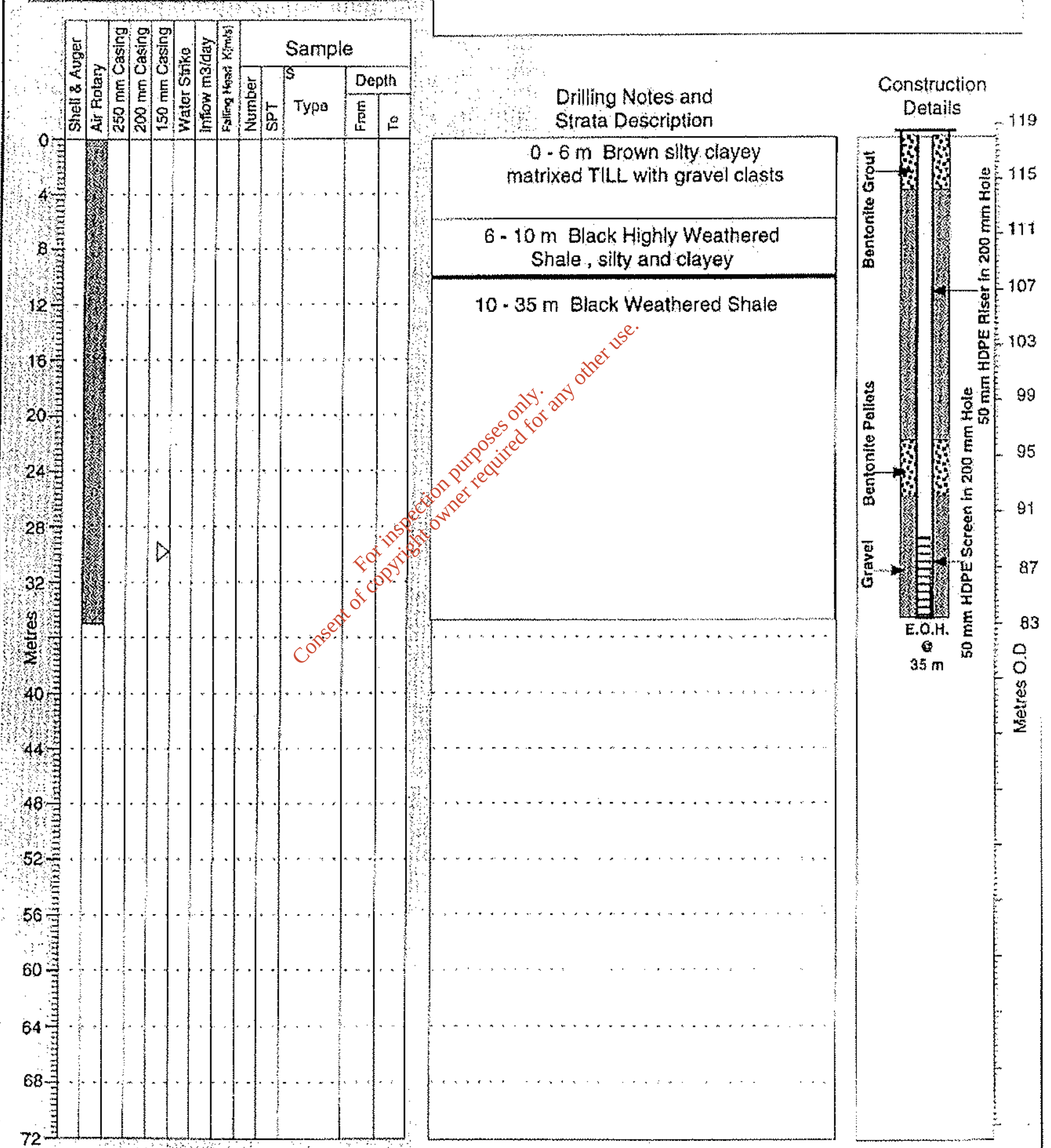
Operator A Hoey

Monitoring Well Log

Monitoring Well BH 5

Client : Seamus Murphy.
Location : Hollywood, Co. Dublin
Job No : 1698
Date : 3/9/98
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name :
National Grid Co. Ord. : 315796 East 258328 North
Ground Surface Elev. : 118.2 m OD Malin Head
Logged by : Clare Glanville



0 - 6 m Brown silty clayey matrixed TILL with gravel clasts

6 - 10 m Black Highly Weathered Shale , silty and clayey

10 - 35 m Black Weathered Shale

K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants

Sample / Test Legend
U - U100 Tubes
SS - Slit Spoon
SPT - Standard Penetration Test

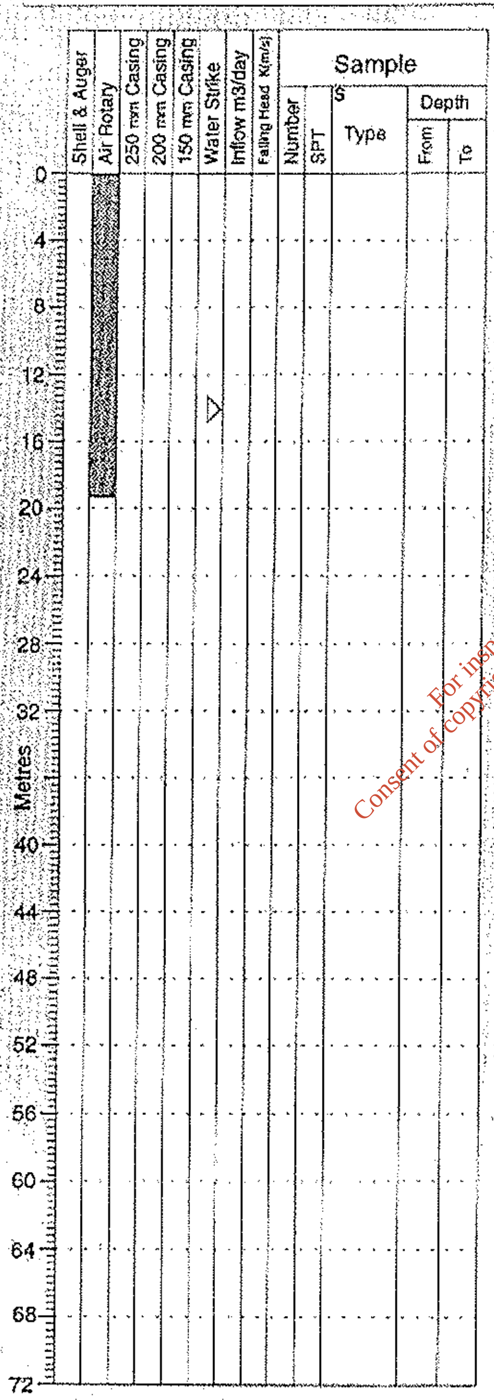
Figure No.

Monitoring Well Log

Monitoring Well BH 6

Client : Seamus Murphy.
Location : Hollywood, Co. Dublin
Job No : 1698
Date : 3/9/98
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name :
National Grid Co. Ord. : 315644 East 258506 North
Ground Surface Elev. : 117 m OD Malin Head
Logged by : Clare Glanville



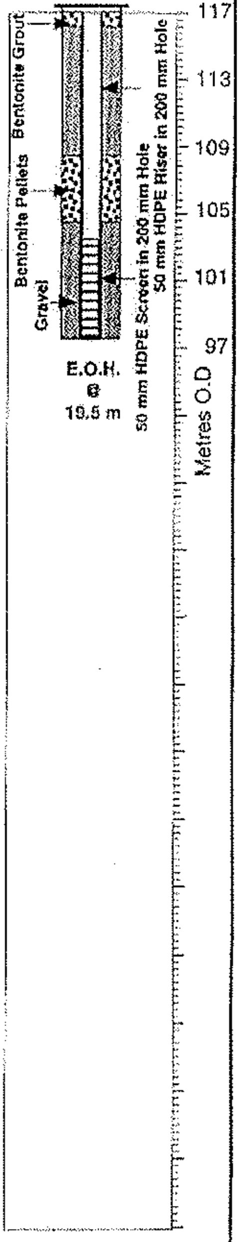
Drilling Notes and Strata Description

0 - 4 m Brown/Grey Clayey TILL

4 - 12 m Black Silty Clay with WEATHERED ROCK

12 - 19.5 m Black Shale BEDROCK

Construction Details



Sample / Test Legend

U - U100 Tubes
SS - Slit Spoon
SPT - Standard Penetration Test

Figure No.

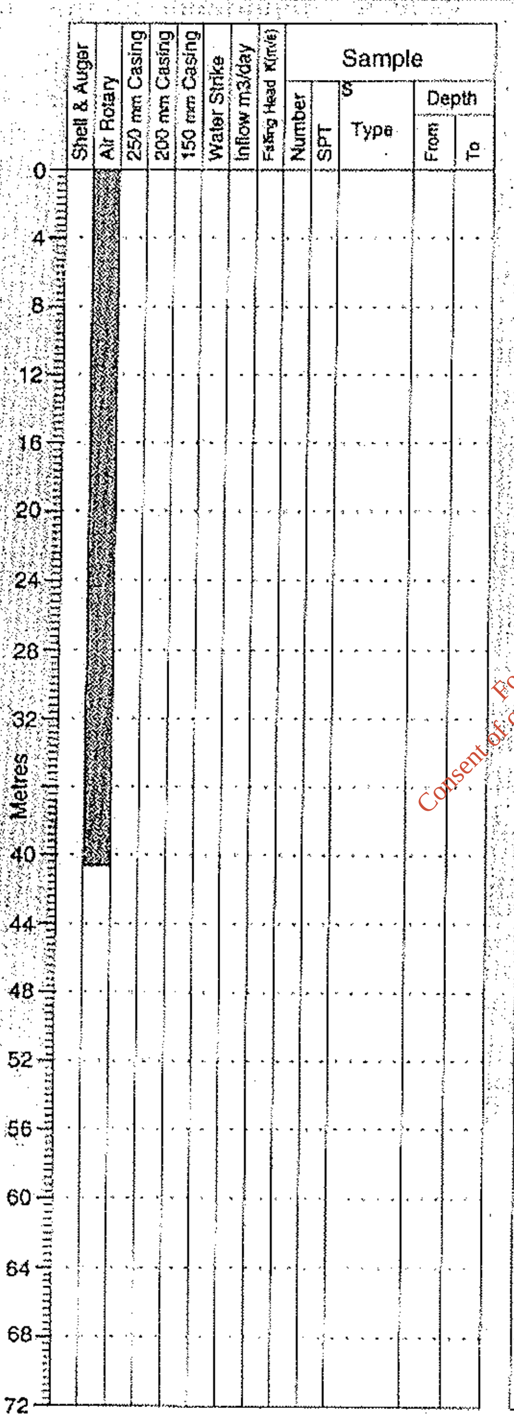
K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants

Monitoring Well Log

Monitoring Well BH 7

Client : Seamus Murphy.
Location : Hollywood, Co. Dublin
Job No : 1698
Date : 7/9/98
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name :
National Grid Co. Ord. : East North
Ground Surface Elev. : 132 m OD Malin Head
Logged by : Clare Glanville



Drilling Notes and Strata Description

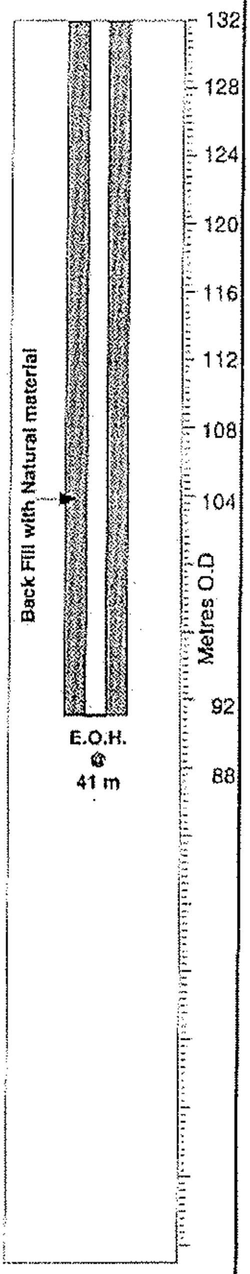
0 - 2 m Brown TILL with a silty to Clayey matrix

2 - 18 m Grey/Brown Silty weathered shale

18- 26 m Grey/Black weathered shale

No Further samples taken -Hole abandoned at 41 m

Construction Details



Sample / Test Legend
U - U100 Tubes
SS - Slit Spoon
SPT - Standard Penetration Test

K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants

Figure No.

Well Log

Well No. BH8 New
Grid Reference
Project No. 1698
Client Seamus Murphy
Drill Date 17/08/01
Well Type Groundwater Monitoring
Location Hollywood Great Quarry
Geologist F White

SUBSURFACE PROFILE

Description | **Depth** | **Symbol** | **Well Construction**

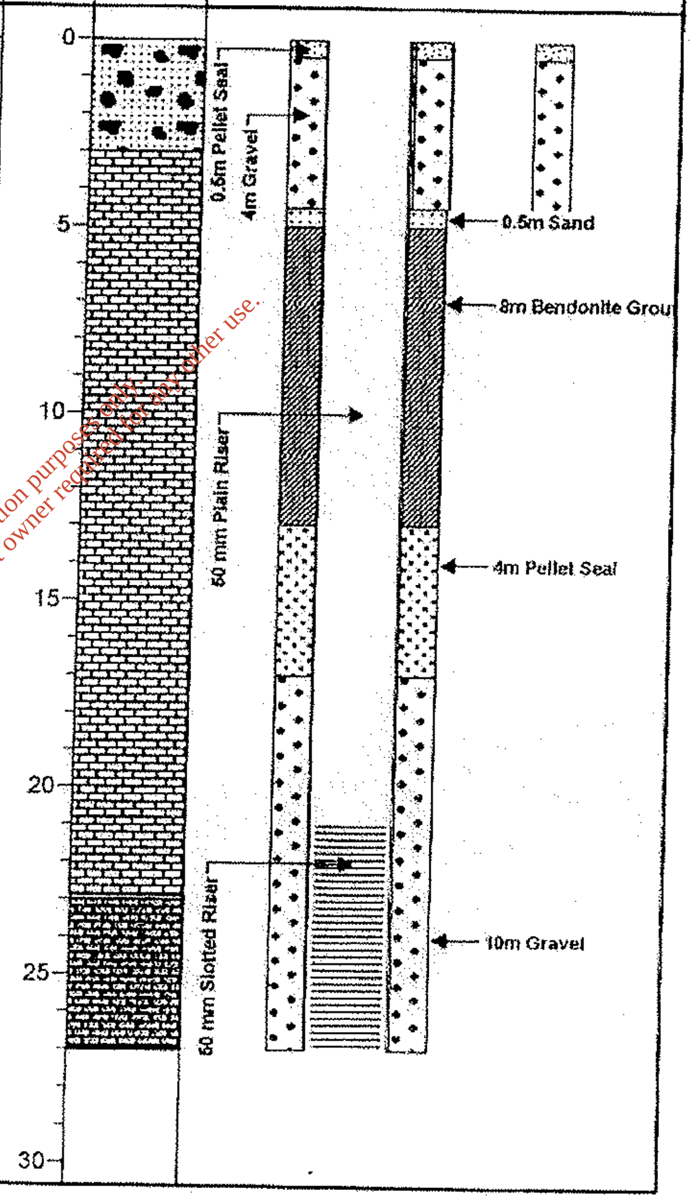
Ground Surface

OVERBURDEN
Overburden BOULDER CLAY

SHALE
Black SHALE bedrock

SHALE
Broken Black SHALE

End of Borehole



K.T.Cullen & Co. Ltd.

Drill Method Air Rotary
Casing Length (m)
Driller Glover Site Investigations
Hole Size (mm)
Ground Level (mOD)
Static Water Level (bgl)

Well Log

Well No. BH9

Grid Reference

Project No. 1698

Client Seamus Murphy

Drill Date 3/8/01

Well Type

Location Hollywood Great

Geologist Ben Whitfield

SUBSURFACE PROFILE

Description

Ground Surface

Colluvium and highly weathered shale
black loamy fine to medium sand
easy drilling; moist

light brown/dark brown gravelly medium clay; moist
Gravel dominantly black shale
Very moist thin layer 10.0 - 10.5
easy to medium drilling

Shale bedrock
black sand to gravel (granulated shale), moist
medium drilling

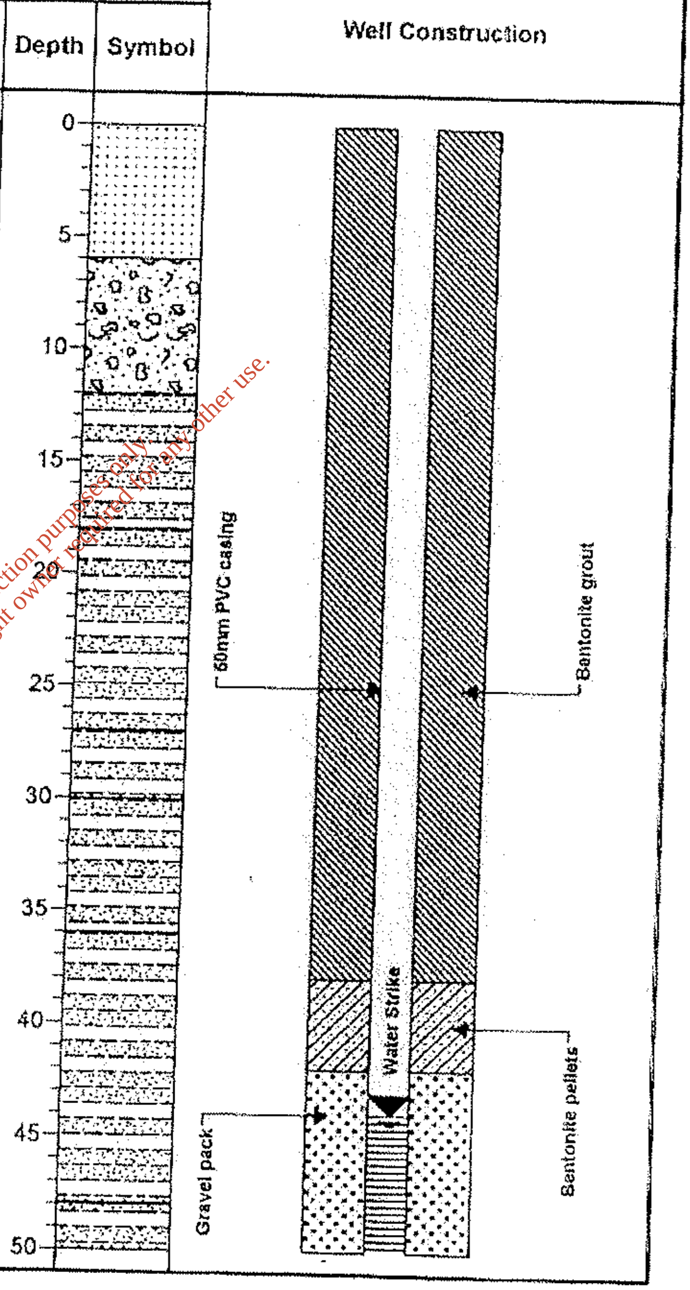
black sand to gravel, as above
gravel sized chips dominant

brown sand to gravel
gravel shale and minor calcareous siltstone
minor clay, moist

black sand to gravel
dominantly shale

black coarse sand to gravel shale chips
very moist@42
very easy drilling 40 - 41m
Water table 44m
Yield 500 gal/hr

End of Borehole



S.T.Cullen & Co. Ltd.

Drill Method Air rotary

Casing Length (m) 50

Driller Glovers Site Investigations

Hole Size (mm) 200

Ground Level (mOD)

Static Water Level (bgl)

PROJECT: 07507190035 Murphy's Hollywood

RECORD OF MONITORING WELL BH10A

SHEET 1 OF 1

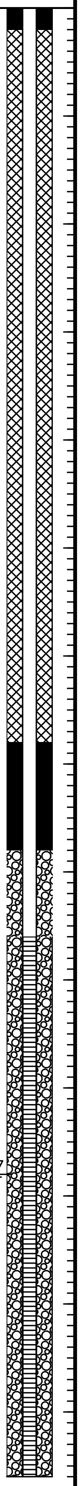
LOCATION: Murphy's Hollywood

BORING DATE: 5/3/2007

DATUM:

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	GEOTECH NO.	ENV NO.	TYPE	ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE										Top of Pipe Elev. 137.140
0	Monitoring Borehole Air Rotary	Overburden-brown soil		0.00								Bentonite seal
10		Weathered shale		10.00								
20		Limestone		21.00								Riser pipe
35												Bentonite Plug
40												Riser pipe and gravel pack
55												Entry 5/3/07 Screen and gravel pack
68				68.00								EOH

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70



DEPTH SCALE
1 : 350

Golder Associates

LOGGED: CG
CHECKED: TVM

2 MURPHY HOLLYWOOD.GPJ GLDR_LDN.GDT 17/7/07 DATA INPUT:

PROJECT: 07507190035 Murphy's Hollywood

RECORD OF MONITORING WELL BH11A

SHEET 1 OF 1

LOCATION: Murphy's Hollywood

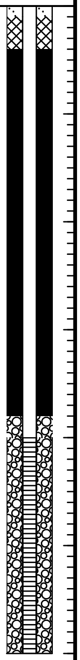
BORING DATE: 2/5/07

DATUM:

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. DEPTH (m)	INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		Top of Pipe Elev. 100.01
0	Monitoring Borehole Air Rotary	Overburden/madeground	0.00	Cement Backfill
		Weathered grey shale	2.00	
		Fractured shale	8.00	Bentonite
		Shale	12.00	
		Heavily weathered shale	18.00	Gravel pack
		Grey sandy shale	21.00	Screen and gravel pack
			30.00	

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES: GEOTECH NO., ENV NO., TYPE; ELEVATION; DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa, nat V. + Q - ●, rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT, Wp ⊢—○W—⊣ Wl (10, 20, 30, 40); ADDITIONAL LAB. TESTING

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70



DEPTH SCALE

1 : 350

Golder Associates

LOGGED: AS

CHECKED: TVM

PROJECT: 07507190035 Murphy's Hollywood

RECORD OF MONITORING WELL BH12

SHEET 1 OF 1

LOCATION: Murphy's Hollywood

BORING DATE: 1/5/07

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: GEOTECH NO.	ENV NO.	TYPE	ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS
		PAVEMENT SURFACE										Top of Pipe Elev. 146.994
0	Limestone Groundwater Monitoring Borehole Symetrex	Concrete		0.30								Concrete seal
		Overburden		5.50								
5		Shale		46.00								Backfill
46		Limestone		65.00								Bentonite plug Gravel Pack Screen and gravel pack

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

DEPTH SCALE

1 : 350

Golder Associates

LOGGED: AS

CHECKED: TVM

2 MURPHY HOLLYWOOD.GPJ GLDR_LDN.GDT 17/7/07 DATA INPUT:

PROJECT: 07507190035 Murphy's Hollywood

RECORD OF MONITORING WELL BH13

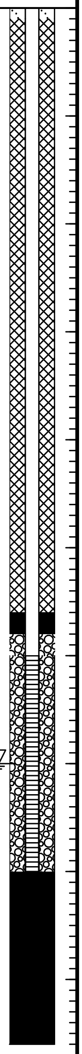
SHEET 1 OF 1

LOCATION: Murphy's Hollywood

BORING DATE: 15/04/07

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	GEOTECH NO.	ENV NO.	TYPE	ELEVATION	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS
		PAVEMENT SURFACE										Top of Pipe Elev. 146.922
0	Shale Groundwater Monitoring Point Air Rotary	Pavement		0.30								Concrete seal
		Overburden										
5		Shale		5.50								
15												Riser
28												Bentonite Plug Gravel Pack
35												Gravel Pack, 50mm Screen Water Level 16/04/07
43												Bentonite Backfill
46		Limestone		46.00								
48				48.00								



DEPTH SCALE
1 : 350

Golder Associates

LOGGED: AS
CHECKED: TVM

PROJECT: 07507190035 Murphy's Hollywood

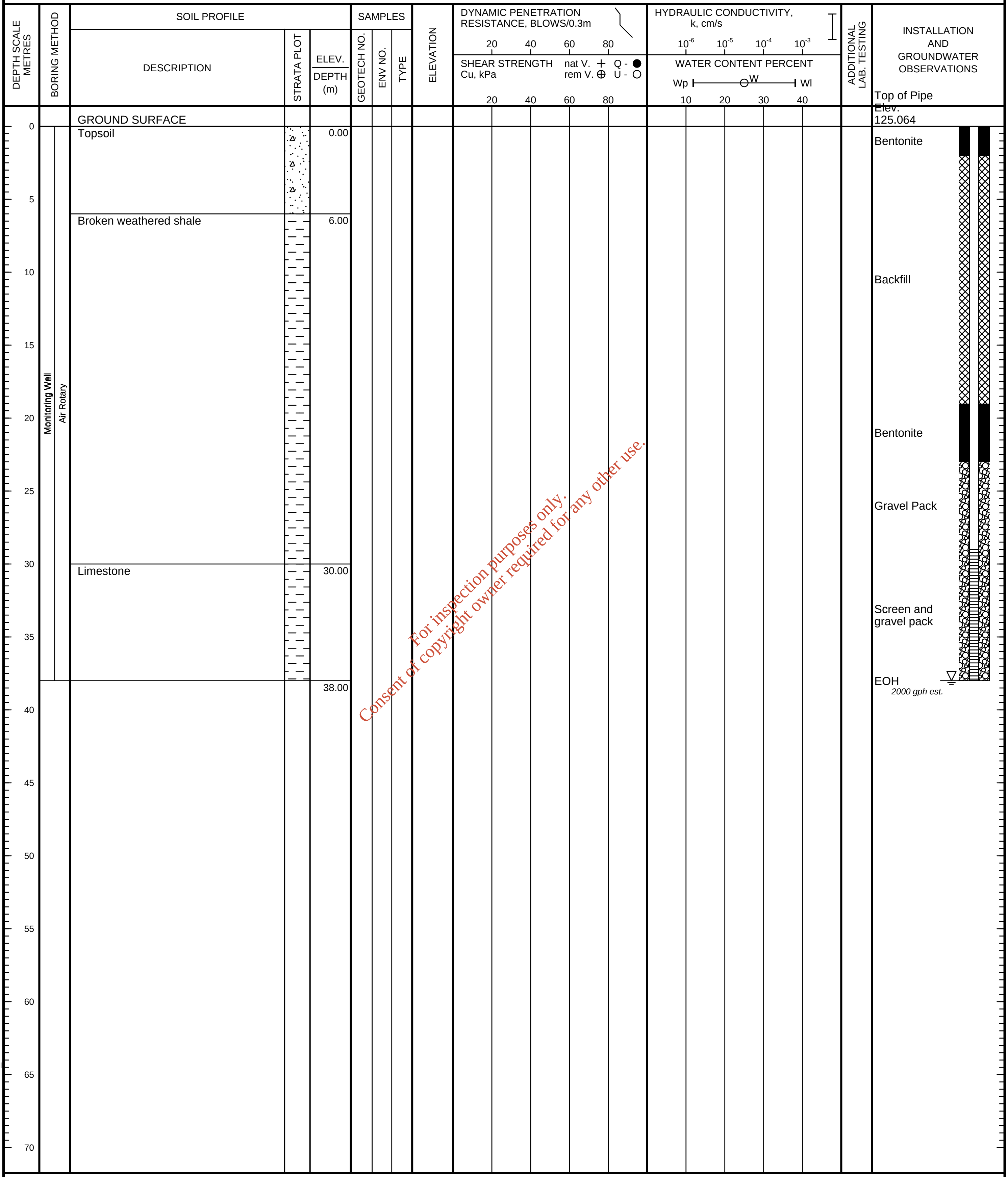
RECORD OF MONITORING WELL BH14

SHEET 1 OF 1

LOCATION: Murphy's Hollywood

BORING DATE: 2/3/2007

DATUM:



DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	
Topsoil	0.00
Broken weathered shale	6.00
Limestone	30.00
	38.00

Top of Pipe Elev. 125.064

Bentonite

Backfill

Bentonite

Gravel Pack

Screen and gravel pack

EOH

2000 gph est.

DEPTH SCALE

1 : 350

Golder Associates

LOGGED: TVM

CHECKED: TVM

Appendix A14.4.2

Drillers' logs for newly constructed boreholes

Petersen Drilling Services - Daily Logsheet

Location:	**Job Nr.:**	**Date:**	**Day:**	**Borehole No.:**
Phoenix	PDS 07/10	06.04.10 - 12.04.10	Tuesday / Monday	BH 15
Driller:	**Assistant1:**	**Assistant2:**	**Client:**	
S Petersen	P Butler		IGSL	
Type of Drilling:	**Type of Flush:**	**Coreliner used:**	**Coreboxes:**	
8"Open Hole/Geobore S	Air / Polymer Gel	yes	21	
Casing depth:	**Symetrix from-to:**	**Openhole 5" from-to:**	**Openhole 8" from-to:**	
0.80 m			0.00 - 0.80 m	

Geo S core from:	Geo S core to:	Length:	Core Recovery:	Corebox No.:
0.80 m	1.80 m	1.00 m	0.90 m	1
1.80 m	3.30 m	1.50 m	1.20 m	2
3.30 m	4.80 m	1.50 m	1.50 m	3
4.80 m	6.30 m	1.50 m	1.50 m	4
6.30 m	7.80 m	1.50 m	1.15 m	5
7.80 m	9.30 m	1.50 m	1.50 m	6
9.30 m	10.50 m	1.20 m	0.70 m	7
10.50 m	12.00 m	1.50 m	1.50 m	8
12.00 m	13.60 m	1.60 m	1.60 m	9
13.60 m	15.10 m	1.50 m	1.00 m	10
15.10 m	16.60 m	1.50 m	1.10 m	11
16.60 m	18.20 m	1.60 m	1.60 m	12
18.20 m	19.80 m	1.60 m	1.25 m	13
19.80 m	21.30 m	1.40 m	1.00 m	14
21.30 m	22.80 m	1.60 m	1.50 m	15
22.80 m	24.30 m	1.50 m	1.50 m	16
24.30 m	25.80 m	1.50 m	1.40 m	17
25.80 m	27.30 m	1.50 m	1.40 m	18
27.30 m	28.80 m	1.50 m	0.70 m	19
28.80 m	30.40 m	1.60 m	1.60 m	20
30.40 m	31.90 m	1.50 m	1.50 m	21
		Total: 31.10 m		

CPT's @ depth:	**Nr. of blow's Seating**	**No. of blow's on 75mm**	**Bagsamples from-to**	**Dayworks:**
				7¾ hours

Geology:
0.00 m Brown highly weathered Shaley Mudstone, Sandy Gravely Clay Layers
25.30 m large open Fracture
25.50 m Grey Mudstone / Limestone, some Clayey Fractures
30.60 m large open Fracture

Remarks:
06.04.10 Mobilisation of all Plant and Equipment to Site near Naul Co. Dublin
09.04.10 100% Flush losses at 25.30 m, 10% Flush returning at approx 29.00 m followed by 100% losses at 31.90 m
09.04.10 14.00 - 14.45 Awaiting Instructions of Consulting Engineer regarding final depth of Borehole ¾ hour Dayworks
12.04.10 8.30 - 9.30 Setup Single Packer for Test at 30.00 - 31.90 m 1 hour Dayworks
12.04.10 9.30 - 10.00 Moved Packer 0.50 m down to 30.50 m due to possible bad seal ½ hour Dayworks
12.04.10 10.00 - 11.00 Unable to pressurise Test section due to large open Fracture. Pumped at max. output 3.9 m³/h but only achieved 0.2 bar pressure. Continued pumping at 3.9 m³/h for ½ hour with no increase in Pressure. 1 hour Dayworks
12.04.10 11.00 - 15.30 Waiting for Briodys to finish Grouting 4½ hours

Used Materials:
21 Geobore Coreboxes, 31.5 m Geobore Liner

Waterlevel @ time:	**Installation type:**	**Filter screen @ depth**	**Backfill type:**	**Depth @ end of shift:**
5.70 m 8.30am 12.04.10	none		Cement Grout	31.90 m

Signature Driller: **Signature Client:**

Petersen Drilling Services - Daily Logsheet

Location:	***Job Nr.:***	***Date:***	***Day:***	***Borehole No.:***
Phoenix	PDS 07/10	12.04.10 - 20.04.10	Monday / Tuesday	BH 16

Driller:	***Assistant1:***	***Assistant2:***	***Client:***
S Petersen	P Butler		IGSL

Type of Drilling:	***Type of Flush:***	***Coreliner used:***	***Coreboxes:***
8"Open Hole/Geobore S	Air / Polymer Gel	yes	37

Casing depth:	***Symetrix from-to:***	***Openhole 5" from-to:***	***Openhole 8" from-to:***
0.80 m			0.00 - 0.80 m

Geo S core from:	***Geo S core to:***	***Length:***	***Core Recovery:***	***Corebox No.:***
0.80 m	1.60 m	0.80 m	0.80 m	1
1.60 m	3.10 m	1.50 m	1.30 m	2
3.10 m	4.70 m	1.60 m	1.60 m	3
4.70 m	6.20 m	1.50 m	1.50 m	4
6.20 m	7.60 m	1.40 m	1.00 m	5
7.60 m	9.10 m	1.50 m	1.50 m	6
9.10 m	10.60 m	1.50 m	1.00 m	7
10.60 m	12.10 m	1.50 m	1.50 m	8
12.10 m	13.60 m	1.50 m	0.90 m	9
13.60 m	15.10 m	1.50 m	0.90 m	10
15.10 m	16.60 m	1.50 m	1.00 m	11
16.60 m	17.50 m	0.90 m	0.80 m	12
17.50 m	18.00 m	0.50 m	0.00 m	
18.00 m	19.00 m	1.00 m	0.50 m	13
19.00 m	19.60 m	0.60 m	0.60 m	13
19.60 m	20.70 m	1.10 m	1.00 m	14
20.70 m	21.10 m	0.40 m	0.40 m	14
21.10 m	22.60 m	1.50 m	0.50 m	15
22.60 m	23.80 m	1.20 m	1.00 m	15
23.80 m	24.60 m	0.80 m	0.60 m	16
24.60 m	25.50 m	0.90 m	0.80 m	16
25.50 m	27.00 m	1.50 m	1.30 m	17
27.00 m	28.50 m	1.50 m	0.00 m	18
28.50 m	30.00 m	1.50 m	0.50 m	18
30.00 m	31.50 m	1.50 m	0.90 m	18
31.50 m	33.00 m	1.50 m	1.30 m	19
33.00 m	34.50 m	1.50 m	1.20 m	20
34.50 m	36.00 m	1.50 m	1.50 m	21
36.00 m	37.00 m	1.00 m	0.90 m	22
37.00 m	37.50 m	0.50 m	0.30 m	22
37.50 m	38.30 m	0.80 m	0.70 m	23
38.30 m	39.00 m	0.70 m	0.70 m	23
39.00 m	40.50 m	1.50 m	1.50 m	24
40.50 m	42.00 m	1.50 m	1.50 m	25
42.00 m	43.50 m	1.50 m	1.30 m	26
43.50 m	45.00 m	1.50 m	1.50 m	27
45.00 m	46.50 m	1.50 m	1.50 m	28
46.50 m	48.00 m	1.50 m	1.50 m	29
48.00 m	49.50 m	1.50 m	1.50 m	30
49.50 m	51.00 m	1.50 m	1.50 m	31
51.00 m	52.50 m	1.50 m	1.40 m	32
52.50 m	54.00 m	1.50 m	1.50 m	33
54.00 m	55.50 m	1.50 m	1.40 m	34
55.50 m	57.00 m	1.50 m	1.50 m	35
57.00 m	58.50 m	1.50 m	1.50 m	36
58.50 m	60.00 m	1.50 m	1.40 m	37
		Total: 59.20 m		

CPT's @ depth:	***Nr. of blow's Seating***	***No. of blow's on 75mm***	***Bagsamples from-to***	***Dayworks:***
				9.5 hours

Geology:

0.00 m Brown highly weathered Shaley Mudstone / Sandstone, Sandy Gravely Clay Layers
0.90 m Black partly highly Fractured Mudstone / Sandstone, some Clay Layers
12.20 m Brown/Grey highly weathered Shaley Sandstone / Mudstone, some Sand and Gravel Layers, some Brown Clay Layers
25.00 m Black Mudstone / Sandstone , some Clay Layers
27.00 m Brown Sand
29.00 m Black Mudstone / Sandstone , some Clay Layers, partly very Fractured
58.00 m Black Limestone, some Mudstone and Clay Layers
59.00 m Black Mudstone / Sandstone , some Clay Layers

Remarks:

30% Flush losses between 12.20 m and 19.60 m, 20% Flush losses between 19.60m and 24.60 m
10% Flush losses between 48.00 m and 55.50 m
19.04.10   Setup and dismantled Double Packers at Testsections 42.00 - 44.00 m & 54.00 - 56.00 m
3 hours Dayworks
19.04.10 13.00 - 14.00 Packertest @ 42.00 - 44.00 m   1 hour Dayworks
19.04.10 14.30 - 15.00 Packertest @ 54.00 - 56.00 m   ½ hour Dayworks
19.04.10 16.30 - 18.45 Waiting for Briodys to finish Grouting from 60.00 - 30.00 m   2¼ hours
20.04.10 8.00 - 9.30 Groutlevel at 33.00 m filled Borehole to 24.00 m with Bentonite Pellets and Installed 50 mm Standpipe at 24.00 m
20.04.10 9.30 - 12.15 Waiting for Briodys to finish Grouting from 18.00 m - GL   2¾ hours Dayworks

Used Materials:

37 Geobore Coreboxes, 60 m Geobore S Liner
2.00 m 50 mm Slotted (20 - 22), 22.40 m 50 mm Solid (20 - +0.40 & 22 - 24), 4.00 m Gravel (23 - 19),
9.00 m Bentonite (33 - 24),2.00 m Sand (23 - 24 & 19 - 18), 2.00 m Filter Sock, 1 Bottom Cap
45.00 m Cement Grout (60 - 33 & 18 - GL),
All Grout supplied and installed by Briodys, Gravel supplied by Murphys, Cover to be installed later

Waterlevel @ time:	***Installation type:***	***Filter screen @ depth***	***Backfill type:***	***Depth @ end of shift:***
2.50 m	50 mm HDPE	20.00 - 22.00	Cement Grout	60.00 m
8.30am 19.04.10				

Signature Driller: ***Signature Client:***

Petersen Drilling Services - Daily Logsheet

Location:	***Job Nr.:***	***Date:***	***Day:***	***Borehole No.:***
Phoenix	PDS 07/10	20.04.10 - 22.04.10	Tuesday / Thursday	BH 18
Driller:	***Assistant1:***	***Assistant2:***	***Client:***	
S Petersen	P Butler		IGSL	
Type of Drilling:	***Type of Flush:***	***Coreliner used:***	***Coreboxes:***	
8"Open Hole/Geobore S	Air / Polymer Gel	yes	14	
Casing depth:	***Symetrix from-to:***	***Openhole 5" from-to:***	***Openhole 8" from-to:***	
0.60 m			0.00 - 0.60 m	

Geo S core from:	***Geo S core to:***	***Length:***	***Core Recovery:***	***Corebox No.:***
0.60 m	1.60 m	1.00 m	1.00 m	1
1.60 m	3.10 m	1.50 m	1.50 m	2
3.10 m	4.60 m	1.50 m	1.50 m	3
4.60 m	6.10 m	1.50 m	1.50 m	4
6.10 m	7.60 m	1.50 m	1.50 m	5
7.60 m	8.80 m	1.20 m	0.90 m	6
8.80 m	10.40 m	1.60 m	1.60 m	7
10.40 m	11.40 m	1.00 m	1.00 m	8
11.40 m	12.00 m	0.60 m	0.60 m	8
12.00 m	13.60 m	1.60 m	1.60 m	9
13.60 m	15.10 m	1.50 m	1.40 m	10
15.10 m	16.60 m	1.50 m	1.50 m	11
16.60 m	18.10 m	1.50 m	1.40 m	12
18.10 m	19.60 m	1.50 m	1.50 m	13
19.60 m	21.20 m	1.60 m	1.60 m	14
		Total: 20.60 m		

CPT's @ depth:	***Nr. of blow's Seating***	***No. of blow's on 75mm***	***Bagsamples from-to***	***Dayworks:***
				4¾ hours

Geology:
0.00 m Brown highly weathered Shaley Mudstone / Sandstone, some Clay Layers
15.00 m Grey Limestone, some shaley Mudstone Layers, some Fractures
15.40 m - 15.70 m Cavity possible Clay or Sand filled
16.30 m - 16.50 m Cavity possible Clay or Sand filled

Remarks:
21.04.10 100% Flush losses from 14.80 m
22.04.10 8.15 - 9.30   Setup Single Packer at 17.00 - 18.00 m   1¼ hour Dayworks
22.04.10 9.30 - 11.00 Packertest 18.00 - 21.20 m   1½ hours Dayworks
22.04.10 11.00 - 11.30 Pulled Packer and dismantled all Equipment   ½ hour Dayworks
22.04.10 Installed 50 mm Standpipe and Backfill to 21.20 m
22.04.10 13.00 - 14.30 Waiting for Briodys to finish Grouting 1½ hours Dayworks

Used Materials:
14 Geobore Coreboxes, 21.00 m Geobore Liner
2.00 m 50 mm Slotted (19 - 17), 18.40 m 50 mm Solid (17 - +0.40 & 20 - 19), 4.00 m Gravel (20 - 16),
2.20 m Sand (21.2 - 20 & 16 - 15), 2.00 m Filter Sock, 1 Bottom Cap
15.00 m Cement Grout (15 - GL),
All Grout supplied and installed by Briodys, Gravel supplied by Murphys, Cover to be installed later

Waterlevel @ time:	***Installation type:***	***Filter screen @ depth***	***Backfill type:***	***Depth @ end of shift:***
9.00 m 8.15am 22.04.10	50 mm HDPE	19.00 m - 17.00 m	Cement Grout	21.20 m

Signature Driller: ***Signature Client:***

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DRILLING LOG 12-4-2010

BH.15
Arrived on site @ 11.00am
Grout borehole from 32.8m to ground level
Grouting time 12.30 to 3.30 plus wash down of tremie pipes and grout plant total 4.30pm
65 bags of cement (25kg bags) used .
4 samples of grout taken
Losses of grout were incurred using double of anticipated amount approx.

BH.15 Monitoring Well

Located 4 metres from grouted geobore borehole

Date 16-4-2010

0-3m 10" diameter Coarse sand fine gravel
3-6m 10" diameter clay covered coarse material
6-9m 10" diameter 2" square stone to brown water 200gls/hr
9-12m 10" diameter 3"/4"choclate brown
60min Airlifting @ 12m for delivering 200gls/hr
12m of 8" steel casing installed
12-15m 8" coarse material grey colour
15-18m 8" very wet with 4" stone water strike increase +300gls/hr
6m of 8" casing installed
18-21m Huge water strike washing out a lot of material
21-24m 8" top of lough shinney @ 24m calcite material in stone
45 min Surging and well development increasing yield with washed material + 8000gls/hr
6m of 8" casing installed
24-27m 8" Still drilling lough shinney open hole section of borehole completely collapsing washing out 4" stone
27-29m conditions for drilling requiring more casing developing borehole for 1 hr water cleaning very quickly particulary with surging and very high yielding

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BH.15
19-4-10

6m of casing installed (total casing string 30m)
29-30m drilling partly black mudstone very silty when developed slow to fully clean.
60 min surging and well development with very little improvement on silty mud water, yield decreased with casing down to 30 m
Installed 2" piezometer pipe as per instruction 1m plain on bottom then 1m screen section followed with 28m of plain pipe. Gravel pack to 26m with 1m of sand layer/barrier to 25m.
Pulled casing back to 28m.

Decision made to grout BH.16 from 60m to 30m instructed to use 25 bags of cement to achieve desired depth.

Grouting from 4.30pm 7.00pm.

20-4-10

Replaced pull cord on grout plant and went for 2 tonne of cement

Started grouting BH.16 from 18m to surface using 32 bags of cement.
Grouting time from 9.30am to 12.15pm

1.30pm Returned to BH.15
Pulled casing from 28m back to 24m
Started pumping grout until grey colour water returning to surface through casing while monitoring water in piezometer and remaining static.
Pulled casing to 21m and continued pumping grout no returns to surface lifted casing to 18m. Annular spacing dipping to 22.4m with 66 bags of cement used and no returns
Finished at 7.30pm

21-4-10

Dipped BH.15 annular space at 9.15am to 22.4m
Dipped 2" piezometer 29.7m
Added 6 bags of bentonite dipping to 21.4m
Added 6 bags of bentonite dipping to 20.4m
Added 3 bags of bentonite dipping to 18.4m
Added 3 bags of bentonite dipping to 16.4m
Added 3 bags of bentonite dipping to 14.4m
Added 3 bags of bentonite dipping to 12.4m
Started pumping grout with 12m of casing in borehole grout coming over well head.

Pulled 3m of casing losing grout again added a further 20 bags of bentonite in a combined grout mix using 40 bags of cement.

Dipped for grout at 8m hard at 11.5m stopped grouting at 1.30pm

Mobilised to BH.19 at 2.00pm with rig

Returned to BH.15 AT 3.00pm and dipped grout at 8.5m used a further 5 bags of cement and 6 bags of bentonite to 3m.

Drilling BH.19 @ 3.30pm
Drilled 10" diameter to 6m All brown dry weathered material
Installed 6m of 8" steel casing.
Drilled at 8" to 9m red band of sandstone? @ 7m with water.
60/min Developing and surging @ 7m yielding 100gls/hr
Engineers concerned that we might be on the wrong side of fault therefore perhaps abandon borehole @ 18m decision to be made for following morning 22-4-10. Therefore we decided not to drill out borehole to avoid overnight unstabilising of exposed weathering sections.

22-4-10

Arrived at 8.00am

Awaiting confirmation of borehole spec
Dipped Bh.19 Static water level @ 1.45m
9-12m 8" brown fill material borehole yielding 20gls/hr
12-15m 8" reasonably competent brown rock
15-18m 8" black mudstone at 18m with specks of red chip
60 min Surged and well development yielding 150gls/hr Surging opening apertures.

Install 1m plain on bottom them 1m screen followed by 16m of plain

Backfilled with gravel to 14m then 1m of sand to 13m installed grout pipe and pulled casing

11.15am went to hardware for cement

Topped BH.15 with a further 18 bags of cement and fitted hinged lockable stand cover

Totals of cement for Monitoring BH.15

Cement 129 bags and 49 bags of bentonite

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22-4-10

12.00pm to 1.30pm

Grouted BH.18 using 35 bags of cement (15 metres)

1.30pm to 3.30pm

Grouted BH.19 using 42 bags of cement (13 metres)

Started drilling BH20 @ 3.40pm

0-3m 10" gravel is angular fine to coarse of sandstone
3-6m 10" black silt stone
6m of 8" steel casing installed
6-16m 8" black silt stone moderately weak fine grained with .5m clay filled @ 11m water 100gls/hr
16-21m 8" returns of brown clayey sandy gravel gravel angular increase in water + 500gls/hr developed zone for 30 min flow consistant
21-30m 8" black siltstone

Returned to BH19 and fitted cover also fitted cover on BH18.

Left site 6.00pm

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23-4-10

Water level in BH.20 @9.00am 1.7m

Borehole clear to 12m with collapse from 12m to 17/18m Significant increase in water yield from 3000/3500gls/hr surging and well development for 60 min cleaning out clayey gravel zone.

After airlift drilled from 30m to 32m loosing all air return to surface with air pressure gauge blowing off @ 350psi indicating continous collapse mostly from 12m.

Decision made on the basis that to progress borehole upper material needed to be cased off and allowing a return to drilling dry blacksiltstone meaning better stability.

From 10.45am to 12.00pm installed 30m of 6" steel casing

30m to 42m drilling reasonably competent black mudstone

42m to 48m massive water strike with estimated yield of in excess of 10000gls/hr bad fracture in the mudstone with 2" rectangular stone coming to surface.

Volume of water presenting problems to drill as the volume of water is causing hammer to water out..

Pulled rods from hole and checked depth with dipper BH clear to 42m. 6" casing stopped at 30m and open hole section is clear to 42m even with 10000gls/hr of water washing sides of borehole.

Made foam mix pumping through water pump with approval by engineer

90 min Airlifting and surging for to try and clean out 42m to 48m section

48 to 52m competent mudstone with particles of calcite @ 48m. Volume of water slowing hammer speed however foam mix is vital for velocity and suspending material

Details of foam requested by engineer..
Engineer requesting a note to explain reasons for slow progress...

Pulled rods back to 30m

Finished 6.00pm

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26th April 2010

Installed 6m of 6" casing which was driven with ¼ Tonne of puldown pressure @ 90psi hammer speed. Refusal to drive beyond 36m and cautious not to over exert pressure as casing needs to be retrived.

42-48m section collapsing continuously drilled to 54m with air/foam mix @ 54m on better competent rock. Drilling from 48 to 54m was smooth with steady penetration. Cuttings showing traces of limestone however cuttings are distorted due to collapsing material washing away direct returns.

11.00AM-3.30PM Time spent developing cleaning and surging 42-48m section. Yield in this section producing 7,000/8,000 gls/hr washing out black 2/3" flint like stone. Water exceptionally clean and crystal clear to the eye. However still collapsing after cleaning and surging.

3.30pm Tripped rods out of borehole and dipped same dipping out to 33m.
Met Eugene Daly and Maria who visited site and explained conditions encountered and that borehole was now dipping @ 33m. Eugene expressed a wish to clean borehole, as the preferred option was to install piezometer to 42m.

3.45-5.30pm Tripped rods back into borehole and clean and developed down to 46m for 90min.

5.30pm Installed piezometer to 43m. 1m plain on bottom then 2m screen then 40m of plain.
Gravel pack from 43m to 38m then 1m of sand to 37m

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27 April 2010
BOREHOLE 20.

9.30AM Dipped 2" piezometer 43m deep

39M depth to pea gravel backfilled with pea gravel to 38m then sand to 37m

10.30am tried pulling 36m 6" casing with drill head unsuccessful

11.00am welded coupling onto 6" casing and used rig jacks to pull no movement

12.00pm used back hammer on rig with constant air and 2.5 tonne pressure for 60 min approx casing not lifting

2.30pm Met Maria and spoke to Eugene Daly on phone explained issues with retrieval of casing decision made to leave 6" casing in borehole and grout from 37m back into 6" casing for 3-4metres. Pull outer 8" casing out of borehole.

3.15pm Went to hardwares for 2 tonne of cement

4.00pm Returned to site with cement

4.15pm Started pulling 8" casing with back hammer.

5.00pm Started grouting from 37m

6.50pm Left site after pumping 20 bags of cement.

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28th April 2010

Borehole 20.

9.30am Dipped borehole after pumping grout the night before using 20 bags. Grout made no returns still dipping to 37m.

10.00-11.30 Pumped a further 15 bags of cement.

12.30pm-3.30pm Checked grout level after 1hr curing, Still at 37m
Started adding Bentonite similar to borehole 15. after 12 bags bentonite back to 34m.
Bentonite added very slowly and BH.dipped after every bag to monitor how quicklt bentonite was rising

3.30-4.00pm Went to hardwares for Paint for wells.

4.00-6.15pm Started loading trailer with casing for return journey to yard.

8

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29 April 2010

10.00AM Loaded trailer with more casing and all other associated materials

Welded and secured all Monitoring wells with hingable lids and painted all protective casings and cleaned spoil around all boreholes

Left safety sign on site for other rig to use on start of water well

25 Bags of bentonite left in Store shed

24 grout samples of all wells marked and labeled also left in store shed

Left site at 2.00pm

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Patrick Briody & Sons Ltd.

DRILLING LOG

AQUADRILL SERVICES

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0736

Consultant/Engineer Arup

Client MEHL

Borehole Reference No. P. AW 1 Sheet 1 of 3

Borehole Location

Date of Drilling	Depth (from - to) Mtrs/Ft.	Actual Drilling Diametre	Drilling Conditions / Water Strike
5-5-10	Mobilised Drill	rig	to site and
	set up	over	trial hole to
	retrieve	casing.	
6-5-10	retrieved	all	casing between clamps
	and casing	hammer	pumped water
	after each	6m	pull to check if
	returns but	none	so used
	bentonite	50 bags	in total keeping
	it topped	up	into the casing.
	biggest loss	around	24-30 m area

Total Depth of Well

Estimated Yield

Depth to Rock

Steel Casing Installed

P.V.C. Casing/Screen Installed

Other Remarks

Lead Driller Drilling Rig

Engineer Approval

Schematic View

Patrick Briody & Sons Ltd.

DRILLING LOG

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0737

Consultant/Engineer ARUP.

Client MEHL

Borehole Reference No. PW1 Sheet 2 of 3

Borehole Location beside ramp

Date of Drilling	Depth (from - to) Mtrs/Ft.	Actual Drilling Diametre	Drilling Conditions / Water Strike
6-5-10	Set up	over	location and clamped
	clamps etc	to	start drilling in casing
	installed 6m	x	300mm steel casing
7-5-10	prepared to	R.C.	drill drilled
	to 25m	using	water only started
	to have	losses	from 20m then
	added polymer	to	raise vis
	1st water strike	@	15m 500 gls/hr.
	next @	24-27	possibly 5000gls/hr
	changed bit	to	ballistic for better penetration
10-5-10	Drilled from	27	-40m. Mixed up
	Polymer based	mud	in morning held
	back problem	from	24-27. quite
	broken or	fractured	esp @ 33-35 or
	37-40 big	mud	losses at these depths
	blocked, drill	bit	Twice, at these

areas also due to volume of stone entering bit.

Total Depth of Well.............................

Estimated Yield.............................

Depth to Rock.............................

Steel Casing Installed.............................

P.V.C. Casing/Screen Installed.............................

Other Remarks.............................

Lead Driller.............................Drilling Rig.............................

Engineer Approval.............................

Schematic View

Patrick Briody & Sons Ltd.

DRILLING LOG

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0738

Consultant/Engineer: ARUP.

Client: MEHL

Borehole Reference No.: PWL Sheet 2 of 3

Borehole Location: beside ramp.

Date of Drilling	Depth (from - to) Mtrs/Ft.	Actual Drilling Diametre	Drilling Conditions / Water Strike
11-5-10	drilled from	40	to 55m.
	51-55 more	competent	with calcite;
	conditioned	polymer	back to install
	PVC 10×5m	and	2×1m screen under
	instruction from		Catherine (eng) developed 2hrs
	ie 2×5m screen	, 8	× 5m plain, 2 × 1m screen
	then emplaced		10 ton of P gravel
	back to	23m	from surface big
	losses around		27m!
12-5-10	started to	develop @	11am big concent
	of polymer	@ start	and settlement of
	gravel. very		discoloured @ 1pm.
	airlifted	with 6pm	quite good at
	end but	with	small agression still
	discoloured.		
13-5-10	30 bags of	bentonite	to get return and

Pumped 125 bag of cement.

Total Depth of Well

Estimated Yield lockable lid

Depth to Rock

Steel Casing Installed

P.V.C. Casing/Screen Installed

Other Remarks

Lead Driller Drilling Rig

Engineer Approval

Schematic View

Patrick Briody & Sons Ltd.

DRILLING LOG

AQUADRILL SERVICES

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0739

Consultant/Engineer........ARUP........

Client........MEHL........

Borehole Reference No.................... Sheet........1......of......1........

Borehole Location..

Date of Drilling	Depth (from - to) Mtrs/Ft.	Actual Drilling Diametre	Drilling Conditions / Water Strike
12-5-10	started developing		@ BH 19 @ 11am
Thomas	until 2.30pm		
	started	BH	18. 3.30 – 630
		BH	.16 pm
		BH	15
13-5-10		BH	20 1 hour 11-12
	Had to	bail	no 18 due to
	depth down	to	water

Total Depth of Well..

Estimated Yield..

Depth to Rock..

Steel Casing Installed..

P.V.C. Casing/Screen Installed..

Other Remarks..

....

....

....

Lead Driller.......................... Drilling Rig....................

Engineer Approval..

Schematic View

Appendix A14.4.3

IGSL geotechnical logs for shell and auger boreholes and coreholes

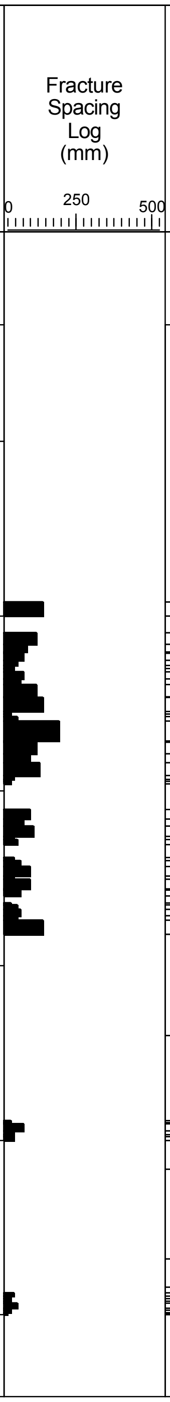
GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Phoniex Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 1 of 4
CO-ORDINATES	315,799.58 E 257,926.09 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
0.80	0	0	0
1.80	100	0	12
3.30	87	13	9
4.80	100	80	0
6.30	100	39	0
7.80	80	9	0
9.30	100	3	0
	67	33	0



Description	Depth (m)	Elevation
SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered mudstone	0.80	105.09
Highly weathered rock recovered as soft, orange/brown, sandy CLAY/SILT	1.10	104.79
Highly weathered rock recovered as stiff, dark brown, slightly sandy, slightly gravelly CLAY/SILT. Gravel is angular, fine to coarse of sandstone.	2.30	103.59
Highly weathered rock recovered as stiff, orange/brown, slightly sandy, slightly gravelly CLAY/SILT. Gravel is angular, fine to coarse of sandstone.	2.75	103.14
Highly weathered rock recovered as medium dense, orange/brown, clayey, gravelly SAND. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone.	3.20	102.69
Moderately strong to moderately weak, thickly laminated to thinly bedded (to structureless where clay-filled), interbedded fine-grained SANDSTONE and MUDSTONE with large amounts of orange/yellow/brown clay infill (Balrickard Formation), moderately to locally slightly weathered. Discontinuities are smooth, planar. Apertures are tight to open, commonly clay-filled (especially at 4.74-4.96m & 5.70-5.76m), commonly penetrative iron-oxide stained. Dips are sub-horizontal & locally sub-vertical.	6.00	99.89
Highly weathered rock recovered as brown clayey sandy GRAVEL. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone with pennetrative iron-oxide staining - Loss of recovery.	6.90	98.99
Weak, thinly bedded (to structureless where clay-filled), grey/dark grey/orange/brown, interbedded fine-grained SANDSTONE and SILTSTONE, moderately weathered. Discontinuities are smooth to rough, irregular. Apertures are tight to open, commonly clay-filled (especially at 7.20-7.40m & 7.80-8.05m). Dips are irregular.	8.00	97.89
Highly weathered rock recovered as brown clayey sandy GRAVEL. Sand is fine to coarse. Gravel is angular, fine to coarse of sandstone with pennetrative iron-oxide staining - Loss of recovery.	8.80	97.09
Highly weathered rock recovered as stiff, orange, slightly sandy CLAY.	9.00	96.89

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

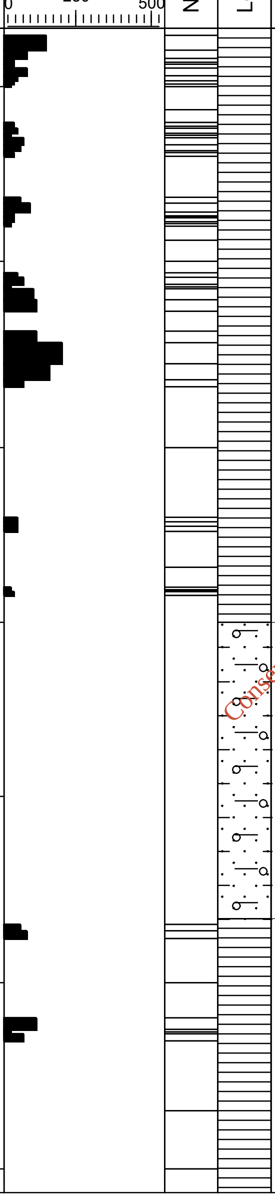
INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Phoniex Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 2 of 4
CO-ORDINATES	315,799.58 E 257,926.09 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
RIG TYPE		**DRILLED BY**	Petersen
FLUSH	Air/Mist	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		
CLIENT	MEHL		
ENGINEER	ARUP		



Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
10	10.50				Strong to moderately strong/weak, medium to thinly bedded (to structureless where clay-filled), grey/dark grey, interbedded fine-grained SANDSTONE and SILTSTONE with large amounts of brown clay infill (Donore Formation), slightly to moderately weathered. Core loss due to probable sandy clay-filled fracture at 9.3-9.9m & 13.6-14.1m). Discontinuities are smooth, planar. Apertures are tight to open, commonly clay-filled (especially at 10.70-10.81m, 11.10-11.45m, 11.70-11.82m, 12.00-12.10m, 12.43-12.60m, 13.08-13.60m, 14.32-14.63m), locally slightly iron-oxide stained. Dips are sub-horizontal & sub-vertical. *(continued)*				
11	12.00	93	14	0					
12	13.60	100	51	0					
13, 14	15.10	67	11	0		15.10	90.79		
15, 16	16.60	100	0	0	Highly weathered rock recovered as dense, dark brown/orange mottled, clayey gravelly SAND with occasional cobbles. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse of sandstone. Cobbles are sub-angular to sub-rounded of sandstone.				
17	18.20	100	9	0		17.65	88.24		
18, 19	19.80	81	14	0					

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

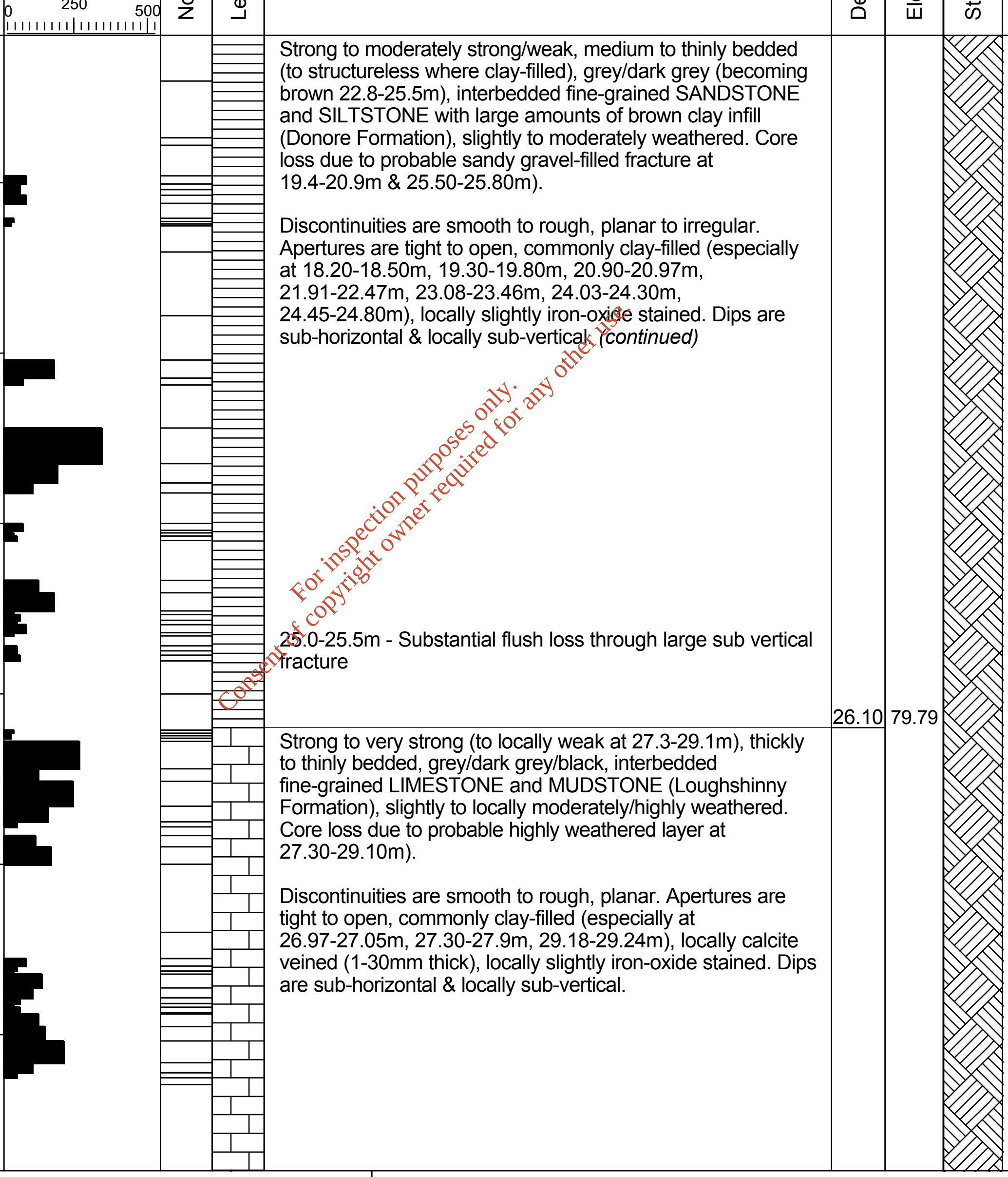
INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Phoniex Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 3 of 4
CO-ORDINATES	315,799.58 E 257,926.09 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		



Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation	SPT (N Value)
20–21.30	21.30	73	13	0	Strong to moderately strong/weak, medium to thinly bedded (to structureless where clay-filled), grey/dark grey (becoming brown 22.8-25.5m), interbedded fine-grained SANDSTONE and SILTSTONE with large amounts of brown clay infill (Donore Formation), slightly to moderately weathered. Core loss due to probable sandy gravel-filled fracture at 19.4-20.9m & 25.50-25.80m). Discontinuities are smooth to rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 18.20-18.50m, 19.30-19.80m, 20.90-20.97m, 21.91-22.47m, 23.08-23.46m, 24.03-24.30m, 24.45-24.80m), locally slightly iron-oxide stained. Dips are sub-horizontal & locally sub-vertical. *(continued)* 25.0-25.5m - Substantial flush loss through large sub vertical fracture	26.10	79.79	
	22.80	100	19	0				
	24.30	100	59	34				
	25.80	100	38	10				
	27.30	100	71	55	Strong to very strong (to locally weak at 27.3-29.1m), thickly to thinly bedded, grey/dark grey/black, interbedded fine-grained LIMESTONE and MUDSTONE (Loughshinny Formation), slightly to locally moderately/highly weathered. Core loss due to probable highly weathered layer at 27.30-29.10m). Discontinuities are smooth to rough, planar. Apertures are tight to open, commonly clay-filled (especially at 26.97-27.05m, 27.30-27.9m, 29.18-29.24m), locally calcite veined (1-30mm thick), locally slightly iron-oxide stained. Dips are sub-horizontal & locally sub-vertical.			
	28.80	60	5	0				
		100	76	36				

REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

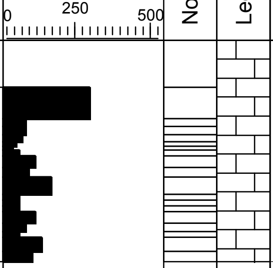
Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Phoniex Integrated Waste Management Facility	**DRILLHOLE NO**	**BH15**
		SHEET	Sheet 4 of 4
CO-ORDINATES	315,799.58 E 257,926.09 N	**DATE DRILLED**	06/04/2010
GROUND LEVEL (mOD)	105.89	**DATE LOGGED**	12/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm)	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	SPT (N Value)
30	30.40											
31		100	70	35				30.5-31.0m - Substantial flush loss through large sub vertical, partially calcite-filled fracture.				
	31.90								31.90	73.99		
32								End of Borehole at 31.90 m				
33												
34												
35												
36												
37												
38												
39												



REMARKS

Driller standing 5.25. hrs (Awaiting instruction 0.75hrs, grouting 4.5hrs). 2 no. single packer tests attempted at bottom of the hole, unable to pressurise test section in both cases due to sub-vertical fractures with large water loss.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
12-04-10	31.90	31.90	5.70	

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 1 of 6
CO-ORDINATES	315,875.22 E 258,294.73 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
RIG TYPE		**DRILLED BY**	Petersen
FLUSH	Air/Mist	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		
CLIENT	MEHL		
ENGINEER	ARUP		

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
0.00-0.80			
0.80-1.60	100	0	0
1.60-3.10	93	0	0
3.10-4.70	100	0	0
4.70-6.20	100	0	0
6.20-7.60	71	13	0
7.60-9.10	100	7	0
9.10-	80	0	0

Description	Depth (m)	Elevation
SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered shaley mudstone/sandstone with sandy gravelly clay layers.	0.80	103.99
Weak, structureless, black, highly weathered fine-grained MUDSTONE - recovered as angular gravel with bands of black sandy gravelly clay.	4.20	100.59
Weak, structureless, black, highly weathered fine-grained MUDSTONE - recovered as angular gravel with occasional bands of black sandy gravelly clay.	6.85	97.94
Moderately weak to moderately strong, thinly bedded to thinly laminated, dark grey/black, interbedded fine-grained SANDSTONE & SILTSTONE/MUDSTONE with large amounts of black clay infill (Walshestown Formation), moderately/highly to very locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 10.72-10.90m & 11.50-12.0m). Dips are 20-30° & sub-vertical.		

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER	14695
CONTRACT	Project Phoenix
DRILLHOLE NO	**BH16**
SHEET	Sheet 2 of 6
CO-ORDINATES	315,875.22 E 258,294.73 N
GROUND LEVEL (mOD)	104.79
DATE DRILLED	12/04/2010
DATE LOGGED	20/04/2010
RIG TYPE	
FLUSH	Air/Mist
INCLINATION (deg)	-90
CORE DIAMETER (mm)	102
CLIENT	MEHL
ENGINEER	ARUP
DRILLED BY	Petersen
LOGGED BY	D.O'Shea

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
10.60			
10.60–12.10	100	0	0
12.10–13.60	73	0	0
13.60–15.10	67	12	0
15.10–16.60	67	7	0
16.60–17.50	100	0	0
17.50–18.00	0	0	0
18.00–19.00	55	0	0
19.00–19.60	100	0	0

Fracture Spacing Log (mm): 0 – 250 – 500

Description	Depth (m)	Elevation
Moderately weak to moderately strong, thinly bedded to thinly laminated, dark grey/black, interbedded fine-grained SANDSTONE & SILTSTONE/MUDSTONE with large amounts of black clay infill (Walshestown Formation), moderately/highly to very locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 10.72-10.90m & 11.50-12.0m). Dips are 20-30° & sub-vertical. *(continued)*	12.00	92.79
Weak, structureless, orange/brown/black, highly weathered interbedded fine-grained SANDSTONE & MUDSTONE - recovered as angular gravel with bands of black sandy gravelly clay. Gravel is angular, fine to coarse with orange/brown, iron-oxide staining.	14.40	90.39
Weak, structureless, orange/brown/black/grey, highly weathered fine-grained interbedded SANDSTONE & MUDSTONE - recovered as sandy angular gravel. 17.5-18.0m - No recovery - probable highly weathered rock.	19.70	85.09

Backfill Elevation (mOD): 86.79, 85.79, 84.79

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT Project Phoenix

DRILLHOLE NO **BH16**
SHEET Sheet 3 of 6

CO-ORDINATES 315,875.22 E
258,294.73 N
GROUND LEVEL (mOD) 104.79

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

DATE DRILLED 12/04/2010
DATE LOGGED 20/04/2010

CLIENT MEHL
ENGINEER ARUP

DRILLED BY Petersen
LOGGED BY D.O'Shea

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
20.70	100	16	15
21.10	100	0	0
22.60	33	0	0
23.80	88	4	0
24.60	94	6	0
25.50	89	19	0
27.00	100	18	0
28.50	7	0	0
30.00	33	12	0

Description	Depth (m)	Elevation
Moderately weak to moderately strong, thinly bedded to thinly laminated, grey/orange/brown, fine-grained SANDSTONE (Walshestown Formation), moderately weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-smeared, commonly moderately iron-oxide stained. Dips are 20-30° & sub-vertical. *(continued)*	25.00	79.79
Moderately strong, medium to thinly bedded, black, fine-grained MUDSTONE (Walshestown Formation), slightly weathered. Discontinuities are smooth, planar. Apertures are tight to moderately open, locally clay-smeared. Dips are 20-30° & sub-vertical.	25.50	79.29
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black/brown, interbedded fine-grained SILTSTONE & MUDSTONE with large amounts of black clay infill (Walshestown Formation), slightly to locally moderately/highly weathered. Discontinuities are smooth to locally rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 26.0-26.15m, 26.42-26.47m, 30.98-31.18m, 31.33-31.41m). Dips are 20-30° & sub-vertical. 27.0-27.5m - No recovery - probable highly weathered rock.		

Backfill Elevation (mOD): 82.79, 81.79, 80.79

REMARKS
Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GROUNDWATER DETAILS

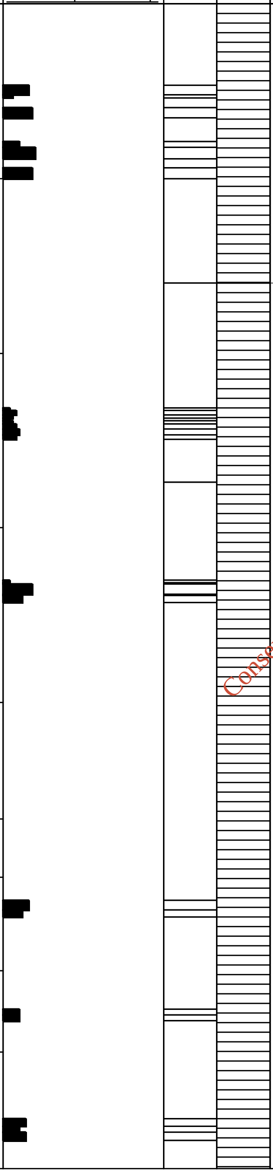
Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 4 of 6
CO-ORDINATES	315,875.22 E 258,294.73 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
30 – 31.50	31.50	60	5	0
31.50 – 33.00	33.00	80	18	14
33.00 – 34.50	34.50	80	22	0
34.50 – 36.00	36.00	100	19	0
36.00 – 37.00	37.00	100	10	0
37.00 – 37.50	37.50	100	10	0
37.50 – 38.30	38.30	88	18	0
38.30 – 39.00	39.00	100	10	0
39.00 –		100	23	0



Description	Depth (m)	Elevation
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black/brown, interbedded fine-grained SILTSTONE & MUDSTONE with large amounts of black clay infill (Walshestown Formation), slightly to locally moderately/highly weathered. Discontinuities are smooth to locally rough, planar to irregular. Apertures are tight to open, commonly clay-filled (especially at 26.0-26.15m, 26.42-26.47m, 30.98-31.18m, 31.33-31.41m). Dips are 20-30° & sub-vertical. *(continued)*	32.40	72.39
Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical.		

Standpipe Details | Backfill Elevation (mOD)

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

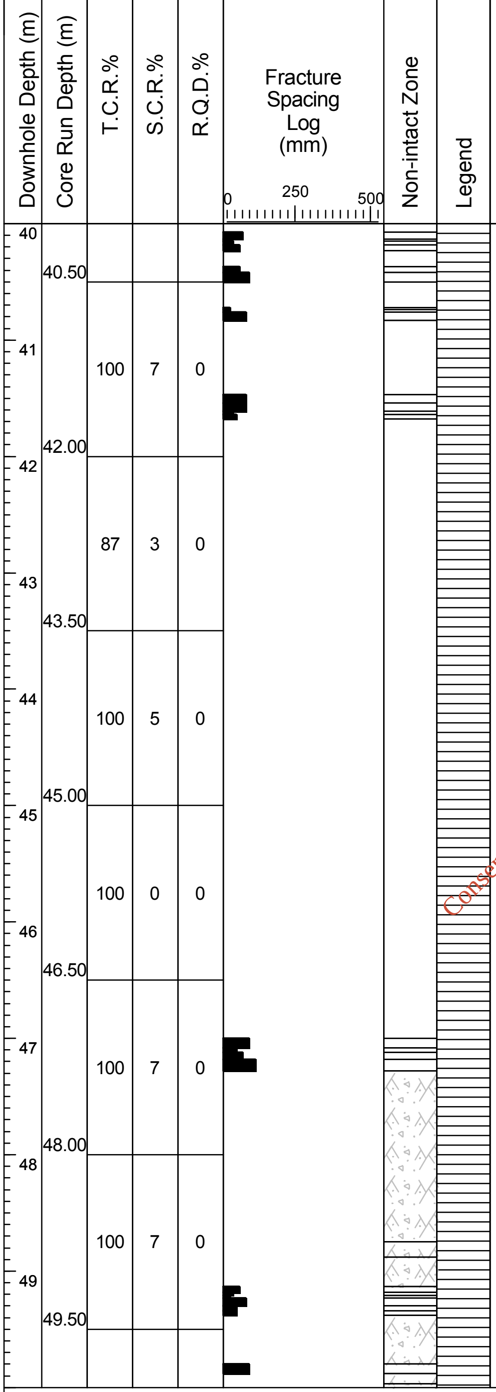
GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 5 of 6
CO-ORDINATES	315,875.22 E 258,294.73 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
40.50			
42.00	100	7	0
43.50	87	3	0
45.00	100	5	0
46.50	100	0	0
48.00	100	7	0
49.50	100	7	0

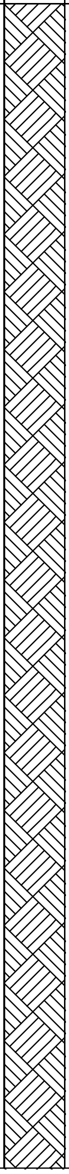


Description

Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered.

Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical.
(continued)

Depth (m) | Elevation | Standpipe Details | Backfill Elevation (mOD)



REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

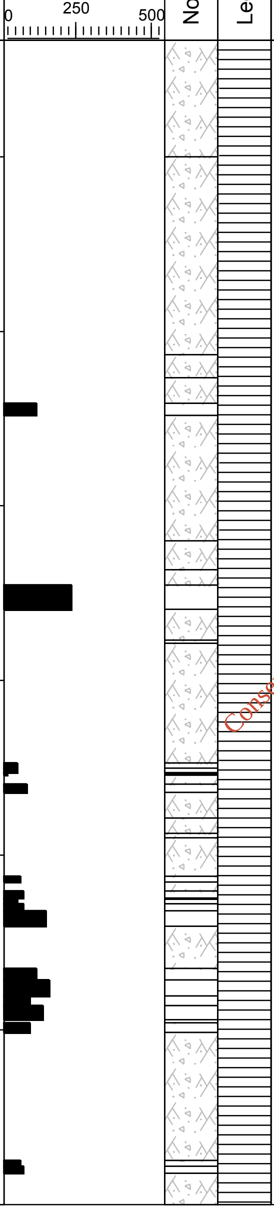
Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH16**
		SHEET	Sheet 6 of 6
CO-ORDINATES	315,875.22 E 258,294.73 N	**DATE DRILLED**	12/04/2010
GROUND LEVEL (mOD)	104.79	**DATE LOGGED**	20/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		

Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
50		100	16	0
51	51.00	100	2	0
52	52.50	100	4	0
53–54	54.00	100	15	0
55	55.50	100	7	0
56–57	57.00	100	31	9
58	58.50	87	8	0
59	60.00			



Description

Moderately weak to moderately strong, medium bedded to thinly laminated, dark grey/black, MUDSTONE (Walshestown Formation possibly grading into the Balrickard Formation from approx. 58.00m), fresh to locally slightly weathered.

Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 48.75-48.89m, 52.7-52.9m, 54.3-54.55m, 55.14-55.18m, 56.46-56.68m, 56.81-56.85m, 57.61-57.97m), locally slightly iron-oxide stained. Dips are 20-30° & sub-vertical.
(continued)

58.07-58.20m - Limestone layer

Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
60.00	44.79		44.79

End of Borehole at 60.00 m

REMARKS

Driller standing 5 hrs (grouting 5hrs). 2 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
19-04-10	60.00	60.00	2.50	

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
20-04-10	24.00	18.00	24.00	50mm SP

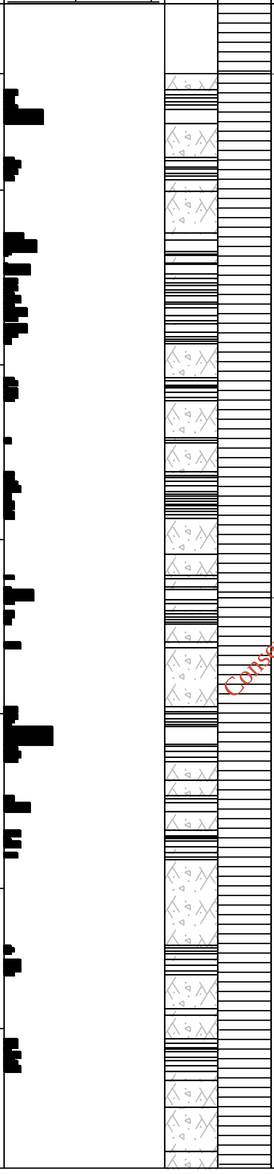
GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

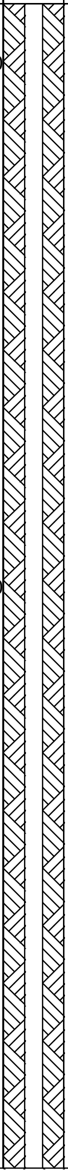
CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,724.24 E 258,072.82 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea

RIG TYPE
FLUSH Air/Mist
INCLINATION (deg) -90
CORE DIAMETER (mm) 102

Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%
0.60			
1.60	100	14	0
3.10	100	12	0
4.60	100	19	0
6.10	100	24	0
7.60	100	39	0
8.80	100	13	0
	100	17	0



Description	Depth (m)	Elevation
SYMMETRIX OPEN HOLE DRILLING: Observed by driller as returns of brown highly weathered shaley mudstone/sandstone with clay layers.	0.60	109.90
Moderately strong to moderately weak, thickly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey/brown interbedded fine-grained SANDSTONE and MUDSTONE with large amounts of orange/yellow/brown clay infill (Possible Balrickard Formation), moderately to locally slightly weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 1.61-1.97m, 2.72-2.75m, 3.41-3.73m, 4.73-4.91m & 4.94-5.01m), strongly iron-oxide stained. Dips are 20-30° & 70° to sub-vertical.	5.10	105.40
Moderately strong to moderately weak, thinly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey interbedded fine-grained SANDSTONE and MUDSTONE (Possible Donore Formation), slightly to locally moderately weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 5.53-6.04m, 7.35-8.09m, 9.25-9.48m, 9.86-10.11m, 10.29-10.4m, 11.14-11.31m, 11.66-12.0m, 12.08-12.11m, 12.51-13.0m, 13.21-13.44m, 13.79-13.93m, 14.23-14.51m, 14.86-15.2m), strongly iron-oxide stained. Dips are 30-50° & locally sub-vertical. 7.5-8.05m -poor recovery - probable highly weathered rock.		



REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	19.00	15.00	21.20	50mm SP
22-04-10	20.00	15.00	21.20	50mm SP

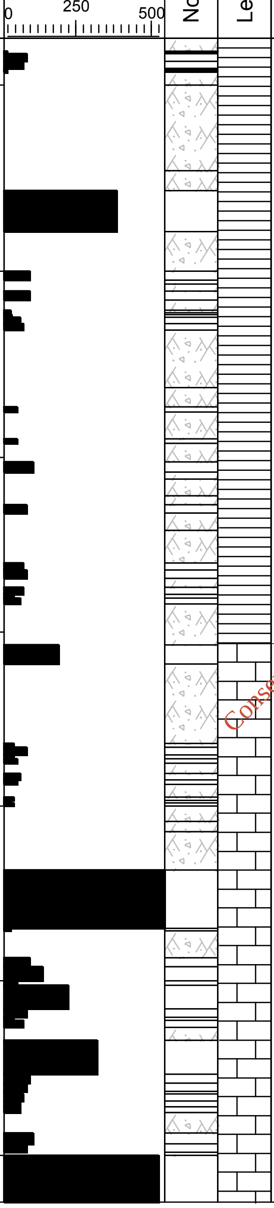
GROUNDWATER DETAILS

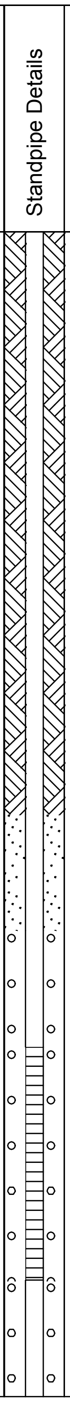
Date	Hole Depth	Casing Depth	Depth to Water	Comments

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,724.24 E 258,072.82 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**INCLINATION (deg)**	-90
ENGINEER	ARUP	**CORE DIAMETER (mm)**	102
DRILLED BY	Petersen	**LOGGED BY**	D.O'Shea





Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Description	Depth (m)	Elevation	Backfill Elevation (mOD)
10	10.40				Moderately strong to moderately weak, thinly laminated to medium bedded (to structureless where clay-filled), black/grey/dark grey interbedded fine-grained SANDSTONE and MUDSTONE (Possible Donore Formation), slightly to locally moderately weathered. Discontinuities are smooth to locally rough, planar. Apertures are tight to open, commonly clay-filled (especially at 5.53-6.04m, 7.35-8.09m, 9.25-9.48m, 9.86-10.11m, 10.29-10.4m, 11.14-11.31m, 11.66-12.0m, 12.08-12.11m, 12.51-13.0m, 13.21-13.44m, 13.79-13.93m, 14.23-14.51m, 14.86-15.2m), strongly iron-oxide stained. Dips are 30-50° & locally sub-vertical. *(continued)*			
11		100	5	0				
12	12.00	100	19	0	12.7-12.85m -clay layer with angular and linear white mineralisation			
13	13.60							
14		100	8	0	14.80m - Substantial flush loss (100%)			95.50
15	15.10					15.20	95.30	
		100	22	11	Strong to very strong (to locally weak where shale), thickly bedded to thinly laminated, grey/dark grey/black, interbedded fine-grained LIMESTONE and MUDSTONE (Shale) (Loughshinny Formation), slightly to locally moderately/highly weathered. Discontinuities are smooth to locally rough, planar to locally stepped. Apertures are tight to open, locally clay-filled (especially at 15.38-16.06m), strongly iron-oxide stained, locally calcite-veined (2-8mm thick). Dips are 10-20° & locally 70-80°.			94.50
16	16.60							
17		100	59	36				93.50
18	18.10							
		100	81	29	18.6-19.0m - Large sub vertical fracture			91.50
19	19.60							90.50

REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

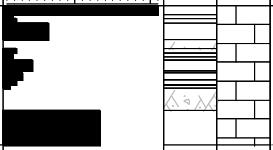
INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	19.00	15.00	21.20	50mm SP
22-04-10	20.00	15.00	21.20	50mm SP

GEOTECHNICAL CORE LOG RECORD

REPORT NUMBER 14695

CONTRACT	Project Phoenix	**DRILLHOLE NO**	**BH18**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,724.24 E 258,072.82 N	**DATE DRILLED**	20/04/2010
GROUND LEVEL (mOD)	110.50	**DATE LOGGED**	22/04/2010
RIG TYPE			
FLUSH	Air/Mist		
CLIENT	MEHL	**DRILLED BY**	Petersen
ENGINEER	ARUP	**LOGGED BY**	D.O'Shea
INCLINATION (deg)	-90		
CORE DIAMETER (mm)	102		



Downhole Depth (m)	Core Run Depth (m)	T.C.R.%	S.C.R.%	R.Q.D.%	Fracture Spacing Log (mm)	Non-intact Zone	Legend	Description	Depth (m)	Elevation	Standpipe Details	Backfill Elevation (mOD)
20		100	81	51								
21	21.20							End of Borehole at 21.20 m	21.20	89.30		89.30
22												
23												
24												
25												
26												
27												
28												
29												

REMARKS

Driller standing 1.5 hrs (grouting). 1 no. packer tests attempted.

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike recorded

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type
22-04-10	19.00	15.00	21.20	50mm SP
22-04-10	20.00	15.00	21.20	50mm SP

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments
22-04-10	21.20	0.60	9.00	

GEOTECHNICAL BORING RECORD

REPORT NUMBER	14695
CONTRACT	MEHL Integrated Waste Management Facility
BOREHOLE NO.	**BH21**
SHEET	Sheet 1 of 2
CO-ORDINATES	316,074.94 E 258,199.63 N
GROUND LEVEL (m AOD)	120.70
RIG TYPE	Dando
BOREHOLE DIAMETER (mm)	200
BOREHOLE DEPTH (m)	20.00
DATE DRILLED	14/04/2010
DATE LOGGED	14/04/2010
CLIENT	MEHL
ENGINEER	WYG
SPT HAMMER REF. NO.	
ENERGY RATIO (%)	
BORED BY	J.Edwards
PROCESSED BY	F.C

Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Samples Sample Type	Samples Depth (m)	Samples Recovery	Field Test Results	Standpipe Details
MADE GROUND (Stockpile - Comprised of dark grey sandy gravelly clay)									
				R2005	B	0.50-0.50			
				R2006	B	1.00-1.00			
				R2007	U	1.00-1.45	50%rec 12 blows		
				R2008	D	1.45-1.60			
				R2009	B	2.00-2.00			
				R2010	D	2.50-2.50			
				R2011	U	3.00-3.45	50%rec 9 blows		
				R2012	D	3.45-3.60			
				R2013	B	4.00-4.00			
				R2014	D	4.50-4.50			
				R2015	U	5.00-5.45	60%rec 12 blows		
				R2016	D	5.45-5.60			
				R2017	B	6.00-6.00			
		114.00	6.70	R2018	D	6.50-6.50			
Light brown sandy gravelly CLAY with some cobbles (occasionally grading to clayey gravel)				R2019	B	6.70-6.70			
				R2020	U	7.00-7.45	80%rec 29 blows		
				R2021	D	7.45-7.60			
				R2022	B	8.00-8.00			
				R2023	D	8.50-8.50			
		111.40	9.30	R2024	U	9.00-9.45	60%rec 42 blows		
Black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2025	D	9.45-9.60			

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
7.7	7.8	0.75	
11	11.05	0.5	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Hole located on top of clay stockpile

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH21**
		SHEET	Sheet 2 of 2
CO-ORDINATES	316,074.94 E 258,199.63 N	**DATE DRILLED**	14/04/2010
GROUND LEVEL (m AOD)	120.70	**DATE LOGGED**	14/04/2010
RIG TYPE	Dando	**BORED BY**	J.Edwards
BOREHOLE DIAMETER (mm)	200	**PROCESSED BY**	F.C
BOREHOLE DEPTH (m)	20.00		
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
10	Black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone *(continued)*				R2026	B	10.00-10.00			
			110.00	10.70	R2027	D	10.50-10.50			
11	Angular cobbly gravel of moderately weathered SILTSTONE/MUDSTONE		109.60	11.10	R2028	B	11.00-11.00			
	Black/orange sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2029	D	11.50-11.50			
12					R2030	U	12.00-12.45	80%rec 39 blows		
			108.00	12.70	R2031	D	12.45-12.60			
13	Dark brown/orange sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2032	B	13.00-13.00			
					R2033	D	13.50-13.50			
14					R2034	U	14.00-14.60	0%rec 43 blows		
					R2035	D	14.50-14.50			
15					R2036	B	15.00-15.00			
					R2037	D	15.50-15.50			
16					R2038	U	16.00-16.45	60%rec 44 blows		
					R2039	D	16.45-16.60			
17					R2040	B	17.00-17.00			
					R2041	D	17.50-17.50			
18			102.30	18.40	R2042	U	18.00-18.45	15%rec 72 blows		
	Grey brown / green sandy gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				R2043	D	18.45-18.60			
19					R2044	B	19.00-19.00			
			101.10	19.60	R2045	U	19.40-19.85	100%rec 52 blows		
	Very stiff dark grey/grey sandy gravelly CLAY		100.70	20.00	R2046	D	19.85-20.00			

End of Borehole at 20.00m

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
7.7	7.8	0.75	
11	11.05	0.5	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Hole located on top of clay stockpile

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT MEHL Integrated Waste Management Facility

BOREHOLE NO. **BH22**
SHEET Sheet 1 of 1

CO-ORDINATES 315,961.50 E
258,091.66 N
GROUND LEVEL (m AOD) 123.83

RIG TYPE Dando
BOREHOLE DIAMETER (mm) 200
BOREHOLE DEPTH (m) 5.90

DATE DRILLED 09/04/2010
DATE LOGGED 12/04/2010

CLIENT MEHL
ENGINEER WYG

SPT HAMMER REF. NO.
ENERGY RATIO (%)

BORED BY J.Edwards
PROCESSED BY F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	MADE GROUND (Comprised of brown sandy gravelly clay with cobbles)	▨	122.83	1.00	AJ6563	B	0.50-0.95		N = 12 (1, 3, 3, 3, 3, 3)	
1	Firm, dark brown slightly sandy gravelly SILT with angular cobbles of weathered siltstone / mudstone		117.93	5.90	AJ6564	D	1.00-1.00			
					AJ6565	U	1.50-2.10	0%rec		
2					AJ6566	D	2.00-2.00			
					AJ6567	D	2.50-2.50			
3					AJ6568	B	3.00-3.45		N = 14 (2, 3, 5, 3, 3, 3)	
					AJ6569	D	3.50-3.50			
4					AJ6570	U	4.50-4.95	60%rec 19 blows		
5					AJ6571	D	4.95-5.10			
					AJ6572	B	5.50-5.50			
6	Obstruction End of Borehole at 5.90 m				AJ6573	B	5.90-5.90			
7										
8										
9										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.7	2.75	0.75	
5.1	5.2	0.75	
5.8	5.9	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Obstruction at 5.90m . Moved 1m to BH22A and rebored

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH22A**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	123.73	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	20.60
DATE DRILLED	12/04/2010	**DATE LOGGED**	13/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	MADE GROUND (Comprised of brown sandy gravelly clay with cobbles)		122.73	1.00						
1	Dark brown sandy very gravelly CLAY with occasional cobbles of weathered mudstone / siltstone		117.23	6.50						
	Dark brown slightly sandy gravelly CLAY with angular cobbles of weathered siltstone / mudstone.		116.63	7.10	AJ6574	D	6.50-6.50			
					AJ6575	B	7.00-7.00			
7	Firm to stiff, black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone				AJ6576	U	7.50-7.95			
					AJ6577 AJ6578	D B	7.95-8.10 8.00-8.00			
					AJ6579	D	8.50-8.50			
9					AJ6580 AJ6581	D B	9.00-9.45 9.00-9.50		N = 22 (1, 2, 4, 4, 6, 8)	

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
- D - Small Disturbed (tub)
- B - Bulk Disturbed
- LB - Large Bulk Disturbed
- Env - Environmental Sample (Jar + Vial + Tub)
- U - Undisturbed 100mm Diameter Sample
- P - Undisturbed Piston Sample
- W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH22A**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	123.73	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	20.60
DATE DRILLED	12/04/2010	**DATE LOGGED**	13/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
BORED BY	J.Edwards	**PROCESSED BY**	F.C

Depth (m)	Description	Elevation	Depth (m)	Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results
10	Firm to stiff, black/orange sandy very gravelly CLAY with occasional angular cobbles of weathered mudstone / siltstone *(continued)*	112.73	11.00	AJ6582	B	10.00-10.00		
				AJ6583	U	10.50-10.95	40%rec 20 blows	
11	Firm to stiff dark brown/orange slightly sandy gravelly SILT with occasional cobbles of weathered mudstone / siltstone.	110.73	13.00	AJ6584	D	10.95-11.10		
				AJ6585	B	11.00-11.00		
				AJ6586	D	11.50-11.50		
12				AJ6587	D	12.00-12.45		N = 15 (1, 2, 3, 3, 4, 5)
				AJ6588	B	12.00-12.50		
13	Firm to stiff black /orange sandy gravelly CLAYSILT with occasional cobbles of weathered mudstone / siltstone	106.83	16.90	AJ6589	B	13.00-13.00		
				AJ6590	U	13.50-13.95	50%rec 20 blows	
14				AJ6591	D	13.95-14.10		
				AJ6592	B	14.00-14.00		
				AJ6593	D	14.50-14.50		
15				AJ6594	B	15.00-15.45		N = 50/75 mm (2, 11, 50)
				AJ6595	D	15.50-15.50		
16				AJ6596	B	16.50-16.95		N = 23 (3, 4, 6, 5, 5, 7)
17	Grey/green sandy very gravelly CLAY	106.33	17.40	AJ6597	D	17.00-17.00		
	Very stiff grey/brown/green slightly sandy slightly gravelly CLAY with occasional cobbles of weathered mudstone / siltstone	105.13	18.60	AJ6598	B	17.50-17.50		
18				AJ6599	B	18.00-18.45		N = 49 (5, 7, 13, 12, 12, 12)
	Dark grey/green sandy very gravelly CLAY	104.23	19.50	AJ6600	D	18.50-18.50		
19				AJ6601	B	19.00-19.00		
	Black dense clayey GRAVEL			AJ6602	U	19.50-19.95	90%rec 67 blows	

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER

14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH22A**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,960.83 E 258,090.71 N	**RIG TYPE**	Dando
		BOREHOLE DIAMETER (mm)	200
GROUND LEVEL (m AOD)	123.73	**BOREHOLE DEPTH (m)**	20.60
		DATE DRILLED	12/04/2010
		DATE LOGGED	13/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
20	Black dense clayey GRAVEL *(continued)*		103.13	20.60	AJ6603 AJ6604	D B	19.95-20.10 20.10-20.55		N = 50/225 mm (6, 11, 16, 17, 17)	▨
	End of Borehole at 20.60 m									
21										
22										
23										
24										
25										
26										
27										
28										
29										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.45	2.5	0.5	
6.25	6.3	0.5	
10.1	10.15	0.5	
11.45	11.5	0.5	
15.3	15.4	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Chiselling also 17.45-17.50=0.5hr / Backfill with bentonite GL - 20.60m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH23**
		SHEET	Sheet 1 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N	**RIG TYPE**	Dando
GROUND LEVEL (m AOD)	125.08	**BOREHOLE DIAMETER (mm)**	200
		BOREHOLE DEPTH (m)	22.70
		DATE DRILLED	07/04/2010
		DATE LOGGED	08/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
0	Firm to stiff brown sandy gravelly CLAY with occasional cobbles									
					AJ6528	B	0.50-0.50			
1					AJ6529 AJ6530	D B	1.00-1.45 1.00-1.50		N = 15 (1, 2, 5, 4, 3, 3)	
2					AJ6531	U	2.00-2.45	70%rec 50 blows		
					AJ6532	D	2.45-2.60			
3					AJ6533 AJ6534	D B	3.00-3.45 3.00-3.50		N = 18 (2, 4, 4, 3, 5, 6)	
4			120.98	4.10	AJ6535	D	4.00-4.00			
	Dark brown sandy very gravelly CLAY with some cobbles of weathered mudstone / siltstone		120.28	4.80						
5	Firm to stiff dark brown slightly sandy gravelly CLAY with some cobbles and some bands of yellow/brown sand (grading in places to a clayey sandy gravel)				AJ6536 AJ6537	D B	5.00-5.45 5.00-5.50		N = 14 (2, 3, 5, 3, 3, 3)	
6					AJ6538	U	6.00-6.45	80%rec 28 blows		
					AJ6539	D	6.45-6.60			
7					AJ6540 AJ6541	D B	7.00-7.45 7.00-7.50		N = 12 (1, 2, 3, 3, 3, 3)	
8					AJ6542	U	8.00-8.60	0%rec 57 blows		
9					AJ6543	B	9.00-9.45		N = 23 (2, 5, 6, 6, 5, 6)	
			115.08	10.00						

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

REMARKS Backfill with bentonite GL - 23.00m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH23**
		SHEET	Sheet 2 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N	**RIG TYPE**	Dando
		BOREHOLE DIAMETER (mm)	200
GROUND LEVEL (m AOD)	125.08	**BOREHOLE DEPTH (m)**	22.70
		DATE DRILLED	07/04/2010
		DATE LOGGED	08/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples: Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
10	Purplish brown / grey brown sightly sandy gravelly SILT/CLAY				AJ6544	D	10.00-10.00			
11					AJ6545 AJ6546	D B	11.00-11.45 11.00-11.50		N = 12 (1, 2, 4, 3, 2, 3)	
12					AJ6547	B	12.00-12.45		N = 29 (2, 5, 7, 7, 7, 8)	
13					AJ6548	D	13.00-13.00			
14					AJ6549 AJ6550	D B	14.00-14.45 14.00-14.50		N = 13 (1, 3, 3, 4, 3, 3)	
15					AJ6551	D	15.00-15.00			
16					AJ6552 AJ6553	D B	16.00-16.45 16.00-16.50		N = 48/225 mm (2, 2, 16, 16, 16)	
17					AJ6554	B	17.50-17.95		N = 24 (2, 3, 9, 7, 3, 5)	
			107.08	18.00						
18	Grey green very gravelly CLAY				AJ6555	D	18.00-18.00			
			106.58	18.50						
	Yellow brown clayey GRAVEL / gravelly CLAY									
19			105.68	19.40						
	Medium dense clayey GRAVEL / stiff very gravelly CLAY				AJ6556 AJ6557	B U	19.40-19.40 19.50-19.95	80%rec 32 blows		
			105.18	19.90						

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Backfill with bentonite GL - 23.00m

Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

GEOTECHNICAL BORING RECORD

REPORT NUMBER 14695

CONTRACT	MEHL Integrated Waste Management Facility	**BOREHOLE NO.**	**BH23**
		SHEET	Sheet 3 of 3
CO-ORDINATES	315,960.42 E 257,968.59 N	**RIG TYPE**	Dando
		BOREHOLE DIAMETER (mm)	200
GROUND LEVEL (m AOD)	125.08	**BOREHOLE DEPTH (m)**	22.70
		DATE DRILLED	07/04/2010
		DATE LOGGED	08/04/2010
CLIENT	MEHL	**SPT HAMMER REF. NO.**	
ENGINEER	WYG	**ENERGY RATIO (%)**	
		BORED BY	J.Edwards
		PROCESSED BY	F.C

Depth (m)	Description	Legend	Elevation	Depth (m)	Samples Ref. Number	Sample Type	Depth (m)	Recovery	Field Test Results	Standpipe Details
20	Dark grey/ black slightly sandy slightly gravelly CLAY *(continued)*				AJ6558	D	19.95-20.10			
					AJ6559	B	20.50-20.50			
21					AJ6560	U	21.00-21.45	70%rec 61 blows		
					AJ6561	D	21.45-21.60			
22										
			102.38	22.70	AJ6562	B	22.50-22.70			
	End of Borehole at 22.70 m									
23										
24										
25										
26										
27										
28										
29										

HARD STRATA BORING/CHISELLING

From (m)	To (m)	Time (h)	Comments
2.75	2.8	0.5	
3.85	3.9	0.5	
16.45	16.5	0.5	
20.4	20.5	0.75	
22.6	22.7	1	

WATER STRIKE DETAILS

Water Strike	Casing Depth	Sealed At	Rise To	Time (min)	Comments
					No water strike

INSTALLATION DETAILS

Date	Tip Depth	RZ Top	RZ Base	Type

GROUNDWATER DETAILS

Date	Hole Depth	Casing Depth	Depth to Water	Comments

REMARKS Backfill with bentonite GL - 23.00m

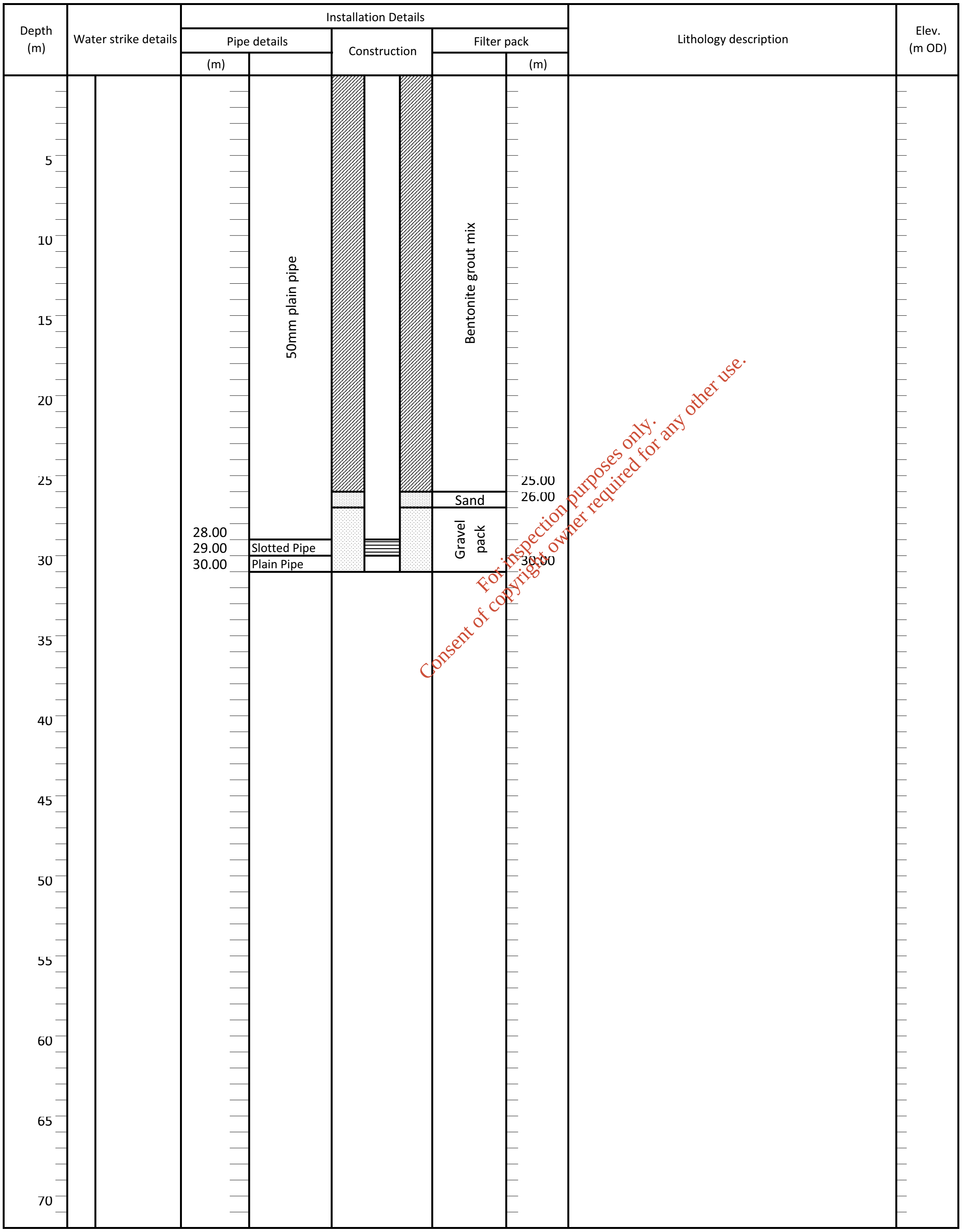
Sample Legend
D - Small Disturbed (tub)
B - Bulk Disturbed
LB - Large Bulk Disturbed
Env - Environmental Sample (Jar + Vial + Tub)
U - Undisturbed 100mm Diameter Sample
P - Undisturbed Piston Sample
W - Water Sample

Appendix A14.4.4

IGSL summary well logs

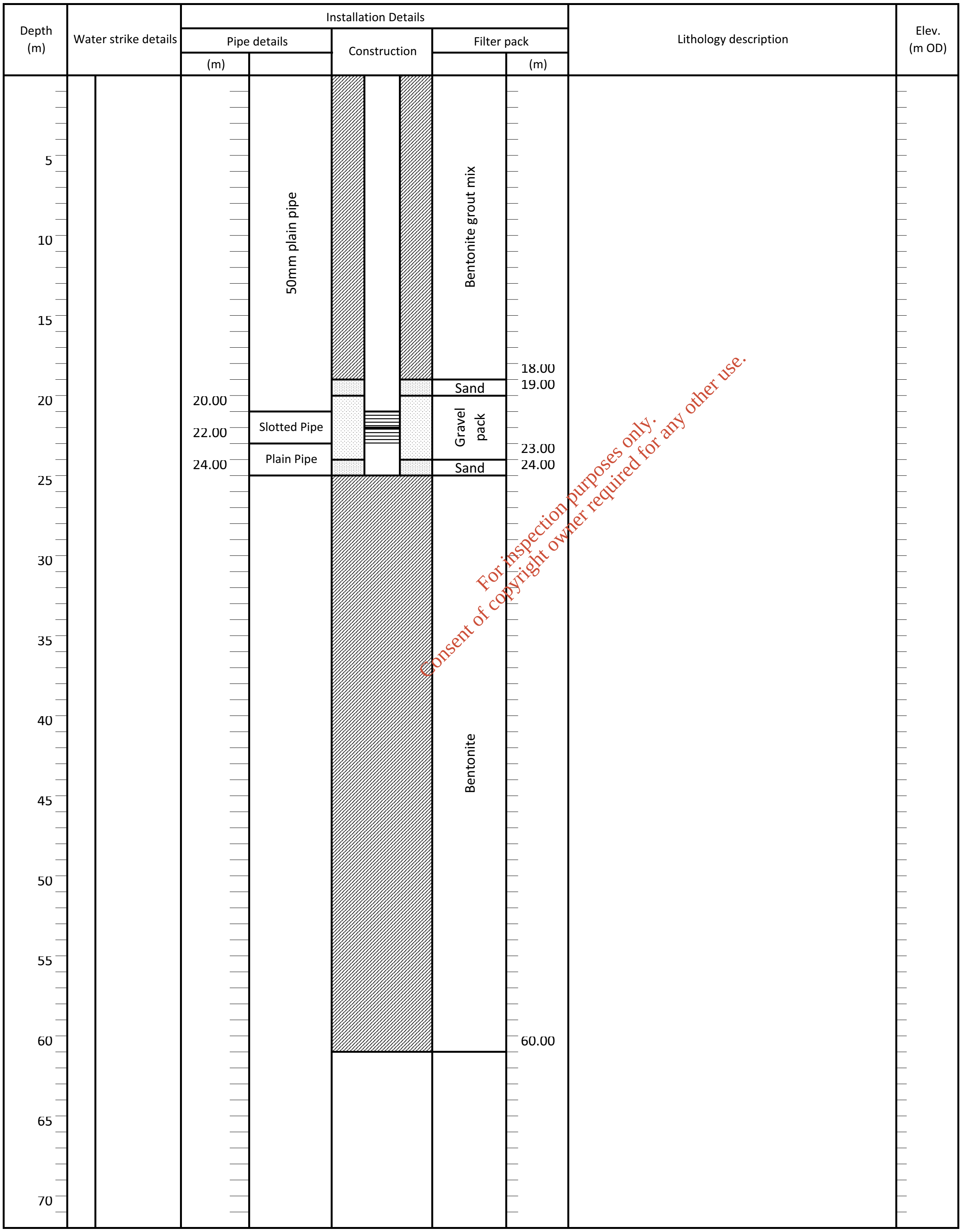
MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH15A**
Date Drilled 16-22/4/2010	Driller Briody	Drill method: Rotary Corehole	X; 315786.30
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Polymer Gel	Y: 257849.63
Comments:		Hole diameter: 150-250	Z (mOD): 105.89



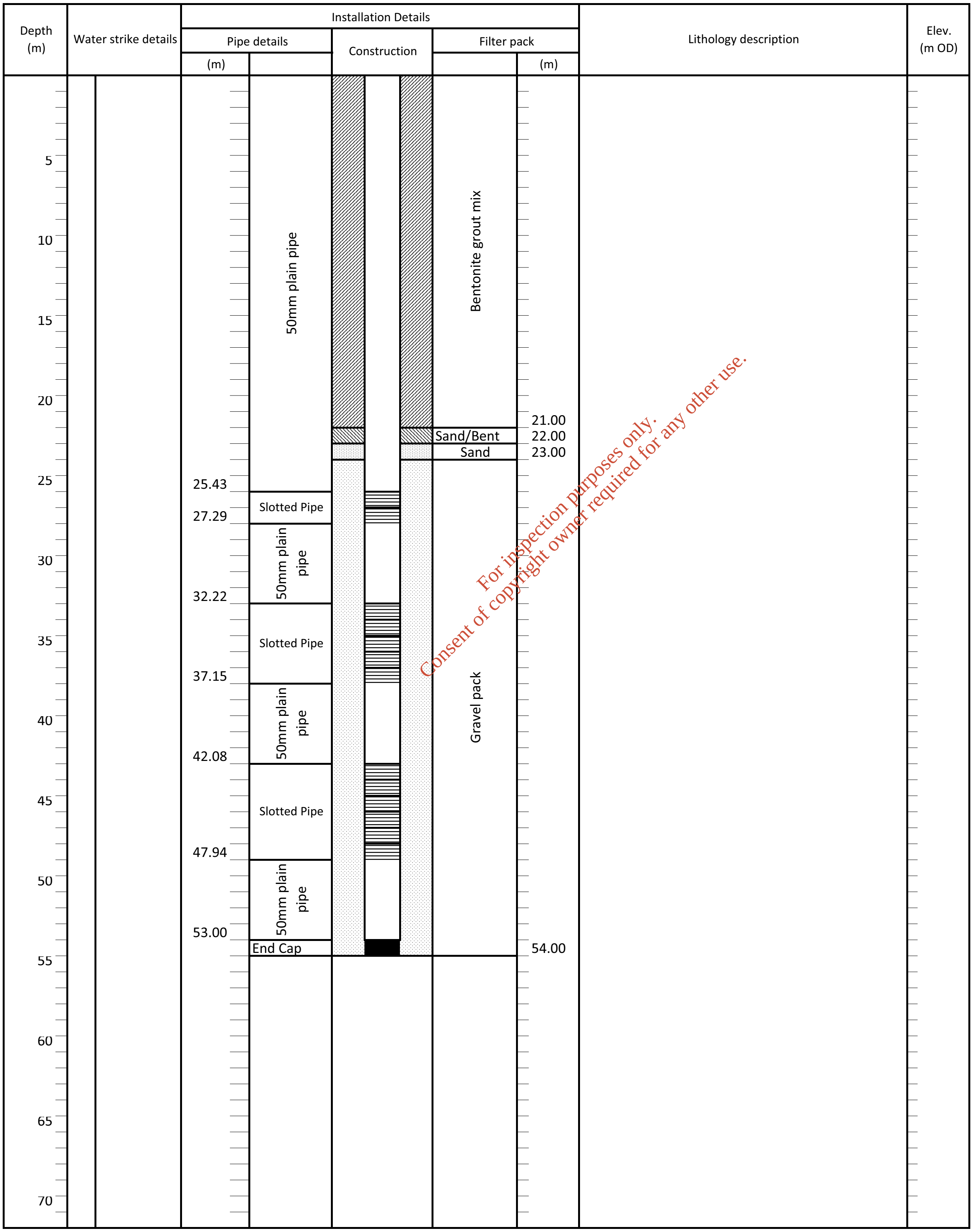
MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH16**
Date Drilled 12-20/4/2010	Driller IGSL	Drill method: Rotary Corehole	X; 315861.921
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Polymer Gel	Y: 258218.233
Comments:		Hole diameter: 150	Z (mOD): 104.789



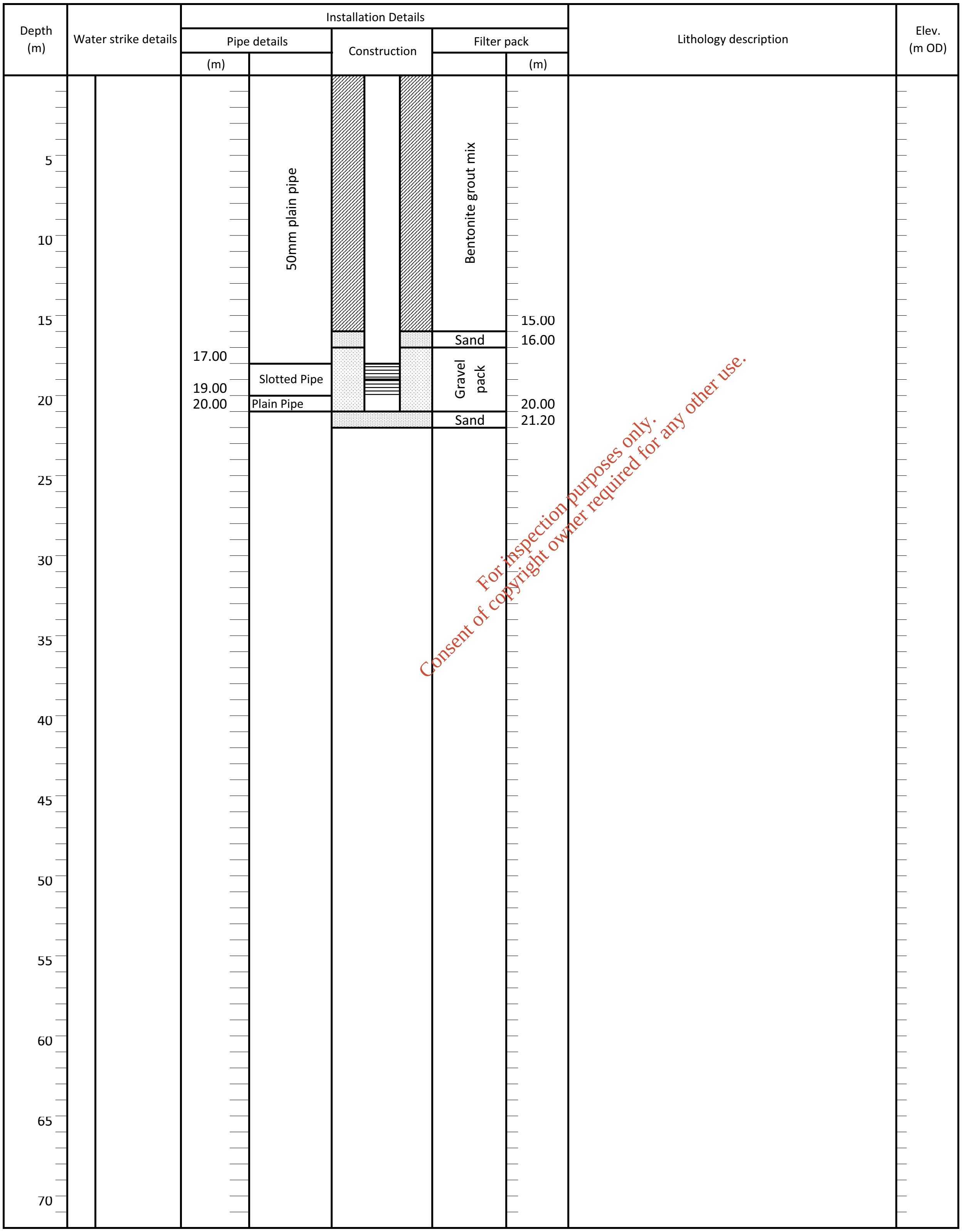
MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH17**
Date Drilled 5-15/5/2010	Driller Briody	Drill method: Rotary Corehole	X; 315794.71
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Mist	Y: 258003.06
Comments:		Hole diameter: 150 - 250	Z (mOD): 105.41



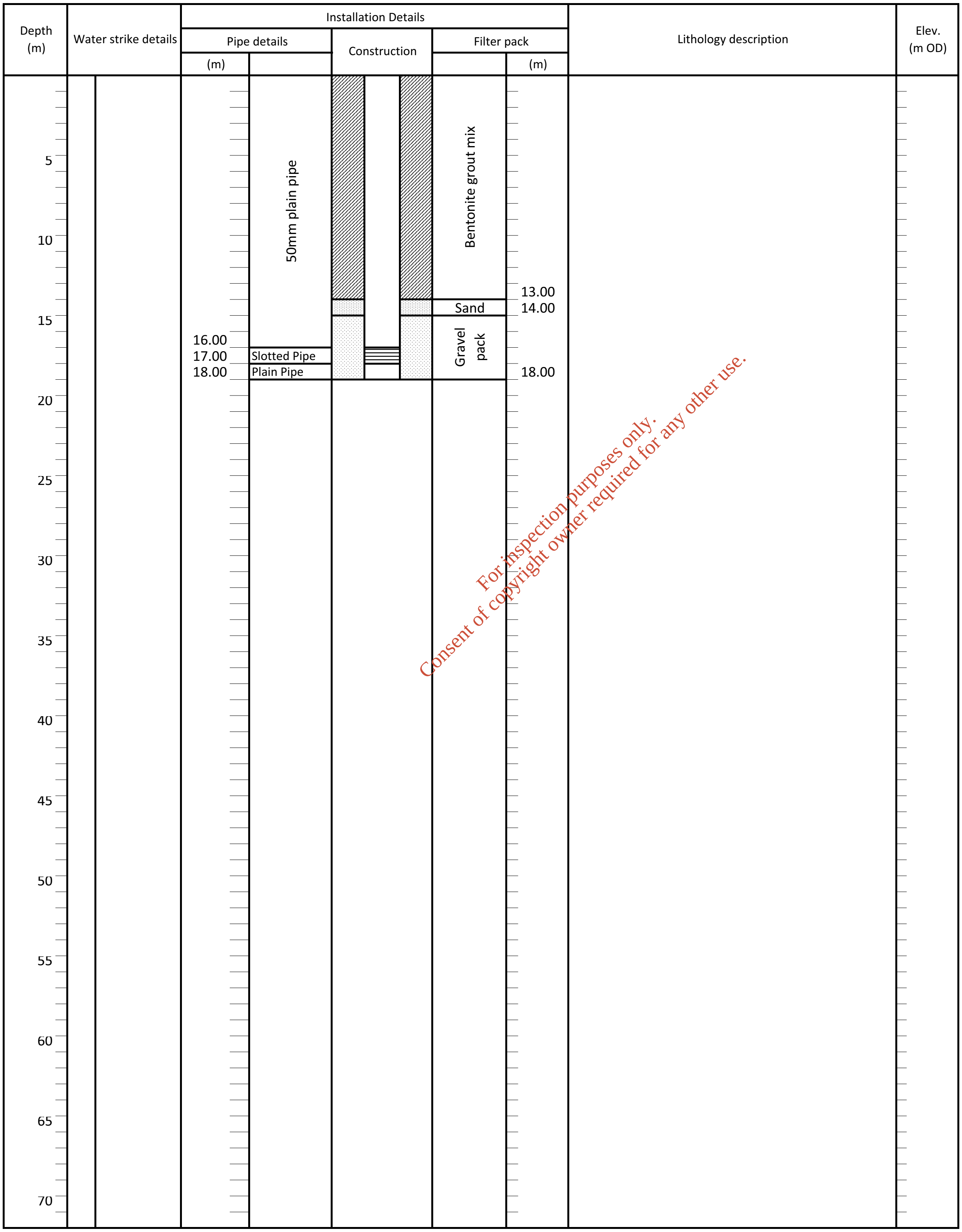
MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH18**
Date Drilled 20-24/4/2010	Driller IGSL	Drill method: Rotary Corehole	X; 315710.959
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Polymer Gel	Y: 257996.351
Comments:		Hole diameter: 150	Z (mOD): 110.501



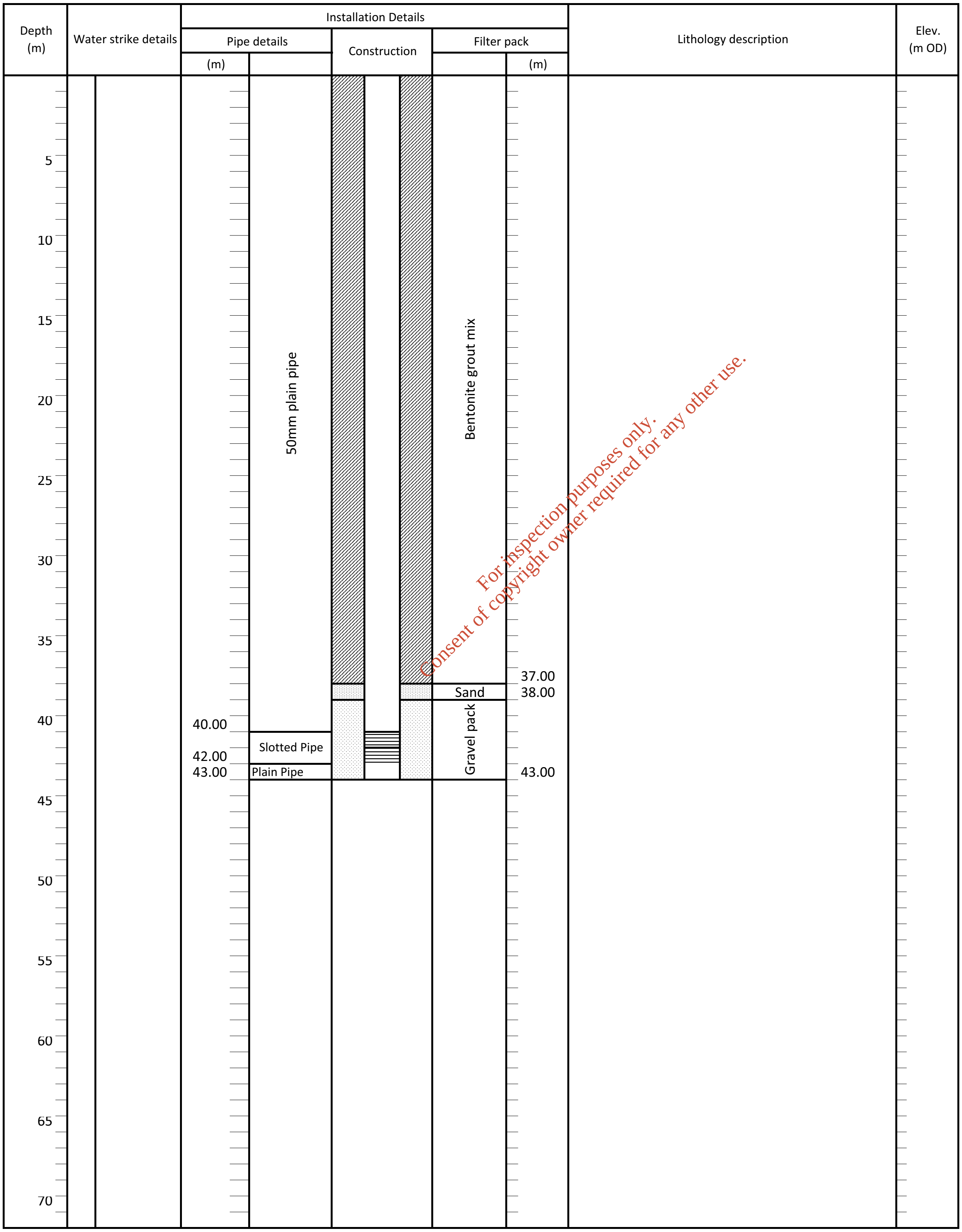
MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH19**
Date Drilled 21-22/4/2010	Driller Briody	Drill method: Rotary Corehole	X; 315887.13
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Mist	Y: 258059.087
Comments:		Hole diameter: 150 - 250	Z (mOD): 105.08



MONITORING WELL LOG

Project title MEHL Integrated Waste Management Facility		Client MEHL	Well No. **BH20**
Date Drilled 22-28/4/2010	Driller Briody	Drill method: Rotary Corehole	X; 315862.63
Date Logged	Site Engineer/Geologist D. O'Shea	Flush: Air/Mist	Y: 258102.33
Comments:		Hole diameter: 150 - 250	Z (mOD): 104.84

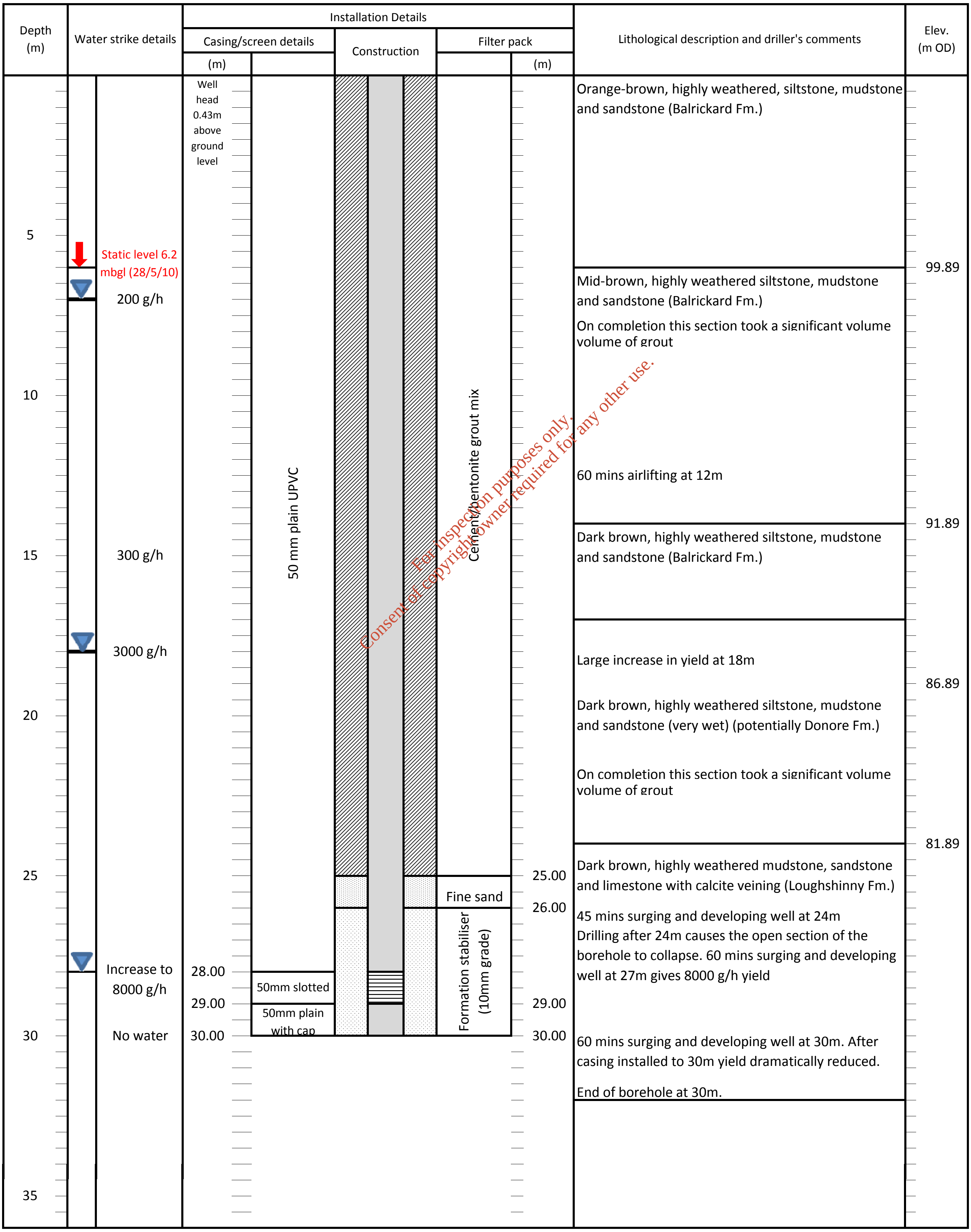


Appendix A14.4.5

Arup interpretive well logs

MONITORING WELL LOG

Project title Integrated Waste Management Facility	Client MEHL	Well No. **BH15a**	Sheet 1 of 1
Date Drilled 16-22/04/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315786.3
Date Logged 16-22/04/2010	Site Engineer/Geologist Sarah Blake	Flush: Air/mist	Y: 257849.6
Comments: Descriptions of chippings from drilling		Borehole diameter: 0.25 m (10") & 0.1m (8")	Z (mOD): 105.89



Orange-brown, highly weathered, siltstone, mudstone and sandstone (Balrickard Fm.)

Mid-brown, highly weathered siltstone, mudstone and sandstone (Balrickard Fm.)

On completion this section took a significant volume volume of grout

60 mins airlifting at 12m

Dark brown, highly weathered siltstone, mudstone and sandstone (Balrickard Fm.)

Large increase in yield at 18m

Dark brown, highly weathered siltstone, mudstone and sandstone (very wet) (potentially Donore Fm.)

On completion this section took a significant volume volume of grout

Dark brown, highly weathered mudstone, sandstone and limestone with calcite veining (Loughshinny Fm.)

45 mins surging and developing well at 24m
Drilling after 24m causes the open section of the borehole to collapse. 60 mins surging and developing well at 27m gives 8000 g/h yield

60 mins surging and developing well at 30m. After casing installed to 30m yield dramatically reduced.

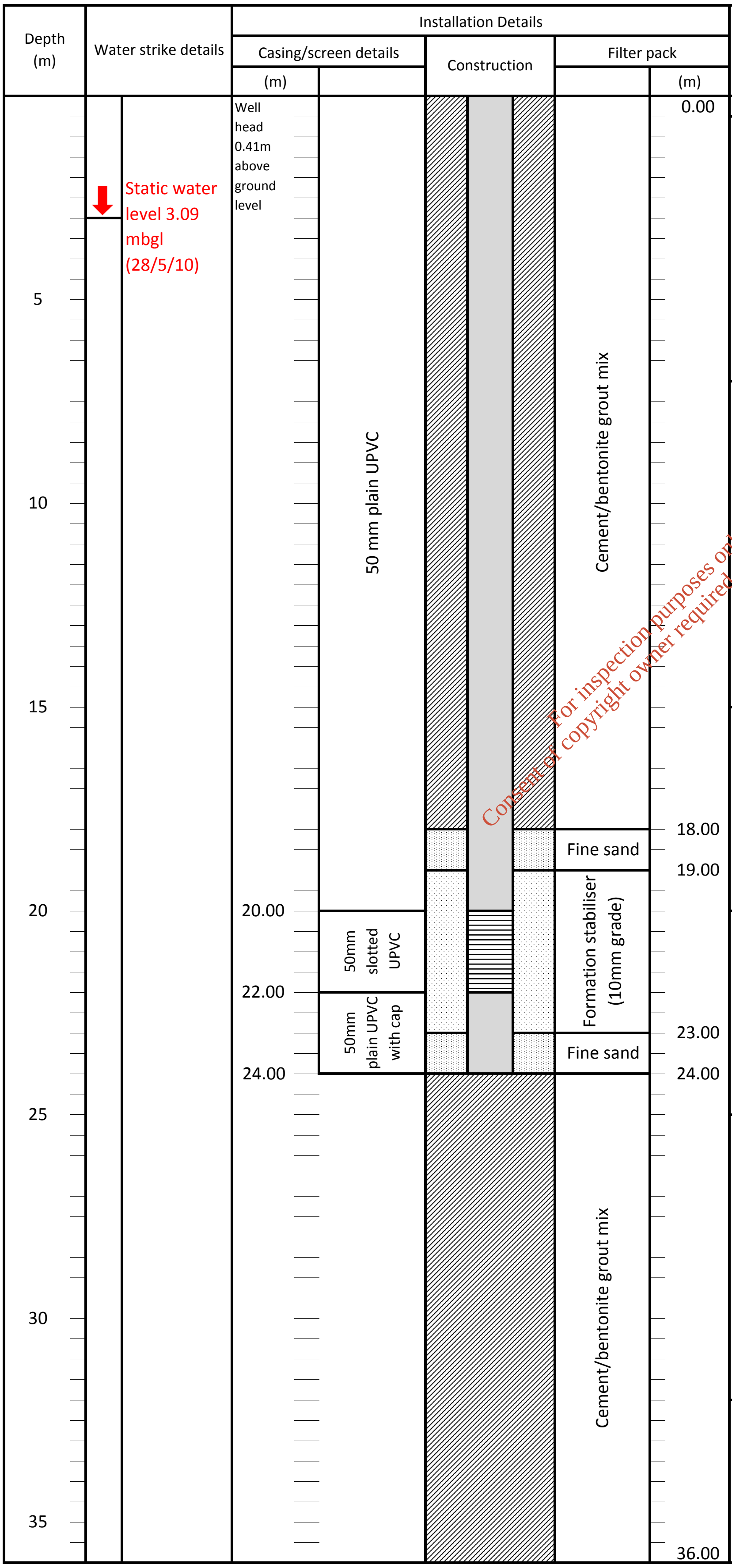
End of borehole at 30m.

ARUP

MONITORING WELL LOG

Project title Integrated Waste Management Facility		Client MEHL	Well No. **BH16**	Sheet 1 of 2

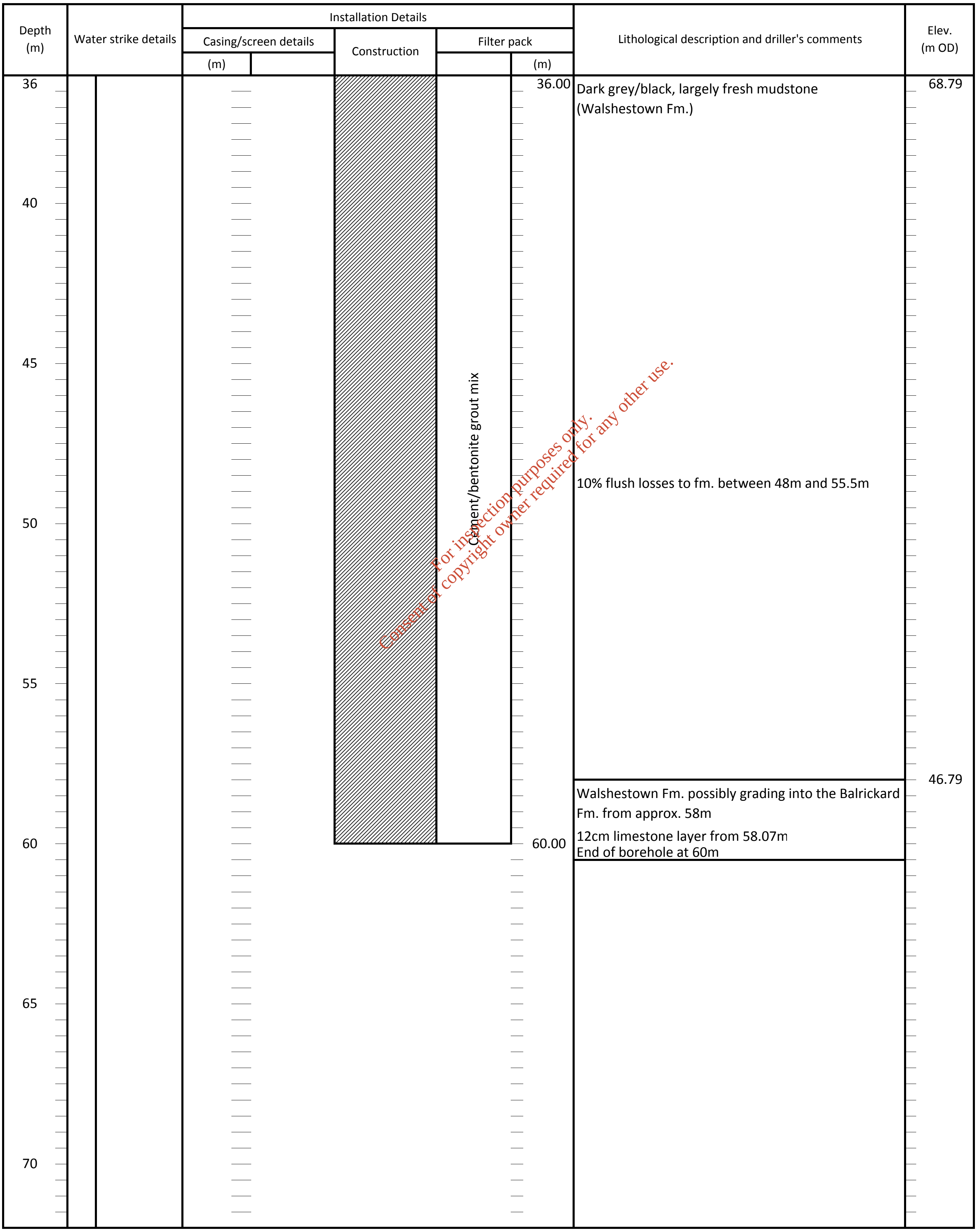
Date Drilled 12-20/04/2010	Driller S. Petersen	Drill method: Geobore 'S'	X; 315861.9
Date Logged 20/04/2010	Site Engineer/Geologist D. O'Shea	Flush: Air/Polymer gel	Y: 258218.2
Comments: Descriptions of cores from Geobore 'S' drilling		Borehole diameter 0.2 m (8")	Z (mOD): 104.79



Lithological description and driller's comments	Elev. (m OD)
Brown highly weathered, shaley mudstones	
Black, highly weathered fine-grained mudstone.	104.29
Dark grey/black, moderately weathered interbedded sandstone and siltstone/mudstone. (Walshestown Fm.)	97.79
Orange/brown/black highly weathered, interbedded sandstone and mudstone. Fe-oxide staining. 30% flush loss to fm. between 12.2m and 19.6m	92.79
Orange/black/brown/grey, highly weathered interbedded sandstone and mudstone. No recovery from 17.5 to 18m, probably highly weathered rock. 30% flush loss to fm. between 12.2m and 19.6m	89.79
Grey/orange/brown, moderately weathered sandstone (Walshestown Fm.) 20% flush losses to fm. between 19.6m and 24.6m	84.79
Dark grey/black/brown, interbedded sandstone and mudstone with large amounts of clay infill (Walshestown Fm.)	79.79
Dark grey/black, largely fresh mudstone (Walshestown Fm.)	72.79

MONITORING WELL LOG

Project title: Integrated Waste Management Facility
Client: MEHL
Well No.: **BH16**
Sheet: 2 of 2
Date Drilled: 12-20/04/2010
Driller: S. Petersen
Drill method: Geobore 'S'
X; 315861.9
Date Logged: 20/04/2010
Site Engineer/Geologist: D. O'Shea
Flush: Air/Polymer gel
Y: 258218.2
Comments: Descriptions of cores from Geobore 'S' drilling
Borehole diameter: 0.2 m (8")
Z (mOD): 104.79



Dark grey/black, largely fresh mudstone (Walshestown Fm.)

10% flush losses to fm. between 48m and 55.5m

Walshestown Fm. possibly grading into the Balrickard Fm. from approx. 58m

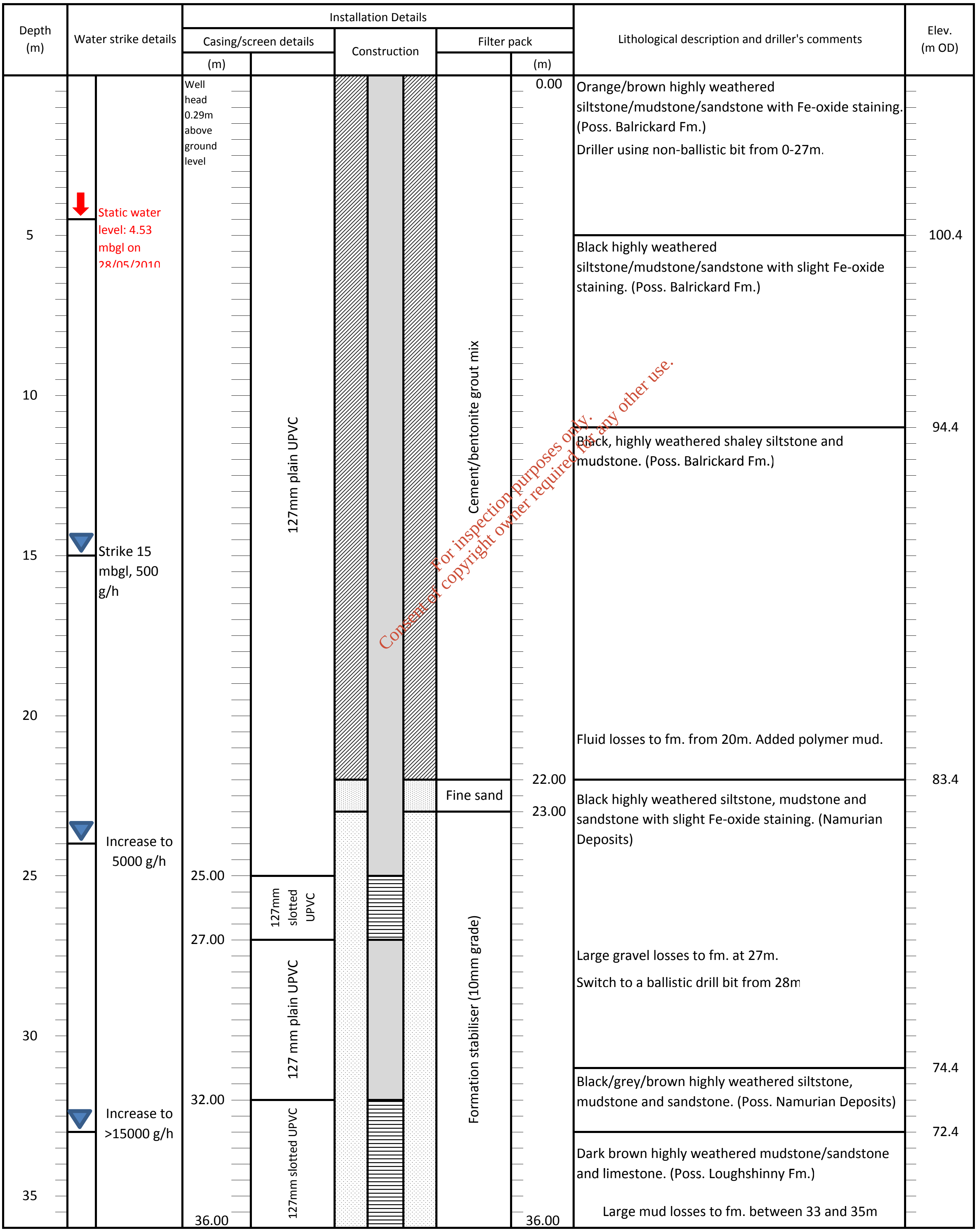
12cm limestone layer from 58.07m

End of borehole at 60m

ARUP

MONITORING WELL LOG

Project title Integrated Waste Management Facility		Client MEHL	Well No. **BH17**
Sheet	1 of 2		
Date Drilled 05/05/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315794.7
Date Logged 05/05/2010	Site Engineer/Geologist Catherine Buckley	Flush: Air/mist	Y: 258003.1
Comments: Descriptions of chippings from drilling		Borehole diameter: 0.25 m (10")	Z (mOD): 105.4

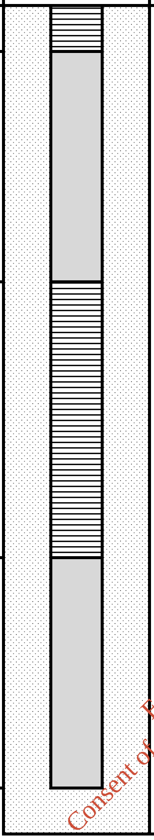


Lithological description and driller's comments	Elev. (m OD)
Orange/brown highly weathered siltstone/mudstone/sandstone with Fe-oxide staining. (Poss. Balrickard Fm.) Driller using non-ballistic bit from 0-27m.	100.4
Black highly weathered siltstone/mudstone/sandstone with slight Fe-oxide staining. (Poss. Balrickard Fm.)	94.4
Black, highly weathered shaley siltstone and mudstone. (Poss. Balrickard Fm.) Fluid losses to fm. from 20m. Added polymer mud.	83.4
Black highly weathered siltstone, mudstone and sandstone with slight Fe-oxide staining. (Namurian Deposits) Large gravel losses to fm. at 27m. Switch to a ballistic drill bit from 28m	74.4
Black/grey/brown highly weathered siltstone, mudstone and sandstone. (Poss. Namurian Deposits)	72.4
Dark brown highly weathered mudstone/sandstone and limestone. (Poss. Loughshinny Fm.) Large mud losses to fm. between 33 and 35m	

ARUP

MONITORING WELL LOG

Project title Integrated Waste Management Facility	Client MEHL	Well No. **BH17**	Sheet 2 of 2
Date Drilled 05/05/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315794.7
Date Logged 05/05/2010	Site Engineer/Geologist Catherine Buckley	Flush: Air/mist	Y: 258003.1
Comments: Descriptions of chippings from drilling		Borehole diameter: 0.25 m (10")	Z (mOD): 105.4



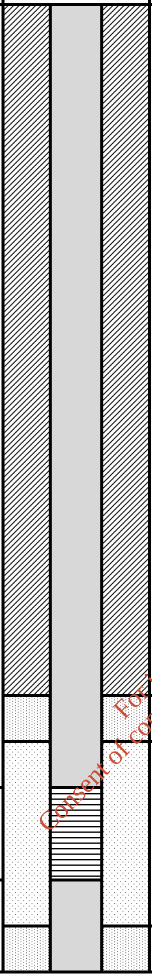
Depth (m)	Water strike details	Installation Details: Casing/screen details (m)		Construction	Filter pack	(m)	Lithological description and driller's comments	Elev. (m OD)
36		36.00	50mm slotted		Formation stabiliser (10mm grade)	36.00		69.4
		37.00	127 mm plain UPVC			37.00	Dark brown highly weathered mudstone, sandstone and limestone. (Poss. Loughshinny Fm.) Large mud losses to fm. between 37 and 40m	68.4
						38.00		
40								
		42.00	127mm slotted UPVC					
						43.00		
45								
		48.00	127 mm plain UPVC with end cap			48.00		
50								
		53.00						
						54.00	End of borehole at 54m	
55								
60								
65								
70								

ARUP

MONITORING WELL LOG

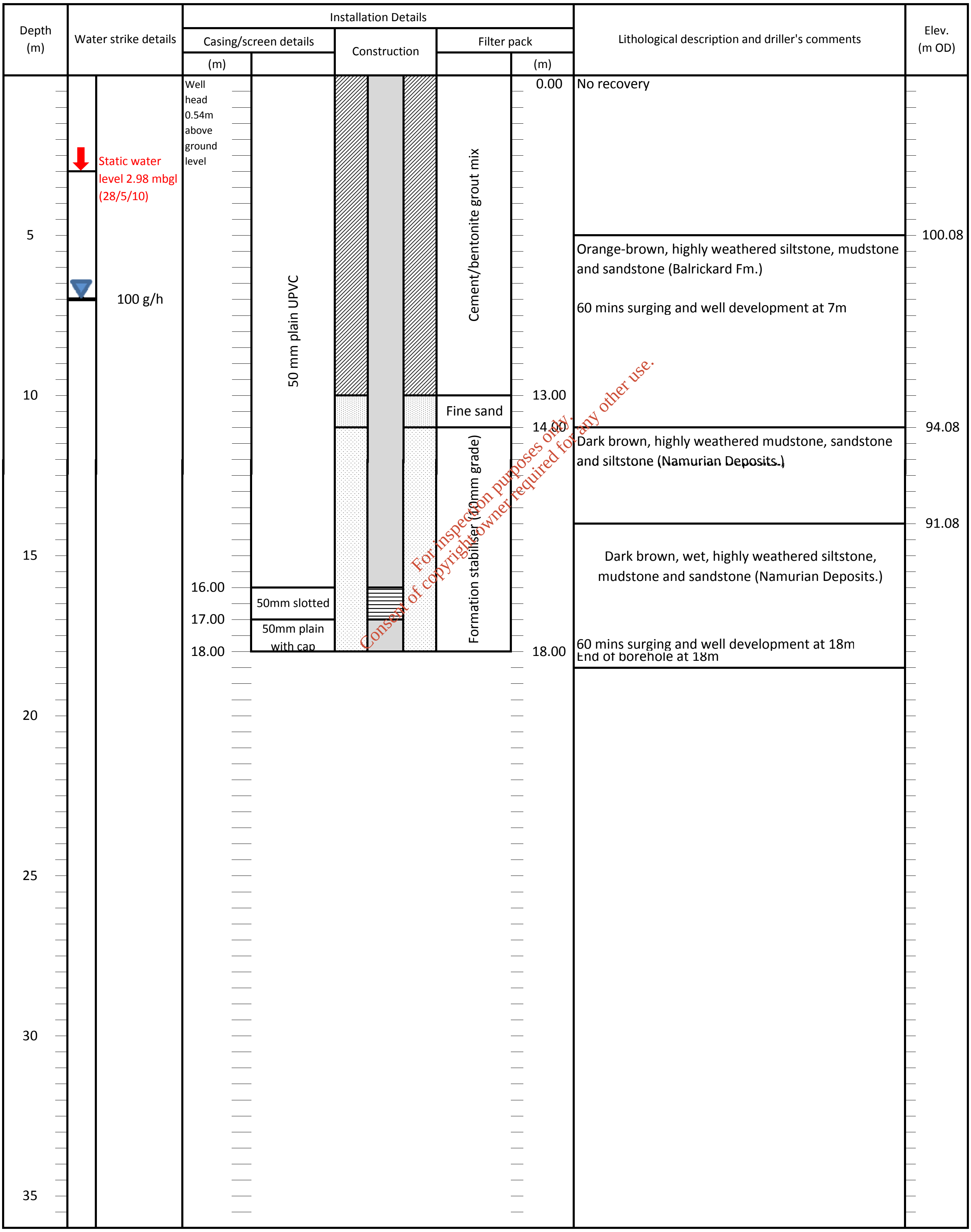
Project title Integrated Waste Management Facility		Client MEHL	Well No. **BH18**	Sheet 1 of 1
Date Drilled 20-24/04/2010	Driller S. Petersen	Drill method: Geobore 'S'	X; 315711	
Date Logged 24/04/2010	Site Engineer/Geologist D. O'Shea	Flush: Air/Polymer gel	Y: 257996.4	
Comments: Descriptions of cores from Geobore 'S' drilling		Borehole diameter: 0.2 m (8")	Z (mOD): 110.5	

Depth (m)	Water strike details	Installation Details: Casing/screen details (m)		Construction	Filter pack	(m)	Lithological description and driller's comments	Elev. (m OD)
		Well head 0.55m above ground level	50 mm plain UPVC		Cement/bentonite grout mix	0.00	Brown highly weathered, shaley mudstones	110
							Black/grey/brown moderately weathered, interbedded sandstone and mudstone with large amounts of clay infill. (Possibly Balrickard Fm.)	
5							Black/grey/dark-grey slightly weathered interbedded sandstone and mudstone (possibly Namurian Deposits.)	105.5
10	Static water level 9.51 mbgl (28/5/10)							
15					Fine sand	15.00	100% flush losses to fm. from 14.80 m Palaeo-analysis indicate Namurian Deposits	95.5
					Formation stabiliser (10mm grade)	16.00	Grey/dark-grey/black, slightly to locally highly weathered, interbedded limestone and shaley mudstones (possibly Loughshinny Fm.)	
		17.00	50mm slotted UPVC					
		19.00	50mm plain with cap					
20					Fine sand	20.00		
		21.00					End of borehole 21.2m	
25								
30								
35								



MONITORING WELL LOG

Project title Integrated Waste Management Facility	Client MEHL	Well No. **BH19**	Sheet 1 of 1
Date Drilled 21-22/04/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315887.1
Date Logged 21-22/04/2010	Site Engineer/Geologist Sarah Blake	Flush: Air/mist	Y: 258059.1
Comments: Descriptions based on chippings from drilling		Borehole diameter: 0.25 m (10")	Z (mOD): 105.08



Lithological description and driller's comments	Elev. (m OD)
No recovery	100.08
Orange-brown, highly weathered siltstone, mudstone and sandstone (Balrickard Fm.) 60 mins surging and well development at 7m	94.08
Dark brown, highly weathered mudstone, sandstone and siltstone (Namurian Deposits.)	91.08
Dark brown, wet, highly weathered siltstone, mudstone and sandstone (Namurian Deposits.) 60 mins surging and well development at 18m End of borehole at 18m	

ARUP

MONITORING WELL LOG

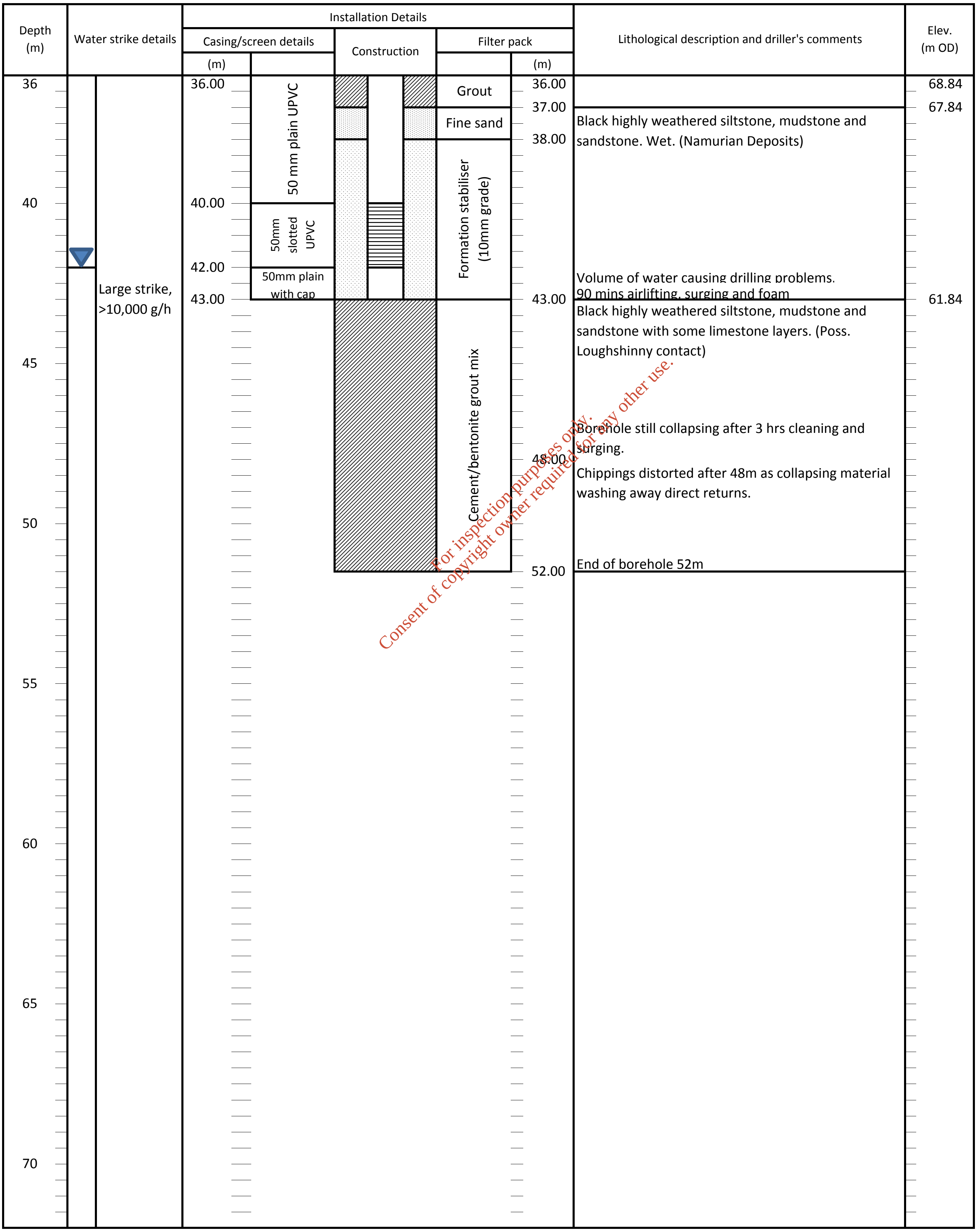
Project title Integrated Waste Management Facility	Client MEHL	Well No. **BH20**	Sheet 1 of 2
Date Drilled 22-27/04/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315862.6
Date Logged 22-27/04/2010	Site Engineer/Geologist Marie Fleming	Flush: Air/mist	Y: 258102.3
Comments: Descriptions of chippings from drilling		Borehole diameter: 0.25 m (10")	Z (mOD): 104.84

Depth (m)	Water strike details	Installation Details: Casing/screen details (m)	Installation Details: Construction	Installation Details: Filter pack (m)	Lithological description and driller's comments	Elev. (m OD)
		Well head 0.45m above ground level		0.00	Grey/black/orange/brown highly weathered siltstone/mudstone. (Poss. Balrickard Fm.)	
	Static water level 3.52 mbgl (28/5/10)					
5					Dark brown/black highly weathered siltstone and mudstone. (Namurian Deposits)	99.84
	Strike 6 mbgl, 100g/h					
					Black, highly weathered siltstone, mudstone and sandstone. (Namurian Deposits)	97.84
10						
15						
	Increase to 500 g/h	50 mm plain UPVC		Cement/bentonite grout mix	Well developed for 30 mins. 500 g/h flow consistent	
20						
25						
30	Increase to 3500 g/h				Significant increase in yield to 3500 g/h. Surging and well development for 60 mins.	
					Black, highly weathered siltstone, mudstone and sandstone. Very wet. (Namurian Deposits)	70.84
35						
		36.00		36.00		

ARUP

MONITORING WELL LOG

Project title Integrated Waste Management Facility		Client MEHL	Well No. **BH20**	Sheet 2 of 2
Date Drilled 22-27/4/2010	Driller Briody & Sons Ltd.	Drill method: Rotary flush	X; 315862.6	
Date Logged 22-27/4/2010	Site Engineer/Geologist Marie Fleming	Flush: Air/mist	Y: 258102.3	
Comments: Descriptions of chippings from drilling		Borehole diameter: 0.25 m (10")	Z (mOD): 104.84	



Large strike, >10,000 g/h

Black highly weathered siltstone, mudstone and sandstone. Wet. (Namurian Deposits)

Volume of water causing drilling problems. 90 mins airlifting, surging and foam

Black highly weathered siltstone, mudstone and sandstone with some limestone layers. (Poss. Loughshinny contact)

Borehole still collapsing after 3 hrs cleaning and surging.

Chippings distorted after 48m as collapsing material washing away direct returns.

End of borehole 52m

Appendix A14.4

Figures

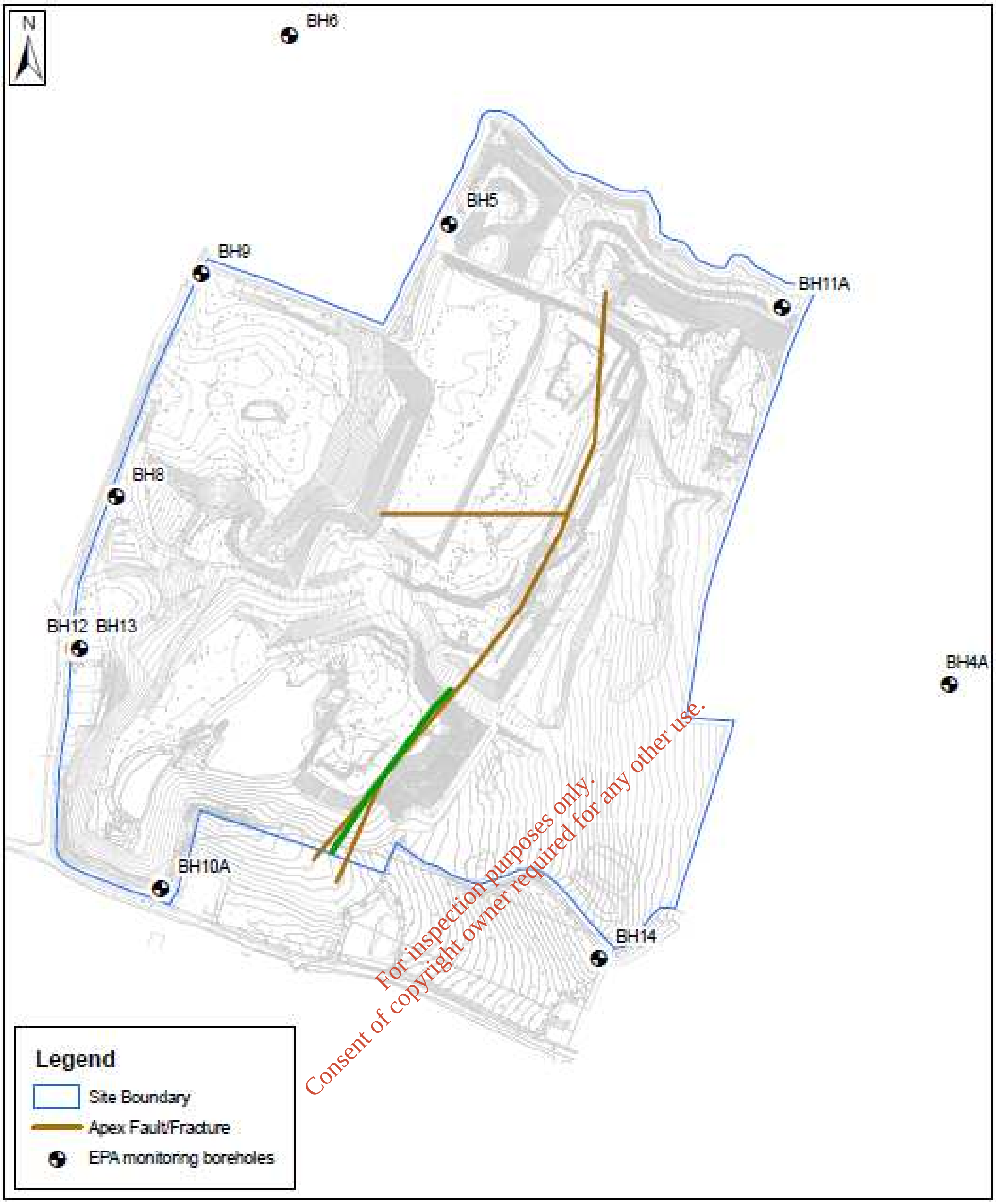


Figure 14.4.1: On-site monitoring network of existing boreholes.

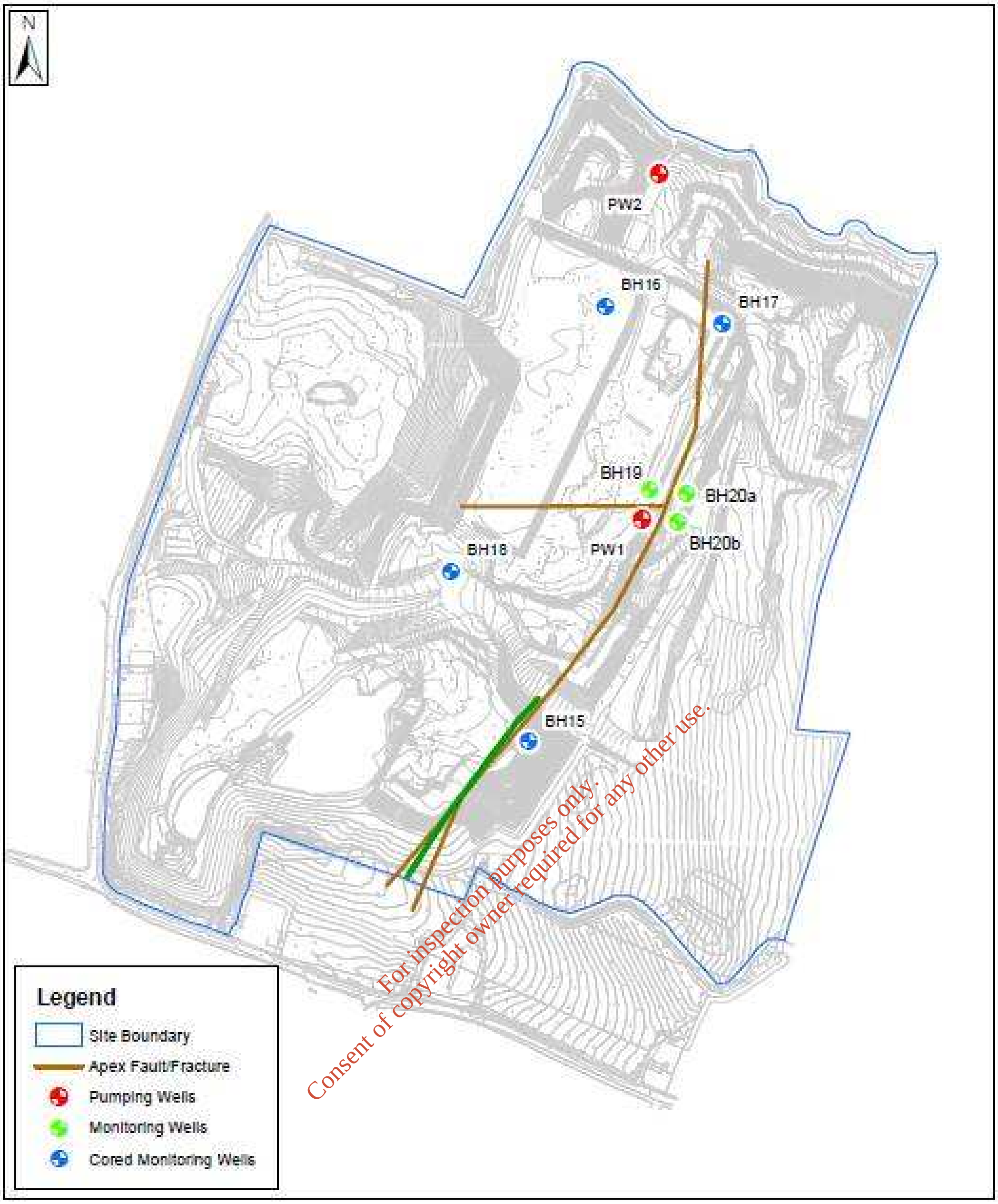


Figure 14.4.2: Initially proposed monitoring and pumping well locations.

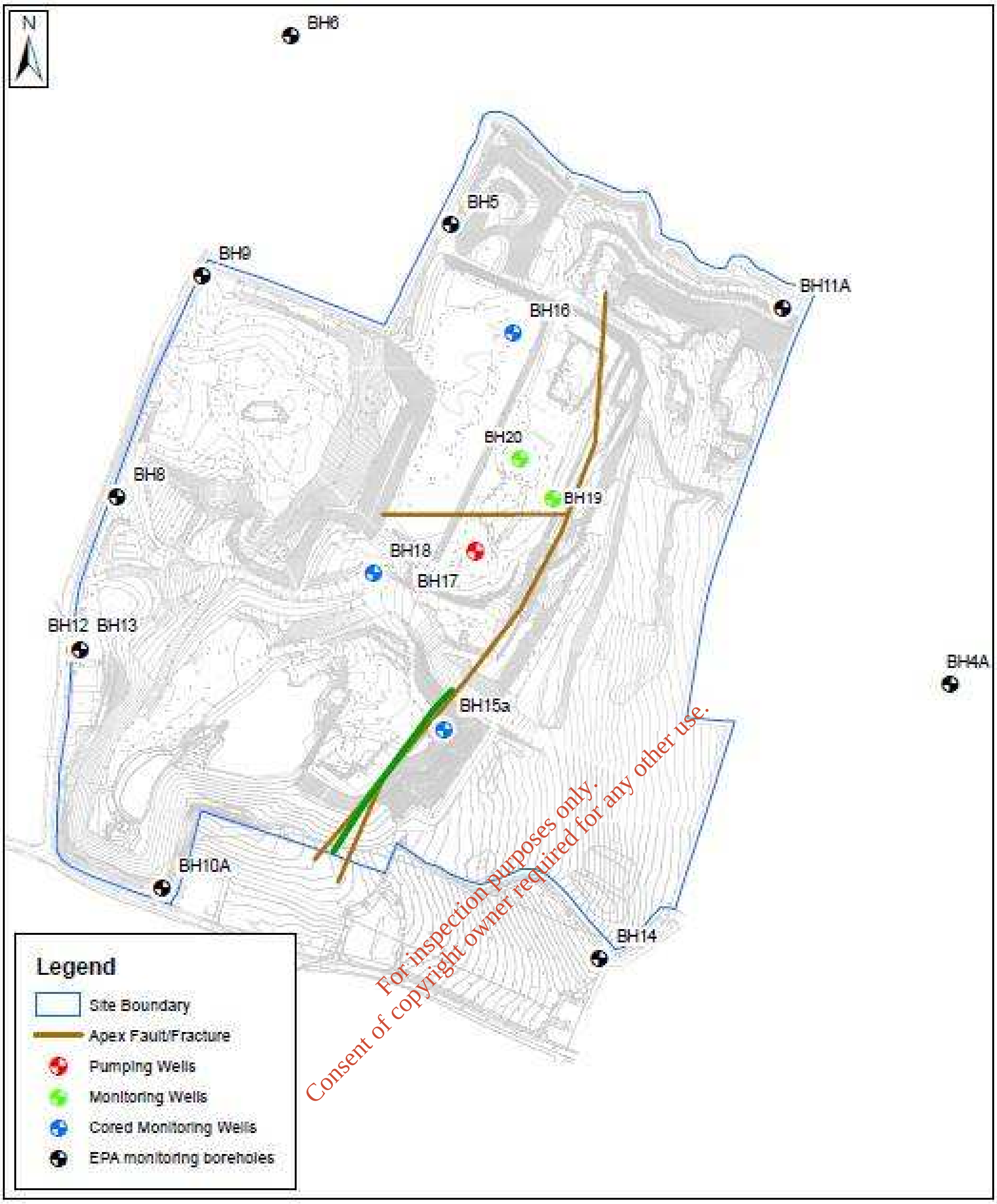


Figure 14.4.3: Final locations for all monitoring boreholes.

Appendix I.4.2

Quantitative Risk Assessment

MEHL

Murphy Environmental Hollywood Ltd. Integrated Waste Management Facility

Hydrogeological Quantitative Risk Assessment

Issue 1 | December 2010

Ove Arup & Partners Ireland

Arup
50 Ringsend Road
Dublin 4
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Job number D 6877.30

ARUP

Document Verification

ARUP

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Document title	Hydrogeological Quantitative Risk Assessment	**File reference**	
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		Name			
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		Signature			

Issue Document Verification with Document ✓

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Executive Summary

Murphy Environmental Hollywood Ltd (MEHL) wishes to apply for planning permission and a waste licence to develop an integrated waste management facility which will accept non-biodegradable, solid hazardous, non-hazardous and inert waste streams at the site in Hollywood, Naul, Co. Dublin.

A detailed hydrogeological investigation was undertaken on the MEHL site in order to develop a conceptual model for the site using site specific data that describes the groundwater system in the vicinity of the site.

This work indicated that the aquifer underlying the site is confined by up to 60 m of aquitard in the northern part of the site and outcrops in the south eastern corner of the site. The placement of the different waste types reflects the vulnerability of the aquifer in each area, with no hazardous waste cells being developed directly on the aquifer.

Based on the information collected during the site investigation a detailed quantitative risk assessment (QRA) modelling exercise was undertaken using the program LandSim v2.5. This model was used to quantify the potential risk to groundwater and groundwater based receptors from the proposed development.

The primary model developed used the landfill design criteria as provided by the landfill designer and all site specific geological and hydrogeological data collected during this assessment. The primary model is designed to represent the environmental impact of leachate leakage from the landfill on the environment. A phantom receptor well was placed on the site boundary to conservatively assess if wells down-gradient of the site will be impacted.

A summary of the results of the primary model are presented below:

- No ‘hazardous substances’ (List 1) predicted to be in groundwater beneath the site (and therefore none detected at the phantom receptor well);
- ‘Non-hazardous pollutants’ (List 2), metals, chloride and sulphate predicted to be present in groundwater beneath the site above Drinking Water Standards after 20,000 years;
- No contaminants at concentrations above Drinking Water Standards predicted to be present at the phantom well receptor.

The results of the LandSim modelling indicate that the risk to the water quality at wells down gradient of the site, from the proposed development, will be insignificant.

Although the primary model is designed to represent the landfill and surrounding environment it should be noted that these results are considered conservative for the following reasons:

- The main aquifer unit beneath the site (the Loughshinny Formation) is observed to be confined, and locally artesian, and therefore downward movement of leachate will be limited by the lower permeability in the overlying horizons. However the model assumes the aquifer is unconfined.
- There are two low permeability liners built into the DAC (Dense Asphaltic Concrete) system, separated by a stabilisation layer which contains a leak detection and collection system. The upper liner is the actual DAC liner and the lower liner is composed of 0.5 m of clay. The lower liner and leak detection system within the DAC system has not been included in the model.
- The additional low permeability bentonite enhanced soil (BES) layer to be installed beneath the liner for the non-hazardous cells has not been included in the model.
- The management control period has been modelled as unrealistically short. The actual management control period will be determined by the Environmental Protection Agency.

Supplementary models were created following consultations with the Environmental Protection Agency. The first supplementary model was developed to simulate the impact of the proposed development on groundwater if there was a significant defect in the liner of the hazardous cells. The second supplementary model was developed to simulate the impact of the proposed development on groundwater without any landfill liners.

A Groundwater and Surface Water Monitoring Plan, which will incorporate the monitoring of both groundwater levels and quality, will be a requirement of the waste licence.

A Closure Restoration and Aftercare Management Plan (CRAMP) will be developed and submitted to the Environmental Protection Agency for approval. Following the cessation of operation at the site the CRAMP will be implemented to the satisfaction of the Environmental Protection Agency.

1 Introduction

Murphy Environmental Hollywood Ltd (MEHL) appointed Arup to undertake a hydrogeological quantitative risk assessment for a proposed development at the MEHL site in Hollywood Great, North County Dublin. The site currently has planning permission (F07A/0262 and F04A/0363) and an EPA waste licence (no. W0129-02) to accept 500,000 tonnes per annum of inert waste to landfill. MEHL wishes to apply for planning permission and a waste licence to develop an integrated waste management facility which will accept non-biodegradable, solid hazardous and non-hazardous waste streams.

An Environmental Impact Assessment was undertaken for this development and this report will be appended to Chapter 14 Soils, Geology and Hydrogeology of the Environmental Impact Statement document. This report will also be submitted to the Environment Protection Agency (EPA) as part of the Waste Licence Application.

This report quantifies the potential risk to groundwater from the proposed development for each of the cells.

2 Site Details

2.1 Site Setting and Location

The MEHL site is located at Hollywood Great, Nag's Head, Naul, County Dublin at national grid reference 315558, 257798 (**Figure 1**). The area of land currently in the ownership and control of MEHL is 54.4 hectares, of which the proposed Planning and EPA waste licence boundary covers 39.8 hectares of the lands owned.

The town of Naul is situated approximately 3 km to the northwest. The site is approximately 32 kilometres north of Dublin City centre and 17 kilometres south of Drogheda.

2.2 History of Site Development

The site at Hollywood was formerly a quarry from which limestone and shale were extracted. Quarrying began in the late 1940s and Murphy Concrete Manufacturing (MCM) Ltd took over operations in 1975. The site continued to operate as a quarry until 2007.

Dublin County Council granted the first planning permission for restoration of the quarry in July 1988 and in 1993 it issued a permit for landfilling under the European Communities (Waste) Regulations. As new waste legislation was introduced, MCM Ltd applied for and obtained a waste licence. In 2002, Murphy Environmental was established as a trading division of MCM Ltd to serve as the waste management division of the company. The sale of aggregate product on a commercial basis from MCM Ltd at the Hollywood facility ceased at the end of 2007. In October 2008, Murphy Environmental Hollywood Ltd (MEHL) was established as a separate legal entity to manage the landfill activity at the Hollywood facility. EPA Licence W0129-02 transferred to MEHL on 1st October 2008. MEHL is responsible for all aspects of the management and operation of the landfill and compliance with the Waste Licence.

In 2004, an application was made to Fingal County Council to renew the planning permission for restoration of the quarry. Planning permission for a period of 15 years was granted in 2004.

An application was lodged in February 2007 to vary the planning permission to permit the infilling of an extended quarry area, and to increase the rate of filling to 500,000 tonnes per year. Planning permission for this development, ref. F07A/0262, was granted in 2007.

2.3 Current Operations

The quarry void is being backfilled and restored in accordance with EPA Waste Licence W0129-02. The site is licensed to accept up to 500,000 tonnes per annum of inert waste, comprising various forms of construction and demolition waste and soils and stone, including mildly contaminated soils, which comply with the limit values for waste acceptable at landfills for inert waste as set out in Section 2.1.2 of EU Council Decision of 19 December 2002 (2003/33/EC) establishing criteria and procedures for the acceptance of waste at landfills.

Seven landfill cells (Cells 1, 2, 3, 3 Extension, 4, 5a and 5b) for inert wastes have been developed since December 2002. The design and construction of the landfill cells have been in accordance with the EPA's Manual on Landfill Site Design (2000) and the Waste Licence. All cells have a base and side slope liner comprising low permeability clay. Cells 1 to 5 are situated in the northern part of the site. Further cells will be developed to the south and east of Cells 1 to 5.

The site entrance, buildings and other infrastructure are located on the west side of the site. Haul roads and ramps have been constructed within the site to allow vehicular access to areas of active landfilling and stockpiling. Other features on the site include stockpiles of topsoil and subsoil at the northern end of the existing quarry and along the eastern side of the site all within the site boundary.

At the lowest point the quarry base is at approximately 88mOD (Malin Head). At the southern end of the site the excavations are deep into the native limestone units. The northern part of the site is being filled and restored with inert waste. At the northern end the surrounding land surface is at 125mOD, approximately. The land surface is slightly higher at the southern end where it is approximately136mOD. The natural high point in the area is 151 mOD.

The maximum height of the restoration contours is 148mOD, rising from 109mOD at the northern end to 148mOD around the existing site entrance area, and then dropping again to 137mOD, at the southern end. The restoration heights are in line with the natural topography of the area.

2.4 Proposed Development

2.4.1 Overview

The development will comprise cells, for the landfilling of solid non-biodegradable hazardous, non hazardous and inert waste, ancillary facilities and a new facility entrance. The ancillary facilities will include haul roads, administration building, weighbridges, wheel washes, car parking, site services and utilities. Flue gas cleaning residues from waste to energy plants will be solidified on site. The solidification plant will be located on the eastern side of the non hazardous cell. A storage building for solidified material will be constructed directly beside the solidification plant, as will a bunded compound to store diesel for machinery and plant.

The hazardous waste cells will be sited in the northern part of the existing quarry. The non hazardous cell will be located in the southern portion of the site with the inert cell to the west of the hazardous and non hazardous cells. The formation level of the liner will be at approximately 102.5mAOD.

For further details on the proposed development, and information on waste acceptance and handling, site management and environmental controls refer to Chapter 4 Proposed Site and Project Description of the EIS.

2.4.2 Liner for Hazardous Waste Cells

It is proposed to use dense asphaltic concrete (DAC) to form the liner for the base and side walls of the hazardous cells. A DAC lining system is engineered to provide complete containment rather than controlled seepage thus making it a more effective landfill barrier than the single, composite or multiple lining systems traditionally used.

The proposed hazardous cell liner system will comprise the following components:

- A geotextile functioning as a filtration layer.
- A minimum 500mm thick drainage stone layer with a hydraulic conductivity > 1.0 x 10^{-3} m/s incorporating a herringbone system of leachate collection pipework.
- Mastic Sealant
- 80mm Dense Asphaltic Concrete
- 60mm Asphaltic Binder Layer
- 200mm Type 1 Granular Sub-base/Stabilising Layer (sprayed with cationic emulsion).
- Geotextile Membrane
- 500mm thick mineral layer of hydraulic conductivity less than or equal to 1.0 x 10^{-9} m/s.

It is proposed to incorporate a leak detection system into the stabilising drainage layer. The leak detection system will comprise of a 250mm HDPE detection standpipe which will be connected to a constructed sump at the base of the landfill cell. The leak detection system will be monitored on a regular basis and could be used as a collection system in the unlikely event that a leak should occur.

2.4.3 Lining System for Non Hazardous Cells

A composite clay and geomembrane liner will be installed on the base and side walls of the proposed non hazardous cells. The liner will meet minimum requirements set out in EC Directive 99/31/EC Annex 1. The landfill base and sides will consist of a mineral layer which satisfies permeability and thickness requirements with a combined effect in terms of protection of soil, groundwater and surface water, at least equivalent to K greater than or equal to 1.0×10^{-9} m/s; thickness >= 1 m.

It is proposed that the non hazardous lining system will be constructed as follows:

- Filtration Layer – Geotextile
- Leachate Collection Layer- 500mm thick drainage stone layer equivalent to 500mm thick granular layer with a hydraulic conductivity > 1.0 x 10^{-3} m/s. Also incorporating a herringbone system of leachate collection pipework.
- Protection Layer - Non woven polyproplene geotextile.
- Barrier Layer - 2mm thick Geomembrane HDPE liner.
- Barrier Layer - 1000mm thick compacted mineral layer having a hydraulic conductivity $\leq$ 1.0 x 10^{-9} m/s.

  As an additional mitigation measure an additional basal barrier layer composed of 1000mm thick bentonite enhanced soil or equivalent providing a hydraulic conductivity of $\leq$ 6.6 x 10^{-10} m/s will be laid beneath the liner of the non-hazardous cells.

2.4.4 Lining System for Inert Cells

A clay liner will be installed on the base and side walls of the proposed inert cell as per the EPA's Manual on Landfill site Design (2000) and the current waste licence requirements and similar to the liner of the existing cells, which have been constructed using on site clay deposits.

The liner will meet minimum requirements set out in EC Directive 99/31/EC Annex 1, landfill for inert waste: K <=1.0×10^{-7} m/s; thickness >= 1 m.

2.4.5 Solidification Plant

The solidification plant will comprise a process building, incorporating the process area which will house a mixing unit, a number of storage silos for flue gas treatment residues, a cement silo, two acid tanks, a storage building for curing solidified ash and welfare facilities.

In the solidification plant flue gas treatment residues and boiler ash will be bound with cement, acid and water in a batch process. The water added to the process will be collected leachate from the landfill. While it is considered likely that the mixing ratios at the proposed MEHL facility will be similar to those at Indaver solidification plant in Antwerp, the final ratios of residue to cement, water/leachate and additives will be defined following a pilot study, as the specific mixing ratio is dependent on the composition of the flue gas treatment residues which is specific to individual waste to energy plants. As is the case in Europe, ash material from other sources where available, could also be used in the solidification process.

The waste acceptance criteria defined for the proposed facility by the EPA, in compliance with Council Decision 2003/33/EC, will have a significant bearing on the ratio of cement, water/leachate and additives used in the process. In a number of EU states including Belgium and the Netherlands, a derogation for a number of the waste acceptance criteria parameters has been granted to facilitate landfilling of solidified flue gas treatment residue in hazardous cells. Up to 3 times the waste acceptance criteria values is permitted in certain circumstances, particularly for total dissolved salts and lead. In the waste licence application, a derogation of three times the waste acceptance criteria limits for hazardous waste will be sought for all applicable parameters.

The solidified material will be held in the storage building for a minimum of 2-4 days to cure the material and to facilitate its handling for onward placement in the hazardous landfill cell. The retention time in the storage buildings may be extended beyond 2-4 days, where storage capacity is available.

Solidified IBC bags/blocks will be transported from the storage building when the storage building capacity is full, by MEHL site vehicles, to a temporary storage area within the active hazardous landfill cell. The temporary storage area will be covered in order to avoid the solidified material coming in contact with rain and thus prevent the generation of leachate. When the solidification plant is not operating at peak capacity and the available storage capacity in the storage building is significantly greater than 2 to 4 days it should be possible to move the solidified material directly from the storage building to the final destination in the hazardous landfill cell.

2.4.6 Waste Inputs

It is proposed that the integrated waste management facility will accept solid non-biodegradable waste, including hazardous and non-hazardous residues from waste-to-energy plants, hazardous and non-hazardous soils and inert soils, and other compatible waste streams.

3 Sources of Information

The existing conditions within the area of the proposed MEHL development have been interpreted from historic studies on the site as well as desk study and ground investigation data. The main sources of information for the study were desk studies of material from the general area and site specific investigations including:

- Site visits
- Desk study comprising published information and site specific historic data and reports.
- Geophysical surveys
- Ground Investigation
- Monitoring data
- Well survey
- Quantitative Risk Assessment (QRA) modelling

3.1 Site Visits

Site visits and walkovers were undertaken by Arup from December 2009 to July 2010. Site supervision of drilling and all hydraulic tests, and ongoing groundwater monitoring were also undertaken by Arup over this period.

3.2 Desk Study

A desk study carried out of the MEHL site availed of the following sources:

3.2.1 Available Publications

- Fingal County Council (2006). Groundwater monitoring of the Bog of the Ring. Final hydrogeological Assessment Report.
- Geological Survey of Ireland (2005). Bog of the Ring: Source Protection Zones. (prepared in association with Final County Council).
- Geological Survey of Ireland (1999). 1:100,000 scale Bedrock Series Geology Map Sheet 13
- Geological Survey of Ireland (19th Century). 1:10,560 scale Bedrock Series Geology Map Sheet Dublin 14/2
- Geological Survey of Ireland (1901). 1:63,360 scale Bedrock Series Geology Map Sheet 102 (1901)
- Geological Survey of Ireland National Draft Bedrock Aquifer map
- Geological Survey of Ireland Groundwater Database
- Geological Survey of Ireland Quaternary Geology Map of Dublin
- McConnell, B., Philcox, M. And Geraghty, M. (2001). Geology of Meath: A geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 13, Meath. Geological Survey of Ireland.

3.2.2 Project Specific

These project specific references are listed in the order that the appendices are presented in the EIS.

- Jones, G.Ll. (2009). Conodate Report on the geology of the landfill site Hollywood, Naul, Co. Fingal. (**Appendix A14.1.1**)
- Jones, G.Ll (2010). Conodate Micropalaeontology report on sample MEHL – 18, 15.2-15.8 m, The Naul, Co. Fingal. (**Appendix A14.1.1**)
- APEX (2010). Report on the Geophysical Survey at the MEHL Integrated Waste Facility Site in Naul, Co. Dublin (**Appendix A14.2**)
- Site investigation report: IGSL (2010) Ground Investigation Factual report on MEHL Integrated Waste Management Facility. (**Appendix A14.3**)
- Borehole logs and well records for monitoring wells drilled as part of the current EPA waste licence (**Appendix A14.4**)
- On site hydraulic test records including pumping tests, infiltration testing etc. (**Appendix A14.5** and **Appendix A14.6**)
- Patel Tonra (2010). Historic groundwater level and quality monitoring data (**Appendix A14.7** and **Appendix A17.8**)
- Minerex (2010) Well survey report. (**Appendix A14.9**)
- White Young Green (2010). Engineering Report for Planning.

3.3 Geophysics

Surface geophysical surveys were undertaken on the site by Apex Geoservices Ltd in two phases as outlined in section 4.3.1. The full geophysical report is included in **Appendix A14.2** and this provides information of the techniques used and how the results were calibrated against the site investigation results.

3.4 Ground Investigations

Numerous boreholes were drilled on the site between 1998 and 2003 as part of the work for the previous and existing EPA waste licences for the MEHL facility (EPA waste license numbers 129-1 and W0129-02). The boreholes are situated on the site perimeter as shown on **Figure 2** and have been used to provide preliminary information on the geology of the site. The geological logs for all boreholes drilled are included in **Appendix A14.4**.

As part of this assessment additional boreholes were drilled in the centre of the site in the proposed locations for the hazardous and non-hazardous waste cells. This information was used to establish the geology in this area and further delineate the geological profile of the site as detailed in section 4.3. These boreholes will be decommissioned and backfilled in line with best practice prior to the construction of the cells in this area to prevent a potential contamination pathway.

The new boreholes were also completed as groundwater monitoring installations to allow the groundwater regime beneath the site to be interpreted further than previous assessments allowed. The locations of these boreholes are shown on **Figure 2**.

A complete list of all boreholes drilled on the site are presented in **Table 3.1** below.

Table 3.1 Drilling Details for all Boreholes on Site

Borehole ID	Date Drilled	Type of Borehole	Drilling supervised by
BH4A	18/11/2008	Monitoring Well	Patel Tonra
BH5	03/09/1998	Monitoring Well	KT Cullen & Co.
BH6	03/09/1998	Monitoring Well	KT Cullen & Co.
BH7	07/09/1998	NA	KT Cullen & Co.
BH8	17/08/2001	Monitoring Well	KT Cullen & Co.
BH9	03/08/2001	N/A	KT Cullen & Co.
BH10	04/08/2001	Monitoring Well	Golder Associates
BH10a	05/03/2007	Monitoring Well	Golder Associates
B11a	02/05/2007	Monitoring Well	Golder Associates
BH12	01/05/2007	Monitoring Well	Golder Associates
BH13	15/04/2007	Monitoring Well	Golder Associates
BH14	02/03/2007	Monitoring Well	Golder Associates
BH15	06/04/2010	Core: backfilled	Arup
BH15a	22/04/2010	Monitoring Well	Arup
BH16	12/04/2010	Core: finished as monitoring well	Arup
BH17	05/05/2010	Pumping well	Arup
BH18	20/04/2010	Core: finished as monitoring well	Arup
BH19	21/04/2010	Monitoring Well	Arup
BH20	22/04/2010	Monitoring Well	Arup

Detailed information of the site investigation works undertaken as part of this assessment, including raw data and interpretation are contained in **Appendices A14.2 – A14.9 and A14.12** of the Environmental Impact Statement**.**

In summary, these works consisted of:

- 3 No. Cable Percussion (Shell and Auger) Boreholes
- 3 No. Geobore S cored boreholes
- 3 No. Monitoring wells
- 1 No. Pump well
- 22 No. Trial pits
- 3 No. Soakaway pits
- 6 No. Side Slope surveys
- Laboratory testing for soil properties
- Groundwater quality analysis
- In situ testing consisting of pump tests, falling and rising head tests, soakaway testing and SPTs in shell and auger boreholes.
- Well development of new and existing wells

3.5 Monitoring data

Groundwater level and quality monitoring has been undertaken on the site since 2003 in accordance with the EPA waste licence. All data collected during this period were made available for use in this assessment.

As outlined in section 3.4, additional monitoring points were constructed as part of the investigations for this assessment. Data collected from these are presented in **Appendix A14.7** and **Appendix A14.8**.

3.6 Well survey

A well survey was undertaken in the area surrounding the MEHL site to determine the locations of any groundwater abstractions in the area. The full details of this are contained in **Appendix 14.9**.

4 Geology

4.1 Landscape and Topography

The broad study area generally incorporates the land from Naul in the northwest to Portrane and the Rogerstown Estuary in the southeast. The local or site-specific area of study incorporates the existing MEHL facility and the immediate surrounding lands.

The area around the site is generally hilly with elevations falling steeply towards the coast where the area becomes flatter. The site is located on a significant bedrock feature that trends in a WNW-ESE direction and which will be discussed in section 4.2.1. Knockbrack Hill to the north east of the site represents the highest elevation in the surrounding area at 176 mOD.

The MEHL site is on a hill with the natural elevations on the western boundary reaching up to 149 mOD and falling to 90 mOD on the eastern boundary. As the site is a former quarry the topography within the site is varied. A topographic map of the site and the surrounding area is shown in **Figure 3**.

The landuse in the area surrounding the MEHL site is predominantly agricultural with some low density housing. The majority of these houses are supplied by mains water.

To the east of the site, at Nevitt, Fingal County Council have been granted planning permission to construct and operate a landfill. The location of the Nevitt landfill in relation to the MEHL site is also shown on **Figure 3**.

4.2 Regional Soils and Geology information

4.2.1 Bedrock Geology

A detailed bedrock geology assessment carried out by Tara Prospecting Ltd. (1985) deals with the rocks in the immediate vicinity of the site and is based on their borehole database and local investigations. In summary, its assessment indicated a complex sequence of lithologies in the area, ranging from Namurian and Brigantian shales to Asbian limestones and volcanics to the north. The Namurian shales dominate the eastern part of the area and the Brigantian shales surround these on all sides.

Several lithologies are reported from the area around Hollywood (Geological Survey of Ireland – Geology of Meath, 2001) as shown on **Figure 4**. The regional geology of Meath can be divided into Ordovician and Silurian Metasediments and Volcanics, granites and other igneous rocks, sedimentary rocks of Carboniferous age and sedimentary rocks which were deposited during the Permian and Triassic periods.

The rocks underlying the area around the site can be described, from youngest to oldest formation, as belonging to the following formations within the Carboniferous Period:

- Walshestown Formation
- Balrickard Formation
- Loughshinny Formation
- Naul Formation
- Lucan Formation

Table 4.1 shows approximate ages for each formation.

Table 4.1 – Regional Formations

System	Series	Stage	Formation	Age
Carboniferous	Silesian	Namurian	Walshestown	313 - 326 ma
			Balrickard	
	Dinantian	Visean	Donore	Donore is thought to be situated in both the Visean and Namurian Stages
			Loughshinny	
			Naul	
			Lucan	326 - 345 ma

The Naul Formation is also a Visean age deposit and is similar to the older Lucan formation, but the limestones are paler and less argillaceous and contains less shale. The Lucan Formation, also known locally as Calp limestone is described as dark grey well bedded cherty, graded limestones and calcareous shales.

The next formation shown on the Regional Geology map is the Loughshinny formation. This is a Dinantian deposit from the Visean stage and is described by the GSI as consisting of limestone breccias formed by debris flows and turbidites. Younger parts of this formation are made up of well graded limestones interbedded with argillaceous limestones and dark shales.

The Donore Formation underlies the Balrickard Formation. This is thought to be an erosional boundary which was formed during a time when sea levels were fluctuating. Geologically it resembles the Balrickard Formation in some places and the Loughshinny Formation in others due to the changing depositional environment. The changes from one formation to the next are difficult to definitively establish and were not directly observed anywhere on site. As can be seen above, the contact between the Visean/Namurian Stages is thought to occur within the Donore Formation. In addition this formation may not be present throughout the area.

The Balrickard Formation is a feldspathic micaceous sandstone with shale and argillaceous fossiliferous micrite of Pendleian age.

The Walshestown Formation is from the Namurian stage of the Silesian Series of the Carboniferous system. The rocks of this formation are described as black shales with ironstone and subordinate siltstone with rippled fine sandstone bands, calcareous mudstone and biosparite. The Walshestown Formation is described within the GSI geological map publication "Geology of Meath, Sheet 13" as "predominantly black shales with subordinate siltstones and/or fine sandstone bands with rippled lenses, calcareous mudstone and occasional limestone (biosparite) of Pendleian to Arnsbergian age."

This area is known as the North Dublin Basin. This is a composite basin of combined sedimentary and structural origin. The location of the MEHL site is at the northern margin of this basin. To the north of the site is the Balbriggan Block. This block was bounded by faults and thrown up relative to the nearby basins. The site is located at one of the transitional areas between a block and a basin. This means that the depositional environments affect the nature of the rocks. The muddier, shaley deposits such as the Walshestown Formation, would have been deposited in deeper waters (basins) as opposed to the Loughshinny Formation deposits which appear to be deposited in warm shallow waters (blocks). This would suggest that the Dublin Basin was becoming deeper with time.

From the GSI geological map publication of the area ("Geology of Meath, Sheet 13"), the Carboniferous rock units (Walshestown, Balrickard, Loughshinny and Naul formations) are folded into a gentle syncline (bowl-shaped fold), whose axis runs roughly WNW-ESE. The Walshestown Formation occupies the centre of the fold, surrounded in sequence by the Balrickard formation, Loughshinny formation and the Naul formation to the south.

The affect of this synclinal structure is to bury the Loughshinny Formation even deeper than would be expected had the rocks in the area not been folded. The Loughshinny Formation is dipping in towards the centre of the syncline, resulting in it becoming deeper as its traced northwards.

Along with the deformation features like the syncline, a number of faults are present in the locality, generally trending N-S or NE-SW. These faults in some cases form contacts between various formations. There are most likely more faults which have not been identified present in the area, as faulting is ubiquitous in Ireland.

4.2.2 Quaternary Geology

The Quaternary (subsoil) strata data are scarce for this area; a map compiled from pre-existing data was produced to accompany an investigation for the location of landfill sites by the Geological Survey of Ireland for Dublin County Council (1979). This provides a guide to the depth and type of Quaternary sediment in the area. The map classifies all the tills as limestone dominated. In addition, the Teagasc Subsoils Map describes the soils around the site as consisting of exposed bedrock (i.e. that there is no soil present), and Till derived from Namurian rocks.

The ice depositing the tills was most likely extending from the Irish midlands, southwards and eastwards across the area and may contain some far travelled limestone clasts. This till deposit is quite common in this region and is typical of the till dominated by clasts of Namurian lithologies, found in north County Dublin.

4.2.3 Soils

The Gley group of soils cover most of the region in which the MEHL site is located, with the exception of Knockbrack Hill/ Nags Head area and the Palmerstown townland area where the soils are of the Brown Earth Group. A small isolated area of peat occurs around the Bog of the Ring Commons area.

The MEHL site is located in the Knockbrack Hill/ Nags Head area and is therefore characterised by the Brown Earth Group soils. These are a relatively mature soil. They are generally well drained mineral soil. The typical profile is uniform with little or no differentiation into horizons. These soils are not extensively leached or degraded and thus there is little evidence in the soil profile of removal and deposition of iron oxides, humus or clay. The soils of this group are generally good arable soils although sometimes low in nutrients. They have good drainage and structure characteristics with medium textures.

4.3 Site Specific Geology Information

A detailed site investigation was undertaken as part of the investigative works at MEHL site. The locations of all investigations are shown on **Figure 5** and the full factual report is presented in **Appendix A14.3**. Due to the weathered/broken condition of the rocks exposed at the MEHL site, intrusive boreholes were drilled and the details of these are presented in **Appendix A14.4**. The cores obtained demonstrated that these rocks are weathered and broken too.

4.3.1 Results of the geophysics

A field mapping exercise was undertaken by G. Ll Jones on the MEHL site and a report is presented in **Appendix A14.1**. In this report a major fault was mapped running roughly N-S across the site. A geophysical survey was undertaken to gain further information about this fault and to establish if there were any other unmapped faults present.

A trial geophysical survey was carried out by Apex Geoservices in January 2010 and this was followed by a detailed geophysical survey. The aim of the main survey was to locate any further faults on the site and also to provide information on deep bedrock. The results of the full survey included a series of interim maps along with a number of cross sections.

The report highlighted another bedrock fault trending E-W through the site which intersects the N-S trending fault. It suggested that this fault had a down-throw on the northern side of up to 60m.

The results from the intrusive investigations were used by Apex to calibrate the results of the geophysical survey. The results of the full survey are presented in **Appendix A14.2**.

4.3.2 Bedrock Geology

Based on the geological mapping report (Jones, 2009), the Apex Geoservices Geophysics Report (Apex, 2010) and the boreholes carried out during this study, a revised geological map has been produced for the site (See **Figure 6**). The revised bedrock geological map presented in **Figure 6** is founded on significantly more detailed geological information than was available during the production of the GSI 1999 publication.

The principal difference between **Figure 6** and the GSI geological map publication of the area ("Geology of Meath, Sheet 13") for the area (**Figure 4**) is that the Loughshinny Formation is now confined to the southwestern end of the site with the Donore, Balrickard and Walshestown Formations immediately underlying the greater part of the MEHL site.

The bedrock geology of the site is further influenced by the main North-South trending fault running through the site. The bedrock to the east of this fault appears to have been downthrown by some tens of metres. Folding was observed in the middle of the succession of rock types present on the site but the upper beds are mostly undisturbed.

Overall the geology of the site youngs to the north, starting with the Loughshinny formation passing upwards and eventually into the Walshestown formation.

A schematic cross section for the site is presented in **Figure 7**.

A summary table of the information from the boreholes used to amend the geology map is presented in the following table, **Table 4.2.**

Table 4.2 – Borehole Summary

Borehole ID	Date Drilled	Strata Encountered	Formation/Description	Depth
BH4A	18/11/2008	Overburden	Clays	0.0 - 4.3
		Bedrock	Loughshinny	4.3 - 12.2
BH5	03/09/1998	Overburden	Clays	0.0 - 6.0
		Bedrock	Walshestown	6.0 - 35.0
BH6	03/09/1998	Overburden	Clays	0.0 - 4.0
		Bedrock	Walshestown	4.0 - 19.5
BH7	07/09/1998	Overburden	Clays	0.0 - 2.0
		Bedrock	Walshestown	2.0 - 26.0
BH8	17/08/2001	Overburden	Clays	0.0 - 3.0
		Bedrock	Walshestown	3.0 - 27.0
BH9	03/08/2001	Overburden	Clays	0.0 - 12.0
		Bedrock	Walshestown	12.0 - 50.0
BH10	04/08/2001	Overburden	Clays	0.0 - 4.0
		Bedrock	Loughshinny	4.0 - 84.0
BH10a	05/03/2007	Overburden	Clays	0.0 - 10.0
		Bedrock	Balrickard/Donore (?)	10.0 - 21.0
		Bedrock	Loughshinny	21.0 - 68.0
B11a	02/05/2007	Overburden	Clays	0.0 - 2.0
		Bedrock	Walshestown	2.0 - 30.0
BH12	01/05/2007	Overburden	Clays	0.0 - 5.5
		Bedrock	Walshestown/Balrickard/Donore (?)	5.5 - 46.0
		Bedrock	Loughshinny	46.0 - 65.0
BH13	15/04/2007	Overburden	Clays	0.0 - 5.5
		Bedrock	Walshestown/Balrickard/Donore (?)	5.5 - 46.0
		Bedrock	Loughshinny	46.0 - 48.0
BH14	02/03/2007	Overburden	Clays	0.0 - 6.0
		Bedrock	Balrickard/Donore (?)	6.0 - 30.0
		Bedrock	Loughshinny	30.0 - 38.0
BH15	06/04/2010	Overburden	Clays	0.0 - 3.2
		Bedrock	Balrickard (?)	3.2 -10.0
		Bedrock	Possible Donore (?)	10.0 - 26.1
		Bedrock	Loughshinny	26.1 - 31.9
BH16	12/04/2010	Overburden	Clays	0.0 - 0.8
		Bedrock	Walshestown	0.8 - 60.0
BH17	05/05/2010	Bedrock	Balrickard/Donore (?)	0.0 -37.0
		Bedrock	Loughshinny	37.0 - 54.0

Borehole ID	Date Drilled	Strata Encountered	Formation/Description	Depth
BH18	20/04/2010	Overburden	Clays	0.0 - 0.6
		Bedrock	Balrickard (?)	0.6 - 5.1
		Bedrock	Donore (?)	5.1 - 15.2
		Bedrock	Loughshinny	15.2 - 21.2
BH19	21/04/2010	Overburden	Clays	0.0 -5.0
		Bedrock	Balrickard (?)	5.0 - 14.0
		Bedrock	Donore (?)	14.0 - 18.0
BH20	22/04/2010	Overburden	Clays	0.0 - 7.0
		Bedrock	Walshestown	7.0 - 34.0
		Bedrock	Balrickard/Donore (?)	34.0 - 43.0
		Bedrock	Loughshinny	43.0 - 48.0

The oldest formation observed on site is the Loughshinny Formation. This is Dinantian in age and consists of limestone breccias formed by debris flows and turbidites. Younger parts of this formation are made up of well graded limestones interbedded with argillaceous limestones and dark shales.

The Namurian formations are encountered next and these are composed of shales with argillaceous limestones and sandstones. The oldest Namurian deposit on the site is the Donore Formation. It is thought to form an unconformity between the eroded older units of the Loughshinny Formation and the younger units of the Balrickard Formation. It is of Brigantian to Pendleian in age and is estimated to have a thickness of up to 250m. This formation was difficult to identify from both outcrops and core samples from the underlying and overlying units due it's similarity to both in different areas and the poor quality of much of the core and/or chippings. In BH18 core samples taken at 15 mbgl appeared to be the Loughshinny Formation but palynology proved them to be Namurian in age, indicating were from the Donore Formation.

The next formation encountered is the Balrickard Formation. This was described in the borehole logs as "Moderately strong to moderately weak, thickly laminated to thinly bedded (to structureless where clay-filled), interbedded fine-grained SANDSTONE and MUDSTONE with large amounts of orange/yellow/brown clay infill". It is assumed that the contact between the Walshestown Formation and the Balrickard formation is an erosional contact which follows the topography of the northwestern corner of the site.

There is a possibility that the fault which runs roughly East-West which was identified during the geophysics extends further westward and forms the contact between the two formations. It should be noted that the contact was not directly observed anywhere on site.

In the north of the site, where the Walshestown formation is observed, the rocks are described as black shales with ironstone and subordinate siltstone with rippled fine sandstone bands, calcareous mudstone and biosparite. In the borehole logs it is described as "Moderately weak to moderately strong, thinly bedded to thinly laminated, dark grey/black, interbedded fine-grained SANDSTONE & SILTSTONE/MUDSTONE with large amounts of black clay infill".

It should be borne in mind that the overall geological interpretation has been hindered by the weathered and broken nature of rock on the site and the quality of the materials recovered from the boreholes.

4.3.3 Soils

Much of the naturally occurring soils on-site have been stripped and stockpiled during the quarrying operations. Some stockpiling of soils has been carried out for use in the restoration of the quarry, and for lining and capping activities associated with the landfilling activities.

4.3.4 Quaternary Geology

The Quaternary deposits on the site and in the immediate surrounding areas consist of a till. This varies in thickness and texture but is generally less than 5 m thick and has a clay/silt matrix with dispersed pebble clasts. The till contains weathered clasts of Namurian shale and sandstone, with some limestone. Where the till cover is thin it tends to have a coarser texture, being more silty to sandy.

4.4 Summary of Existing Soils and Geology

- An extensive investigation was undertaken at the MEHL site to assess the local geology.
- Four formations have been identified on site. The Loughshinny and part of the Donore Formations are Dinantian in age, while the other part of the Donore Formation, along with the Balrickard and Walshestown Formations are Namurian in age. The Donore forms an erosional contact between the units.
- Where they occur within this former quarry, the Quaternary deposits consist of Glacial Tills.
- There is a large WNW-ESE trending syncline which means that the Loughshinny Formation is dipping to the north and therefore becoming deeper in that direction. Furthermore, the Loughshinny Formation appears to have been downthrown significantly by the E-W trending fault so that in the north of the site there is over 60m of Namurian deposits above it. This means that the Loughshinny Formation is overlain by increasing thicknesses of the Donore, Balrickard and Walshestown formations moving northwards across the site.
- The main fault appears to run roughly N-S through the site with another two faults running perpendicular to this aligned E-W. These faults may potentially form faulted contacts between Balrickard and Walshestown Formations. The strata in the Loughshinny Formation and the lower parts of the Donore Formations are likely to therefore contain significant faulting and therefore significant permeability.

5 Hydrology

Surface water features in the vicinity of the MEHL site are shown on **Figure 3**. A small stream is present along the northern boundary of the site which flows from west to east. This stream is likely to be fed partially by shallow groundwater and this will be discussed further in section 6.2.3.

The closest weather monitoring station to the site is located at Dublin Airport, approximately 20 km south of the site. Rainfall levels are recorded on a daily basis and the results were used to assist with the analysis of the soakaway and pumping tests and also the interpretation of groundwater levels.

The 30-year average rainfall measured at Dublin airport is 750 mm. Monthly and annual total rainfall for 2003-2010 are presented in **Appendix A14.7** and annual totals are summarised below in **Table 5.1**.

Table 5.1 Annual rainfall and potential evapotranspiration (Penman) measured at Dublin airport

Year	Rainfall (mm/yr)	Potential Evapotranspiration (Penman) (mm/yr)	Effective Rainfall (mm/yr)
2010	-	-	-
2009	920.2	521	399.2
2008	942.3	531	411.3
2007	784.4	531	253.4
2006	740.6	597	143.6
2005	680.3	526	154.3
2004	752.4	563	189.4
2003	643.2	558	85.2

These data shows that since 2005 annual rainfall levels have been increasing and that 2008 and 2009 were particularly wet years. The rainfall data measured in 2010 from January to September show rainfall levels were lower than the equivalent monthly 30 year average data in all months except September.

Monthly potential evapotranspiration (PE) data were collected (Penman method) at Dublin Airport to the south of the MEHL site. This monthly data are presented in **Appendix 14.7** and summarised in **Table 5.1**. The data show that the rate of potential evapotranspiration has not changed much since 2003.

Potential or effective rainfall is the amount of rainfall which is available to infiltrate into the ground and which will not evaporate or be taken up by plants. It is determined by subtracting evapotranspiration from rainfall. The annual effective rainfall is also summarised in **Table 5.1**.

The actual recharge is the measure of how much rainfall can actually be assumed to infiltrate into the ground and recharge the water table. It is based on the potential rainfall but also takes into account rainwater which does not enter the ground but becomes overland flow and enters streams. This occurs when the soil is saturated or has reached its field capacity which is common in Ireland. The Working Group for Groundwater[1] in Ireland has determined that the actual recharge can be set at 95% of the effective rainfall.

This indicates that despite high levels of actual rainfall being measured, the amount of rainfall which may eventually enter groundwater is comparatively low.

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[1] Water Framework Directive (2005). Working group on groundwater guidance document No. 5. Guidance on the assessment of the impact on groundwater abstractions.

6 Hydrogeology

6.1 Regional Hydrogeology

The site is located within the Eastern River Basin District which covers Dublin and the wider surrounding area as far north as Drogheda as shown in **Figure 8**. The geology of the area is composed of different bedrock types and soil deposits which results in a variety of hydrogeological regimes being present in the area.

The Geological Survey of Ireland has devised a system for classifying the aquifers in Ireland based on the hydrogeological characteristics, size and productivity of the groundwater resource. The three main classifications are Regionally Important Aquifers (RI), Locally Important Aquifers (LI) and Poor Aquifers (P).

Table 6.1 summarises the lithologies present on the MEHL site and their GSI aquifer classification. The geology of the MEHL site has been discussed in detail in section 4.3 and the work undertaken as part of this assessment has led to the boundaries of the lithologies on site being refined as indicated in **Figure 6**. From this the aquifer classification has been refined and is presented in **Figure 9.**

Table 6.1 Summary of the GSI aquifer classification for lithologies present on the MEHL site

Lithology	Age (Stage)	GSI Aquifer classification
Loughshinny Formation	Visean	Locally Important Aquifer
Donore Formation	Visean/Namurian	Poor aquifer
Balrickard Formation	Namurian	Poor aquifer
Walshestown Formation	Namurian	Poor aquifer

Based on the geological information for the area outlined above, the hydrogeology of the area can be subdivided into an aquifer unit and an aquitard unit for the purposes of this report.

6.1.1 The Aquifer

The Loughshinny Formation comprises the aquifer in this region. Isolated gravel deposits have been mapped in the region directly above the Loughshinny and these may contribute to the resource of the aquifer.

The aquifer is part of the Lusk – Bog of the Ring Groundwater Body (GWB) as shown on **Figure 8**.

The Loughshinny Formation is characterised as being moderately productive bedrock. Well records indicate that there are numerous wells which tap the Loughshinny Formation with yields of over 100 m^3/day. These wells are often domestic or Council supplies. Typical specific capacities range from 5 – 150 m^3/day and transmissivities up to 1000 m^2/day have been recorded.

The rocks of the Loughshinny Formation are composed of Calp limestones although they are cleaner and more fractured than the typical Calp limestone seen for example in Dublin. The flow regime in this type of material will be dominated by fracture flow and movement through weathered zones with the majority of the storage being in the fractures. There will be little to no storage and groundwater movement though the matrix of the rock.

Weathered beds of the Donore Formation which were deposited in the same environment as the Loughshinny may also comprise part of the aquifer in places. As outlined in section 4.2.1 the Donore Formation is difficult to distinguish as it is similar to the Loughshinny Formation below it and the Balrickard Formation above it depending on the depositional environment it was formed in at any one location. For this reason parts of it will comprise the aquifer and parts will comprise the aquitard.

The quality of a groundwater source relates to both its productiveness (which includes how often it is renewed) and its chemistry. Testing undertaken on the Loughshinny Formation indicates that it is a productive groundwater resource with a quality suitable for water supply (with local variations).

6.1.2 The Aquitard

The aquitard is composed of the formations which were deposited during the Namurian period and is part of the Hynestown GWB (**Figure 8**). As stated above the upper part of the Donore Formation is similar to the overlying Namurian strata and therefore is considered to be part of the aquitard. A geological description of these units is provided in section 4.2.1.

The area defined as the aquitard is composed of a hill (i.e. it is topographically higher than the surrounding area) and is defined by the extent of Namurian rocks. It is characterised by poorly productive bedrock (except in local zones) and has the GSI classification of Pl (Poor Aquifer, Bedrock which is generally unproductive except in local zones). No existing detailed hydrogeological investigations are available in these deposits in this area and the GSI classification is based on the characteristics of the formation elsewhere.

The hydraulic characteristics of the Namurian deposits will vary depending on the lithologies present. Areas of low permeability material such as the siltstones of the Walshestown Formation will allow very little groundwater movement. However weathered or fractured zones in or around the material will allow some groundwater movement through the deposits and may hydraulically connect different lithologies.

6.1.3 Groundwater Flow Direction

The regional groundwater flow direction is towards the south east. This is influenced by the underlying geological structure. As outlined in section 4.2.1 a large syncline is present in the area and this will dominate groundwater flow directions. Groundwater will move along the axis of the syncline as it will be unable to move up out of the syncline due to the overlying impermeable deposits. The syncline dips to the south east and groundwater will flow in this direction rather than directly east as may be expected.

6.1.4 Hydrochemistry

Water quality in the Loughshinny Formation is always hard[2] (usually over 250 mg/l, often over 300 mg/l as $CaCO_3$). Generally the quality is good except for in areas where it is locally contaminated.

Groundwater samples are routinely collected at the Bog of the Ring water supply which abstracts water from the Loughshinny Formation. These are presented in monitoring reports and some data is quoted in the Source Protection Zone report[2] for the Bog of the Ring.

The water data from Bog of the Ring groundwater abstraction are typical of what would be expected from a limestone source [2]. High hardness, alkalinity and Electrical Conductivity (EC) values were observed. Sulphate and chloride values range from 22-82 mg/l and 23-31 mg/l, respectively. Chloride values of this concentration can sometimes indicate organic contamination however in this case they are more likely to be due to the proximity to the coast.

Elevated potassium levels of 0-7 mg/l were observed in the Loughshinny which may indicate organic contamination. However, the Na:K ratio are below the GSI guideline value of 0.3 and as such the elevated potassium levels were attributed to being naturally occurring in the bedrock.

Elevated manganese and iron concentrations were thought to originate from the shaley beds in the limestone.

6.1.4.1 Groundwater Vulnerability

The vulnerability of a groundwater body is the term used to describe the ease with which the groundwater in the area can be contaminated by human activities. The vulnerability is determined by many factors including the travel time, the quantity of contaminants and the capacity of the deposits overlying the bedrock to attenuate contaminants.

These factors in turn are based on the thickness and permeability of the subsoil deposits, e.g. groundwater in bedrock which has a thick cover of low permeability clay is less vulnerable than the groundwater in bedrock which is exposed at the surface. The criteria for determining groundwater vulnerability, as developed by the GSI, are shown in **Table 6.2** below. The Extreme vulnerability class is further sub-divided into Extreme (X) – rock near Surface or Karst and Extreme (E) - subsoils <3m thick.

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[2] Geological Survey of Ireland (2005). Bog of the Ring: Groundwater Source Protection Zones

Table 6.2 GSI Groundwater Vulnerability Mapping Guidelines (DoELG 1999)

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) & Thickness			Unsaturated Zone	Karst Features
	High Permeability (sand/gravel)	Moderate permeability (e.g. sandy subsoil)	Low permeability (e.g. clayey subsoil, clay, peat)	(sand/gravel aquifers only)	(<30m radius)
Extreme (E)	0 – 3.0m	0 – 3.0m	0 – 3.0m	0 – 3.0m	-
High (H)	>3.0m	3.0 – 10.0m	3.0 – 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 – 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes: (1) N/A = not applicable
(2) Precise permeability values cannot be given at present
(3) Release point of contaminants is assumed to be 1-2m below ground surface

The GSI groundwater vulnerability maps show different vulnerability ratings in the site and the surrounding area and these are displayed in **Figure 10**. The vulnerability classification of the MEHL site is 'Extreme Rock near surface or karst'. This would be expected as the site is a former quarry and the natural overburden has been removed in the area.

However, it should be noted that the GSI criteria does not take the permeability of bedrock into account and the presence of low permeability Namurian material over most of the site is not factored into the vulnerability classification.

6.1.5 Groundwater Resources

6.1.5.1 GSI Well Records

Figure 11 shows the locations of all wells recorded by the GSI in the general vicinity of the site. However, as it is not a requirement for wells to be registered with the GSI the GSI list of wells is not necessarily complete.

6.1.5.2 Well Survey

A well survey was undertaken to establish if any wells were present in the area which were not identified on the GSI database.

The full details of the well survey are presented in **Appendix A14.9**. The survey was undertaken for residential properties within a 1km radius down-gradient of the site and 0.5 km radius up gradient of the site. Properties which would potentially have larger abstractions such as businesses/agricultural enterprises were audited within 2 km down-gradient of the site and 1 km up-gradient of the site.

The well survey identified only 3 properties in the area which have wells abstracting from groundwater and their locations are shown on **Figure 11**. As outlined in section 6.1.3 groundwater flow is to the south east. This means that two of these abstraction wells are up-gradient of the site and only one is down-gradient. The down-gradient well is used for watering gardens and is not used for a potable water supply. All three locations where wells were noted are also supplied by mains water.

6.1.5.3 Bog of the Ring

Fingal County Council has developed a well field in the Loughshinny formation at the Bog of the Ring that supplies up to 4,000 m^3/day to Balbriggan and its environs. It located to the north east of the MEHL site as shown on **Figure 11**. The GSI has defined a Source Protection Area (SPA) for this water supply composed of an Inner and Outer Protection Area[2]. The MEHL site is located approximately 1 km outside the Outer Source Protection Area of the abstraction and approximately 3 km from the abstraction locations as shown in **Figure 11**.

The GSI have also mapped a groundwater divide to the north east of the MEHL site on the basis of surface water features in that area. This indicates that groundwater from the MEHL site will not flow towards the Bog of the Ring.

Recent monitoring reports have suggested that the Bog of the Ring supply is in decline “the regional water table is in long term decline and has not reached a steady state at the end of 2005. This is consistent with the ERBD findings that the aquifer is currently at risk from potential over abstraction” (Collins and Herlihy, 2007).

This lowering in groundwater levels is likely to be due to the limited storage contained within faults, fractures and weathered zones in the Loughshinny Formation as outlined in section 6.1.1. It is generally thought that sands and gravels in the vicinity of the Bog of the Ring wellfield provide significant additional storage.

6.2 Site Hydrogeology

The geological mapping work undertaken (Jones, 2009) allowed assessment of the principal geological boundaries and indicated the presence of a N-S trending fault as outlined in section 4.2.1.

Geophysical surveys were undertaken as part of this assessment which identified further faulting on the site trending E-W and intersecting the N-S fault. The faults may influence the hydrogeology of the site by either acting as a conduit for flow or as a barrier to flow.

Many of the monitoring wells and new boreholes drilled on site, as described in section 3.4, were positioned in locations to investigate this. This is described in full in **Appendix A14.4**.

The final network of groundwater monitoring boreholes was developed on site as shown in **Figure 2**. Extensive investigations were undertaken including:

- New monitoring wells
- New pumping wells
- Hydraulic testing
- Pump test
- Well development
- Groundwater level and quality monitoring

Detailed interpretation and data for these are presented in **Appendices A14.3-A14.9 and A14.12**.

Table 6.3 Summary details of monitoring wells

Borehole ID	Depth (m)	Response zone lithology	Comments
BH4A	12.2	Loughshinny	Artesian well & topographically lower
BH5	34.9	Namurian	
BH6	19.5	Namurian	Artesian
BH9	19.01	Namurian	
BH10a	67	Loughshinny	
B11a	30	Namurian	Artesian
BH12	65	Loughshinny	
BH13	40	Namurian	
BH14	38	Loughshinny	
BH15a	30	Loughshinny	
BH16	24	Namurian	Weathered/fractured water bearing zone within Walshestown Formation
BH17	54	Loughshinny	Pumping well
BH18	21	Loughshinny	
BH19	18	Namurian	
BH20	43	Namurian/Aquifer	Possibly finishing in the Donore Fm which may be part of the aquifer here

6.2.1 Aquifer Characteristics

Both the aquifer and aquitard are old indurated rocks and therefore are dominated by secondary permeability. The permeability is likely to be related to particular horizons within the formations.

In order to establish vertical and horizontal permeability of the lithologies on the site, permeability testing was undertaken. Details are provided in the following paragraphs.

6.2.1.1 Infiltration Testing

Infiltration tests were undertaken in trial pits across the base of the excavation to assess the vertical permeability of the deposits.

Full details of the methodology for these tests, the calculations and the interpretation of the results are also included in **Appendix A14.5**. The results of the infiltration tests are summarised below in **Table 6.4**.

Table 6.4 Summary of vertical infiltration calculation

Soakaway pit	Time period ending	Infiltration rate (m/s)
TP1	Test 1	4.22E-07
	Test 2	2.82E-08
TP2	Test 1	4.54E-07
	Test 2	1.53E-07
TP3	Test 1	Not conclusive*

* This test was inconclusive as water levels rose in the pit due to rainfall which did not allow calculations to be undertaken. However, it can be taken that this is an indication that the deposit has a low permeability.

These results indicate that the material at the base of the excavation has a low permeability and as such will provide natural protection to the groundwater resources beneath the site.

It should be noted that the calculations had to be modified as the soakaway pits did not drain over a full weekend. This in itself indicates that the material at the base of the excavation has a low permeability or at least a low vertical infiltration rate.

Furthermore, rain fell over the weekend causing TP3, which is located to the north of the site to over-flow as so little water had drained out of it. This indicates that the values may actually be lower than were calculated above.

6.2.1.2 Variable head testing

Variable head permeability tests were undertaken in many of the boreholes in order to estimate an approximate permeability of the response zone. The full details of these tests including calculations, interpretation and caveats are presented in **Appendix A14.5**. **Table 6.5** summarises the results obtained from those tests.

Table 6.5 Summary results from variable head permeability testing

Borehole ID	Response zone lithology	Method of Analysis	K (m/sec)	Comments
BH5	Namurian	Bouwer & Rice	5.4 x 10-5	
BH6	Namurian	Bouwer & Rice	5.7 x 10-4	Artesian*
BH8	Namurian	Bouwer & Rice	7 x 10-5	
BH11a	Namurian	Bouwer & Rice	5 x 10-5	Artesian*
BH15a	Loughshinny	Bouwer & Rice	1.04 x 10-6	
BH16	Namurian	Bouwer & Rice	6.95 x 10-6	
BH18	Loughshinny	Bouwer & Rice	-	Drawdown not achieved
BH19	Namurian	Bouwer & Rice	1.10 x 10-6	
BH20	Loughshinny	Bouwer & Rice	-	Drawdown not achieved

* Equations may not be valid for artesian wells

Of the three tests undertaken in the Loughshinny Formation, only one yielded results. This is because the groundwater levels in the other two recovered too quickly to allow a drawdown to be measured. This indicates that the Loughshinny Formation has a moderate to high permeability. The value calculated for BH15a should be treated with caution. A large amount of water was found in this monitoring well and such a small drawdown was achieved that the results may be too low and not reflective of the true permeability of the deposit.

The results of the tests undertaken in boreholes tapping the Namurian strata indicate a lower permeability than the Loughshinny Formation.

The caveats associated with the equations and method of testing as outlined in **Appendix A14.5** should be borne in mind when considering these results.

6.2.1.3 Packer Tests

Packer tests were developed to estimate the amount of grout which would have to be used to block a fracture.

Packer tests were undertaken in the open Geo-bore ‘S’ holes in BH15, BH16 and BH18 on the MEHL site.

In BH15, two tests were undertaken in an area in which cores indicated the bedrock was very fractured. The areas where these tests were taken were between 30 - 31.9 mbgl and 30.5 – 31.5 mbgl at the top of the Loughshinny Formation.

The first test was abandoned as a pressure increase was not observed which indicated that the pressure seal was not functioning correctly. No results could be obtained from the second test as the pressure levels could not be increased. This indicated that the fracture encountered was quite large indicating high permeability.

Two tests were also undertaken in BH16. The first was in a shallow area within the Walshestown Formation between 18 - 21.2 mbgl which was highlighted as having a lot of water flow. The packer tests indicated a permeability value of 2.2 x 10^{-6} m/s.

The second packer test in BH16 was undertaken between 54 - 55 mbgl. This area was still within the Walshestown Formation but was highlighted as being more fractured than previously noted areas. The packer tests indicated a permeability value of 3.29 x 10^{-6} m/s for this fractured area in the Walshestown Formation.

The final packer test was undertaken in BH18 between 18-21.2 mbgl. This area was thought to be in the Loughshinny Formation based on the deposits encountered, however it may have also been the Donore Formation due to difficulties in distinguishing between the strata in places.

The packer test yielded a permeability value of 2.2 x 10^{-6} m/s at this location.

The results of all packer tests are summarised in **Table 6.6**.

Table 6.6 Summary Results Of Packer Testing

BH ID	Depth (mbgl)	Geology	K value (m/s)	Comments
BH15	30 - 31.9	Loughshinny Fm	-	No seal obtained
	30.5 – 31.5	Loughshinny Fm	-	Pressure did not increase indicating highly permeable fracture
BH16	18 - 21.2	Walshestown Fm	2.2 x 10-6	
	54 - 55	Walshestown Fm	3.29 x 10-6	
BH18	18-21.2	Loughshinny Fm	2.22 x 10-6	

6.2.1.4 Pumping Test

A pumping test was undertaken in BH17 in order to estimate the horizontal permeability of the Loughshinny deposit and to assess the hydraulic interactions across the site. The full details of the pumping test including the methodology, data correction, raw data, calculations and interpretation are presented in **Appendix A14.6.**

Step drawdown (and recovery) and constant rate (and recovery) tests were undertaken however data from the observation boreholes could not be used to obtain data on the aquifer characteristics. This is because the presence of faults and partially penetrating wells influenced the groundwater levels in the observation wells during the pumping test and made the data unreliable for these calculations.

The recovery data from BH17 (pumping well) from both the step drawdown and constant rate tests were used to obtain data on the aquifer characteristics. The drawdown data obtained in BH17 during Step 1 of the step drawdown test were also used in the calculations by treating the 60 minutes as a constant rate test.

These calculations indicated that the Loughshinny deposit has a high transmissivity of up to 300 m^2/d (indicating a permeability of approximately $1.74x10^{-4}$ m/s if the aquifer is 50 m thick). Specific capacity values of approximately 250m^3/d/m were also calculated from the data available.

While the observation well data could not be used in the calculations, the data obtained from them was useful for undertaking distance-drawdown analysis of the hydraulic conditions.

The distance-drawdown analysis was used to gain information on the hydrogeological characteristics of the faulting on the site. The analysis demonstrated that the N-S trending fault is hindering the movement of water across it rather than acting as a conduit for flow. However, it is not working as a complete barrier to flow.

The E-W trending fault does not appear to have any influence on the flow in the groundwater beneath the site and it is likely to be bringing the aquifer into contact with permeable horizons within the Namurian.

The shape of a semi-log plot of drawdown versus time coupled with a log-log plot of drawdown versus time can often be a useful indicator of the type of aquifer the pump is abstracting water from. The full details of this are presented in **Appendix A14.6** and are summarised below.

Based on the shapes of the curves in the graphs, the groundwater in the aquifer is confined by the overlying low permeability deposits.

The groundwater in BH19, BH16 and BH5 appears to be tapping a linear weathered area, fault or fracture zone.

The shapes of the curves on the graphs also indicated that the majority of the storage is in fractures. This indicates that although a high permeability value was observed over the length of the pumping test, the aquifer at this location may not be a good long term groundwater resource if the storage is only contained within fractures.

The results of the various hydraulic and well tests indicate that the permeability of the Loughshinny Formation (the aquifer) is moderate being of the order of 10^{-4} / 10^{-5} m/s. The permeability of the more permeable horizons in the Namurian appears to be of the order of 10^{-6} m/s. The permeability of the bulk of the Namurian strata appear to be significantly lower and is of the order of 10^{-7} / 10^{-8} m/s.

6.2.2 Groundwater Levels

In accordance with the current EPA waste licence conditions, groundwater monitoring has been undertaken on the site since 2003. Groundwater levels in the new monitoring boreholes (constructed as part of this investigation in April and May 2010) have been measured since their construction. All records for groundwater levels in new and old boreholes, including hydrographs, are available in **Appendix A14.7**.

No dewatering was undertaken on the MEHL site during the assessment and groundwater levels remained below the base of the excavation.

Table 6.7 summarises the maximum, minimum and average groundwater levels recorded on site for all installations.

Table 6.7 Summary Of Groundwater Monitoring Data

Borehole ID	Response zone	Comments	Groundwater level					
			Minimum		Maximum		Average	
			mbgl	mOD	mbgl	mOD	mbgl	mOD
BH4A	Aquifer	Artesian well & topographically lower	-0.70	91.96	-0.70	91.96	-0.70	91.96
BH5	Aquitard		27.08	91.12	14.38	103.80	20.03	98.17
BH6	Aquitard	Artesian	0.17	116.80	-0.31	117.30	-0.30	117.30
BH9	Aquitard		27.54	101.00	20.84	107.72	24.09	104.47
BH10a	Aquifer		48.45	88.39	36.43	100.40	40.70	96.14
B11a	Aquitard	Artesian	4.76	93.41	-0.34	98.51	0.49	97.68
BH12	Aquifer (partially penetrating)		53.85	93.14	46.16	100.83	48.36	98.63
BH13	Aquifer		38.80	108.12	33.50	113.42	35.45	111.47
BH14	Aquifer		32.29	92.56	26.03	98.82	28.04	96.81
BH15a	Aquifer		6.34	99.55	6.02	99.87	6.22	99.66
BH16	Aquitard	Weathered/fractured water bearing zone within Walshestown Formation	4.44	100.30	3.04	101.70	3.18	101.61
BH17	Aquifer	Pumping well	5.03	100.38	4.46	100.95	4.68	100.73
BH18	Aquifer (partially penetrating)		10.40	100.10	9.51	100.99	9.70	100.80
BH19	Aquitard		3.42	101.66	2.85	102.23	3.04	102.04
BH20	Aquifer		3.90	100.94	3.45	101.39	3.60	101.24

Graphs of groundwater levels with corresponding rainfall data are plotted in **Appendix A14.7**. These show that groundwater levels have been higher in recent years which correspond with the country-wide pattern seen due to higher rainfall levels in 2008 and 2009 as outlined in section 5. The hydrographs indicate that recharge/infiltration is slow and relatively low responding to seasonal rainfall rather than individual rainfall events.

Figure 12 shows groundwater levels plotted spatially across the site on 20th May 2010. Groundwater levels recorded in installations in the Loughshinny and in the Namurian deposits are distinguished from each other. This shows that groundwater levels in the Loughshinny are fairly consistent across the whole site demonstrating levels of approximately 100mOD.

The exception to this is BH4A in which the groundwater level was 91.96mOD, however this borehole is at a lower elevation than the rest of the boreholes and is artesian for that reason. The value quoted as the groundwater level is actually the top of the casing implying the actual level is higher.

There is a large pond in the south eastern corner of the excavation and this probably reflects the water table in this part of the site.

The groundwater levels recorded in the Namurian deposits exhibit more variation across the site. In general they are shallower than the levels recorded in the Loughshinny and the values are more dependent on topography than the values recorded in the Loughshinny indicating separation from the water in the aquifer. The values at the base of the excavation demonstrate the shallowest levels recorded in the Namurian while those outside of the excavation pit demonstrate higher levels. However, it is likely that some of the installations in the Namurian deposits which are demonstrating similar groundwater levels to the Loughshinny are part of the Donore Formation. As outlined previously, it is considered that parts of the Donore Formation are part of the aquifer.

The only pattern which can be seen in the groundwater levels in the Namurian is in BH5, BH16 and BH19 which all demonstrate levels of approximately 101.5mOD. The distance drawdown analysis grouped these wells together as potentially harnessing the same fracture/weathered zone.

6.2.3 Hydraulic Conditions and Interactions

The water table map presented in **Figure 12** shows groundwater in the aquifer flowing to the south east. This is in line with the regional pattern discussed in section 6.1 and is due to the geological structure beneath the site.

The site is located on the southern flank of a syncline which forms a basin shaped structure in the wider area. Groundwater can move along the axis of the syncline as the syncline acts as a trap due to groundwater already present. The confining conditions in the Loughshinny and in the Namurian deposits limit the downward movement of water.

The hydraulic gradient in the aquifer is approximately 0.02 – 0.04 indicating that the water table has a moderate gradient.

The groundwater velocity beneath the site is the product of the hydraulic conductivity and the hydraulic gradient divided by the effective porosity. The effective porosity is expected to be very low and estimated to be 1-5%. Using the maximum hydraulic conductivity outlined in section 6.2.1 the groundwater velocity would be approximately 1.48 x 10^{-5} m/s. This assumes that there are no hydraulic barriers or faults retarding flow outside the site which are likely to be present.

There are a series of north-south/north-east south-west trending faults outside the site (Geological map Sheet 13). These are perpendicular to the regional groundwater flow and are likely to retard groundwater movement down-gradient.

The site is located in the upper part of a groundwater catchment. This location, the general absence of large springs in the aquifer, the confined nature of much of the aquifer in the site area and the moderate gradient and velocity indicate that the natural groundwater throughput in the aquifer is relatively low. However, owing to the secondary nature of the permeability in the aquifer, significant volumes of water can be induced to flow under stressed (pumping) conditions.

The hydraulic boundaries of the aquifer in the vicinity of the MEHL site are the confined zone to the north, a groundwater divide to the west, and a small stream and a formation boundary to the south. Down-gradient and to the east the aquifer width narrows and probably discharges to a tributary of the small stream that adjoins the northern boundary of the site.

The stream which runs along the northern boundary of the site may be partially fed by shallow groundwater in places. This stream lies at an elevation of 104 mOD on the north western corner of the site and falls to a level of 93.5mOD on the north eastern corner of the site.

In this area the natural overburden of low permeability clay is still in place. There are two wells screened in the Namurian deposits located very close to the stream (BH6 is 23m south of the stream and BH11A is 14m south of the stream).

Both of these wells are artesian and have groundwater levels of approximately 117mOD and 98mOD for BH6 and BH11A respectively. These groundwater levels are above the level of the stream. This indicates that the stream is not hydraulically connected with the groundwater in the Namurian deposits in this area and that the Namurian deposits are confined by the overburden.

Groundwater is likely to discharge to this stream where the Loughshinny outcrops. As outlined in section 6.1 the Loughshinny is located further to the south than is shown on the geological maps. This indicates that the groundwater may discharge to a tributary of this stream located approximately 1.5km to the east of the site (**Figure 3**).

6.2.4 Hydrochemistry

In accordance with the current waste licence conditions MEHL has been collecting groundwater quality samples on a quarterly basis and the data from this are presented in **Appendix A14.8**. Groundwater samples were collected from all the monitoring points on site, both the existing and the new ones and the detailed analysis of the water chemistry is discussed in **Appendix A14.8** and summarised below.

The groundwater beneath the site is hard, with concentrations of approximately 200 mg/l $CaCO_3$. This is characteristic of limestone deposits and even higher readings would be realistic.

Elevated concentrations of manganese were detected in all boreholes. This is likely to be due to the shaley deposits present on the site and is in line with the regional data presented in section 6.1.3.

Elevated spot concentrations of iron and nitrite were found in BH20 and BH18 respectively.

Sulphate concentrations exceeded the Drinking Water Standard in BH10A in the most recent round. In previous monitoring rounds, the values were within guidelines values.

Elevated concentrations of arsenic were found in 4 boreholes, molybdenum and antimony were both found in BH5 and BH9. It is likely that these metals are naturally occurring.

The potassium : sodium ratio for can be used as indicator for organic contamination. The GSI criterion for this is that the ratio must be less than 0.35 to indicate that no organic contamination is present. BH17 in the centre of the site is the only sample which failed this analysis with a ratio of 1.64 due to the high potassium concentration detected. However, the potassium detected may be naturally occurring.

Ionic balances were used to assess the quality of the data provided by the laboratory.

6.2.4.1 Vulnerability

Based on the results of the site investigation, it can be stated that between 5-10 m of low permeability material overlie the aquifer over the majority of the site. This is a conservative estimate as it takes account of the shallowest water strikes in the boreholes as opposed to the larger water strikes indicative of the presence of the strata to be taken to be the aquifer.

The aquitard strata on-site act as a low permeability layer and confine/isolate groundwaters within the aquifer from the surface

Following the GSI vulnerability criteria outlined in **Table 6.2** this would indicate that the majority of the site has a Moderate vulnerability rather than Extreme.

The exception to this is in the southern corner of the excavation where the bedrock is exposed. In this area the vulnerability is still extreme.

6.3 Summary of Hydrogeological Conditions

A summary of the hydrogeology of the MEHL site is presented here in the form of a site conceptual model. The conceptual model for the site has evolved through the various stages of the project from initial desk study through the final interpretation of site specific data:

- Bedrock beneath this former quarry site can be divided into an aquifer unit, the Loughshinny Formation and the lower part of the overlying Donore Formation and an aquitard unit which consists of the upper part of the Donore Formation and the overlying Balrickard and Walshestown Formations. The aquifer unit is classified by the GSI as a Locally Important Aquifer and the aquitard as a Poor Aquifer
- The majority of the site is underlain by the aquitard. The limestones of the Loughshinny Formation crop out in the southern part of the MEHL site and dip to the north, where they are covered by at least 60 m of aquitard strata in the northern parts of the site.
- There are at least two faults in the central part of the site, a N-S fault which appears to restrict groundwater movement and an E-W fault which does not. The latter appears to bring permeable horizons in the aquitard unit in contact with the aquifer.
- Permeability in the strata beneath the site is predominantly secondary in the form of joints, fractures, weathered/broken zones and faults. Permeability in the aquifer unit is of the order of $10^{-4}/10^{-5}$m/s. In the permeable horizons of the aquitard, permeability is of the order of 10^{-6}m/s and in the remainder of the strata it is of the order of $10^{-7}/10^{-8}$m/s. Storage in all of these strata is low.
- The aquitard strata on-site act as a low permeability layer and confine/isolate groundwaters within the aquifer from the surface. The increasing thickness of these strata reduces the vulnerability to the north.
- The groundwater levels in the aquifer unit are relatively consistent across the site and lie below the floor of the quarry aside from the large pond in the extreme southern part of the site. Groundwater levels in the overlying aquitard strata are more variable, are elevated in relation to those in the underlying aquifer and are artesian in certain horizons. This confirms their position on-site as a confining layer.
- Groundwater level monitoring indicates that recharge/infiltration is slow and relatively low responding to seasonal rainfall rather than individual rainfall events. This also indicates that storage is low in these strata.
- Groundwater flows in a generally east south east direction from the site at a gradient of 0.02-0.05 and a groundwater velocity of approximately 1.48×10^{-5} m/s.
- The regional flow pattern is controlled by the presence of a syncline beneath the site which causes groundwater to flow along its axis.

- The site is located in the upper part of a groundwater catchment. This location, the general absence of large springs in the aquifer, the confined nature of much of the aquifer in the site area and the moderate gradient and velocity indicate that the natural groundwater throughput in the aquifer is relatively low. However, owing to the secondary nature of the permeability in the aquifer, significant volumes of water can be induced to flow under stressed (pumping) conditions.
- The stream on the northern boundary of the site is not hydraulically connected to the groundwater beneath the site as demonstrated by the artesian Namurian boreholes adjacent to it.

7 Conceptual Site Model

A conceptual model describing the impact the proposed development may have on the groundwater environment is presented here in the form of a Source-Pathway-Receptor summary. **Figure 13** illustrates this concept.

7.1 Source

The source of contamination from the proposed development is the leachate that may be generated by the waste. As outlined in section 2.4 the proposed development will accept hazardous, non-hazardous and inert waste.

The placement of the waste with regard to the distribution of the aquifers on the site is as follows:

- Locally Important Aquifer: Inert waste and non-hazardous waste
- Poor Aquifer: Hazardous waste

7.2 Pathway

Potential contaminant pathways through both engineered liners and the natural ground have to be considered when assessing the risk to groundwater from the proposed development.

7.2.1 Engineered Barriers

Hazardous, non-hazardous and inert cells in the proposed development will each have a different landfill liner installed with varying leachate containment properties. The cells where hazardous material is proposed to be placed will have the liner with the highest level of containment properties as outlined in section 2.4.2.

The details of the lining system to be used for each waste type are presented in section 2.4 and are summarised below:

- Hazardous waste: DAC liner system which incorporates two low permeability liners.
- Non-hazardous waste: Clay liner with HDPE cover and an additional clay layer to enhance the natural protection.
- Inert waste: Clay liner.

7.2.2 Unsaturated Zone

The hydraulic properties of the unsaturated zone on the site determine the natural protection that the site offers against contamination generated by the proposed development. The key elements of the unsaturated zone are outlined below:

- The majority of the site is underlain by the aquitard. The limestones of the Loughshinny Formation crop out in the southern part of the MEHL site and dip to the to the north, where they are covered by at least 60 m of aquitard strata in the northern parts of the site. This indicates that to the north of the site there will be up to 60 m of natural protection available.
- Infiltration testing was undertaken to assess the vertical permeability of the material on which the landfill will be constructed. This testing demonstrated that the material has a low permeability of the order of 10^{-8} m/s.
- The pumping test demonstrated that the north-south trending fault appears to be acting to retard flow rather than as a natural pathway. The east-west fault does not appear to influence the flow on site.
- The groundwater within the aquifer is confined by the overlying lower permeability aquitard deposits, where present (across most of the site). This will effectively prevent any leachate from entering the aquifer beneath confining horizons.

7.2.3 Vertical Zone

The vertical zone is the horizon beneath the site which lies between the aquifer and the unsaturated zone. It is composed of the Namurian deposits which form the aquitard but are saturated with water. There is limited movement of groundwater within these deposits and flow will predominantly be upward due the confining conditions observed on the site.

7.2.4 The Aquifer

- Leachate generated by the inert and non-hazardous cells could enter the aquifer (over a long period of time) if the liner failed. However, its downward movement will be limited due to the hydraulic conditions on site.
- The leachate generated by the hazardous cells could enter the aquitard. The downward movement of this leachate is limited by the upward head due to confining conditions within the Loughshinny and also within the Namurian.
- The movement of leachate would be complicated by the presence of faults on the site and to the east of the site. The leachate may move along these; however the pump test demonstrated that the north-south trending fault on the site is hindering groundwater flow rather than enhancing it.

7.3 Receptors

The receptors for any potential contamination arising from the proposed development are:

- Groundwater entering the aquifer beneath the site for ‘hazardous substances’ (List 1 substances defined by the Water Framework Directive).
- Groundwater within the aquifer at the site boundary for ‘non-hazardous pollutants’ (List 2 substances defined by the Water Framework Directive). (The nearest local groundwater well is approximately 935 m down-gradient of the site).

The risk assessment receptors are discussed further in section 8.3.3.

As outlined in section 6.1.5.3, the Bog of the Ring well field to the north east of the site is not considered to be a receptor for contamination from the proposed development. Groundwater flow beneath the site is towards the south east and away from the well field.

Assessing the impact to groundwater in the aquifer at the site boundary will afford adequate protection for all other receptors such as the potential for discharge to the stream 1.5 km to the east of the site

8 Risk Assessment Modelling

8.1 Modelling Approach

The programme chosen to model the risk to groundwater from the proposed Integrated Waste Management Facility at the MEHL site is LandSim v2.5. This software package was designed to provide a means of assessing the risk to groundwater from landfill, either existing or proposed. LandSim was developed in conjunction with and is endorsed by the Environment Agency for England and Wales. LandSim v2.5 models contaminant mobilisation and transport and allows the incorporation of available site investigation data along with site specific landfill design.

LandSim was used at the MEHL site to model the potential for movement of any leachate generated by the waste through the engineered barriers and unsaturated zone into the groundwater beneath the site. It allows an assessment of whether any contamination could enter groundwater and if it was likely to cause pollution at identified groundwater receptors.

LandSim deals with uncertainty by using a probabilistic method of modelling known as the Monte Carlo method. In this method, the calculations are carried out many times, with a different parameter value randomly selected from the input range of values each time. The input range of values for each parameter can be entered as a probability density function. The choice of probability density function depends on how much data is available and the quality of the data. For example, if the porosity is likely to be between 0.2 and 0.3, the operator may select a uniform distribution. This tells LandSim that there is an equal chance of the parameter having all values between 0.2 and 0.3. However, if the site specific data or otherwise suggest that the porosity is between 0.2 and 0.3 but is more likely to have a value of 0.25, a triangular distribution may be used, and values nearer 0.25 will be selected more often by LandSim than values at the upper and lower ends of the range. There are many other types of probability density function that may be used depending on what suits the data best. LandSim then calculates the probability of contaminants reaching a designated receptor.

8.2 Model Scenarios

The primary model for this assessment represents the proposed development with all engineered barriers in place. The details of the engineered cells were obtained from the Engineering Planning report (WYG 2010). The input parameters used in this model are discussed in section 8.3.1. The results from this model are presented in section 8.3.4.

In addition to the primary model, following consultation with the Environmental Protection Agency (EPA), two supplementary models were constructed. These are outlined below:

- Supplementary model 1- the proposed development with a major defect in the liner of one of the hazardous cells.
- Supplementary model 2 - the proposed development with no engineered barriers in place.

Both supplementary models are clearly highly unrealistic, however these supplementary models are useful in assessing the natural protection available on the site. They also highlight the level of protection which the engineered cells provide at the site.

The supplementary models are presented in section 8.4.

8.3 Primary Model

The model was constructed based on site specific information for both the landfill design and the hydraulic characteristics of the ground in order to make it as representative of site conditions as possible.

The Engineering Planning Report (WYG 2010) for the proposed development contains information on the cell layout, phasing and engineered properties of the cells. This information was used to construct the model and provided detailed input parameter information as outlined in sections 8.3.1 - 8.3.2.

As outlined in section 3.4 a detailed hydrogeological investigation was undertaken to gain site specific information on the unsaturated zone and aquifer characteristics. These data allowed the model to be as representative of site conditions as possible.

Where any uncertainty existed with the input parameters a conservative approach was taken.

The input parameters for the model have been separated into those which constitute the ‘source’ of the potential contamination, the ‘pathway’ and the ‘receptor’.

The model input parameters are presented in **Appendix A1.1** as a print out directly from LandSim.

8.3.1 Source Term Input Parameters

The source term input parameters include the physical and chemical characteristics of the waste itself, the cell geometry and phasing details and the infiltration rates. These input parameters are discussed in details in sections 8.3.1.1 to 8.3.1.6. The model print out from LandSim which summarises the input parameters for the primary model are presented in **Appendix A1.1**.

8.3.1.1 Cell Geometry

The cell geometry is used in LandSim for a number of calculations. It determines the volume of waste which will be accepted into the proposed development and thus contributes towards the volume of leachate which may be produced. The area of the base of the cell is also used to determine the area over which leakage may occur out of the cell. LandSim assumes that leakage through the side-walls is insignificant.

LandSim does not allow the actual volume of waste to be entered directly into the model. Instead the value is calculated from the area of the base and top of the cell and the thickness of the waste.

As outlined in section 2.4 the proposed development will accept inert, non-hazardous and hazardous materials and these will be contained within separate cells. For each waste type multiple cells will be constructed to reduce the amount of time that waste remains open to infiltration and to minimise leachate generation.

In order to construct a representative model, each of these cells was modelled as an individual cell within the LandSim model.

On the proposed development many of the cells have been divided in two in order to minimise leachate generation e.g. H1 has been divided into H1a and H1b. The proposed site layout showing the individual cells is presented in **Figure 14**.

As each of these proposed cells will have its own sump they have all been constructed separately in LandSim. This has led to the following cells being constructed in the LandSim model:

- 4 inert cells (Existing, IN1, IN2 and IN3)
- 3 non-hazardous cells (NH1a, NH1b and NH2)
- 6 hazardous cells (H1a, H1b, H2a, H2b, H3a and H3b)

The proposed design for the cells shows them as irregular shapes as shown on **Figure 14**. In the LandSim model these cells were constructed as squares or rectangles with the area of the top and base maintained at the same size as the irregular shape.

Where a cell has been divided in two to minimise leachate generation (e.g. H1 into H1a and H1b) the full design details of each individual cell are not available. For this reason it has presumed that the two cells will be identical with the volume of waste expected in cell H1 divided equally between cell H1a and cell H1b.

The thickness of the waste varies across the site. To account for this variation, the thickness of each cell was entered as a Probabilistic Density Function.

The details of the parameters used for the cell geometry are contained within **Table 8.1**.

Table 8.1 Cell Geometry Input Parameters

Cell number	Base area (ha)	Top area (ha)	Waste thickness			Comments
			Distribution	Min	Max	
Existing	1.08	1.3	Uniform	16.5	29.5	
IN1	2.58	5.1	Uniform	15.5	34.5	Thickness presumed to be same as adjacent non-hazardous cells
IN2	0.73	1.3	Uniform	16.5	29.5	Thickness based on assumption that cell will be same height as existing cells
IN3	1.04	1.9	Uniform	16.5	29.5	Thickness based on assumption that cell will be same height as existing cells
NH1a	0.86	2.24	Uniform	23.5	37.5	Dimensions from site plans and cross sections
NH1b	0.86	2.24	Uniform	23.5	37.5	Dimensions from site plans and cross sections
NH2	0.127	1.1	Uniform	7	16	Dimensions from site plans and cross sections
H1a	1.01	1.71	Uniform	10.5	19.5	Dimensions from site plans and cross sections
H1b	1.01	1.71	Uniform	10.5	19.5	Dimensions from site plans and cross sections
H2a	1.4	2.2	Uniform	11.5	26.5	Dimensions from site plans and cross sections
H2b	1.4	2.2	Uniform	11.5	26.5	Dimensions from site plans and cross sections
H3a	1.29	2.55	Uniform	15.5	34.5	Dimensions from site plans and cross sections
H3b	1.29	2.55	Uniform	15.5	34.5	Dimensions from site plans and cross sections

8.3.1.2 Phasing

Phasing for the proposed development is described in detail in the Engineering Planning Report (WYG, 2010). It is proposed to construct the development in four separate phases. The details of which cell will be filled during each of these along with the length of each phase is contained in **Table 8.2**.

Table 8.2 Landfill Phasing

Phase number	Operational time (years)	Cell numbers
Phase 1	5	H1a, H1b, IN1
Phase 2	11	H2a, H2b, NH1a, NH1b, IN2, IN3
Phase 3	9	H3a, H3b (IN1 & IN2)
Phase 4	2	NH2, (IN1)

IN1 will be constructed in Phase 1 and some waste from the existing landfill will be moved into it. Additional waste will be placed in this cell in Phase1 and also in Phases 3 and 4. For this reason, the duration of filling for IN1 will be set as the total amount of time for Phases: 1, 3 and 4 (i.e. 16 years). This is more conservative than dividing the cell into two as it presumes all the waste placed over both phases is open.

The Engineering Planning Report (WYG, 2010) states that each cell will be capped at the end of its operational phase or the beginning of the following phase at the latest. However, in the LandSim model the cells which will be divided in half will be open for the full length of the phase e.g. H1a and H1b will both be open for the full 5 years. In reality this is a conservative assumption as it is more likely each will be filled separately and may only be open for half the time. In order to maintain a conservative assessment it has been assumed that all cells will remain open for the full length of the phase in which they will be constructed.

In order to build an accurate LandSim model, the phasing had to be adjusted to incorporate the existing cells that will remain in place in the proposed development. This was undertaken by adjusting the time off-set in the model. The model was constructed so that Year 0 is 2003 and the Existing cell in the model was constructed over 8 years. All other cells were modelled as being constructed subsequent to that.

The design life of the proposed development is 25 years, however, in order to account for the existing cells this was increased to 35 years.

8.3.1.3 Management Control

The concept of management control is used in LandSim to simulate the length of time over which a landfill will be maintained by the operator. It assumes that once the management control period is complete the landfill will be 'abandoned' and will have no further maintenance undertaken on it (although this is very unrealistic and contrary to EPA aftercare requirements). This has significant implications for the risk assessment model as beyond the specified management period the leachate level is no longer controlled. The leachate level and, as a result, leakage through the liner will increase.

The management control period is usually set as a long time period in risk assessment models as the license will require that an aftercare management plan is implemented until the landfill's potential to cause pollution is negligible.

The actual period of management control for the proposed development will be agreed with the Environmental Protection Agency in the future. In order to maintain a conservative assessment in this model, the management control period was set as 35 years i.e. that the site will not be maintained once all cells are filled and capped. It should be noted that this is highly conservative.

8.3.1.4 Infiltration

The infiltration rates entered into the LandSim model influence how much leachate will be generated. This is calculated for both the open cells by inputting an infiltration value and the capped cells by assessing the cap design infiltration.

The infiltration rate used in the LandSim model is dependent upon the potential rainfall which may enter the waste. This was determined by subtracting the evapotranspiration rate from the rainfall rate.

Rainfall and evapotranspiration data are discussed in section 5. The data which was used to calculate the general infiltration rate for the LandSim model is presented in **Table 8.3**.

Table 8.3 Climate data measured at Dublin Airport and used to calculate infiltration rate

Time period	30 year average	2008	Comments
Rainfall* (mm/yr)	731.8	942.3	2008 had the highest rainfall in recent years
Potential Evapotranspiration* (mm/yr)	418.4	531	Corresponding PE rates (Penman method) for the same time period
Potential rainfall/Infiltration rate (mm/yr)	313.4	411.3	Infiltration rate to be used in LandSim

*Data source: Met Eireann

In order to minimise the leachate generation in the hazardous cells a temporary cover system will be incorporated into the design of the proposed development. This temporary cover system will be used at night and any rainfall which falls on it will run to surface water drains and be disposed of appropriately.

Therefore it is appropriate to reduce the infiltration rate for the hazardous cells. As the covers will be placed on the cells at night and on Sundays, a 50% reduction in the infiltration rate has been applied to the hazardous cells.

The capping details for each of the cells are outlined in the Engineering Planning Report (WYG, 2010). The infiltration rate through the cap has been set at 50 mm/yr as this is above the maximum infiltration rate of 31.5 mm/yr specified in the EPA Manual on Landfill Site Desgn (EPA, 2000) for a capped landfill and is therefore conservative.

This is a conservative approach as it does not account for the geotextiles or lower permeability material which may be incorporated in the capping systems. The capped infiltration will be lower for some cells (e.g. the hazardous cells which incorporate a geotextile) which would reduce the amount of leachate generated. However, as outlined previously a conservative approach has been taken to model greater leachate generation.

The infiltration input parameters have been summarised in **Table 8.4**.

Table 8.4 LandSim Infiltration Input Parameters

Parameter	Infiltration rate (mm/yr)			Comment
	Distribution	Min	Max	
Hazardous cells infiltration rate	Uniform	156.7	205.7	Half of potential rainfall
Inert and non-hazardous cells infiltration rate	Uniform	313.4	411.4	Potential rainfall
Cap design infiltration rate	Single	50		Conservative infiltration rate for a landfill cap (above EPA rate)

8.3.1.5 Leachate and Waste Characteristics

The physical characteristics of the waste influence how much leachate may be generated while the chemical characteristics influence the contaminants which may arise. The head at which leachate head is maintained at within the system determines how much leachate is allowed to build up within the cell before appropriate removal and disposal.

The head of leachate within the LandSim model was fixed in line with details from the Engineering Planning Report. Within the hazardous and non-hazardous cells the leachate will be allowed to reach a maximum of 1 m above the base of the cell.

There is no requirement to control and dispose of leachate in inert waste cells, however on the MEHL site the leachate is sometimes re-circulated in good conditions to reduce the leachate levels. In order to maintain a conservative model, leachate recirculation has not been included in the model, but a large range of leachate heads have been inputted for the inert cells.

The leachate head details which were inputted into LandSim are summarised in **Table 8.5**.

Table 8.5 Leachate Head Details Inputted To LandSim

Cell number	Leachate head (m)				Comment
	Distribution	Min	Likely	Max	
Existing, IN1, IN2, IN3	Triangular	1	5	10	
NH1a, NH1b, NH2, H1a, H1b, H2a, H2b, H3a, H3b	Uniform	0.5		1	A minimum value of 0.5m was chosen as it is unrealistic that it will be possible to maintain a head of less than 0.5m. The maximum head value has been set as the maximum head stated in the Engineering Report for Planning (WYG, 2010)

The waste porosity, dry density and field capacity influence the amount of leachate which can be produced from the waste.

The hazardous waste will be solidified into blocks to minimise the concentrations of heavy metals in the leachate. This solidification process will also serve to reduce the amount of leachate which may be generated as less water will enter the waste due to the smaller pore sizes.

The values used in the LandSim model are summarised in **Table 8.6** below. Where uncertainty is present over the value used e.g. the characteristics of non-hazardous waste, a sensitivity analysis was undertaken to determine its influence on the model. This is discussed in section 8.3.4.3.

Table 8.6 Waste Characteristics Inputs

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Inert Waste					
Waste porosity (fraction)	Log Uniform	0.01		0.22	Large range used to simulate effective porosity and also effective porosity under stress. Values from Staubb et al (2009)[3]
Waste dry density (kg/l)	Triangular	1.25	1.5	1.75	Value of 1.5 t per m^3 from Leach and Nikitas (2004)[4]. Range added to allow for uncertainty.
Waste field capacity (fraction)	Triangular	0.118	0.15	0.2	Calculated using equation from Kreith and Tchobanoglous (2002)[5]
Non-hazardous Waste					
Waste porosity (fraction)	Uniform	0.18		0.25	Rübner et al (2007)[6]
Waste dry density (kg/l)	Uniform	1.125		1.5	Wet density 1.5-2 t/m3 with 20-25% water content
Waste field capacity (fraction)	Triangular	0.08	0.1	0.12	No value for non-hazardous waste found in literature search. Value for hazardous waste used and a sensitivity analysis undertaken.
Hazardous Waste					
Waste porosity (fraction)	Uniform	0.3		0.35	Minimum value provided by landfill designers (WYG). Max value: (Simons et al, 2006)[7]

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[3] Staub, M., Galietti, B., Oxaranglo, L., Khire, M.V. and Gourc, J.-P. (2009). Porosity and hydraulic conductivity of MSW using laboratory-scale tests. Third Internation Workshop "Hydro-Physcio-Mechanics of Landfills", Braunschweig, Germany; 10-13 March 2009

[4] Leach, B. and Nikitas, C. Waste management capacity in the South East Region. A report to SEERA

[5] Kreith, F. And Tchobanoglous, G. (2002) Handbook of solid waste management. McGraw-Hill Professional, 2002-950 pp.

[6] Rübner, K., Jaa,lems. F. and Linde, O.(2007) Use of municipal solid waste incinerator bottom ash as aggregate in concrete. European Geosciences Union General Assembly 2007, Wien, 15-20 April 2007

[7] Simons, D-J, Bleijerveld, R. and Humez, N. (2006).. solidification/Stabilisation of Hazardous Waste. Sustainable Landfill Foundation

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Waste dry density (kg/l)	Triangular	0.18	1.5	1.72	Likely value provided by landfill designers (WYG). Max and min values: (Jantzen, 2006)[8]
Waste field capacity (fraction)	Triangular	0.08	0.1	0.12	Likely value provided by landfill designers (WYG). Range added to allow for uncertainty

8.3.1.6 Leachate

The likely contaminants which may arise in leachate from the hazardous waste is summarised in **Table 8.7**. These contaminants were also modelled for the inert and non-hazardous wastes although it is unlikely that they will all be present.

The list only includes physical contaminants (e.g. arsenic etc) and does not include indicator parameters (e.g. Total Dissolved Solids) as LandSim cannot model indicators.

The maximum concentrations were set in the LandSim model as 3 times the Waste Acceptance Criteria (set in EU Council Decision 2003/33/EC) for the relevant waste type as a single value. These concentrations are the maximum amount of any particular contaminant which will be accepted into the landfill.

By inputting the concentration as a single value (rather than a probability density function) it presumes that all waste accepted will be at the maximum concentration which is a very conservative scenario. However, by inputting these maximum values the highest potential risk to groundwater can be assessed.

The Waste Acceptance Criteria values used were taken from the Co limit values (concentration of leachate arising from a percolation test) set in EU Council Decision 2003/33/EC rather than the L/S = 10 kg (liquid to solid ratio) values.

This was done for two reasons:

- The Co values were thought to more accurately represent the values for leachate generation from waste. This is because the test to determine Co is undertaken over a longer period of time than the test to determine L/S = 10 kg values and simulates the percolation of leachate out of the waste as water passes through it.
- The Co limit values are also higher than the L/S = 10 kg values and as such are more conservative.

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[8] Jantzen, C.M. (2006). Fluidized bed steam reformer (FBSR) product: Monolith formation and characterization. Savannah River National Laboratory. Prepared for the U.S. Department of Energy

Table 8.7 LandSim Leachate Inventory

Contaminant	Concentrations entered into LandSim (mg/l)		
	Inert waste: 3 x WAC	Non-hazardous waste: 3 x WAC	Hazardous waste: 3 x WAC
Arsenic	0.18	0.9	9
Barium	12	60	180
Cadmium	0.06	0.9	5.1
Total chromium	0.3	7.5	45
Copper	1.8	90	180
Mercury	0.006	0.09	5
Molybdenum	0.6	10.5	30
Nickel	0.36	9	36
Lead	0.45	9	45
Antimony	0.3	0.45	3
Selenium	0.12	0.6	9
Zinc	3.6	45	180
Chloride	1380	25500	45000
Fluoride	7.5	120	360
Sulphate	4500	21000	51000

The following parameters were excluded from the LandSim modelling exercise as there are no Waste Acceptance Criteria limits available for them: Thallium, Vanadium, Cobalt, Manganese and Tin. These contaminants may arise from hazardous waste in small quantities, however, their exclusion can be justified as the contaminants which are modelled display similar characteristics in terms of toxicity and mobility. Therefore, if the model predicts that any other contaminant will reach a receptor, then it may be assumed that these will too. Conversely if the other contaminants are not detected at the receptor then it may be assumed that these will not be either. It should also be noted, that none of these excluded contaminants (Thallium, Vanadium, Cobalt, Manganese and Tin) are ‘hazardous substances’ in the Water Framework Directive.

The source of leachate was set as a ‘Declining Source Term’ in LandSim which allows the source term concentrations to decrease over time. This reflects the expected reduction in concentrations over time.

The half lives of each of the contaminants in the different stages that they move through has been set at the highest level to effectively simulate zero degradation. The half lives used for all contaminants at all phases (e.g. within the liner, unsaturated zone, vertical pathway and aquifer) has been set at 1,000,000,000 years. This is a conservative assumption as it does not allow the contaminants to degrade over time.

8.3.2 Pathway input parameters

The pathway input parameters are those which define the material which the leachate generated at the source has to move through in order to reach the receptors. The pathways in the proposed development include the drainage system, the engineered barriers and the unsaturated zone.

8.3.2.1 Engineered barrier

As outlined in sections 2.4.2 to 2.4.4 the cells for the different waste types will have a different lining system. These lining systems have been dealt with differently in LandSim. The input parameters are summarised in **Table 8.8** and the concepts behind them are explained in the following paragraphs.

Table 8.8 Landfill Liner Input Parameters

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Inert Liner					
Design thickness of clay liner (m)	Single		1		Engineering Planning Report (WYG, 2010)
Moisture content (fraction)	Uniform	0.21		0.39	Staub et al, 2009[3]
Clay hydraulic conductivity (m/s)	Log Triangular	1.00E-10	1.00E-09	1.00E-07	WYG report for max value, on site clay used to date also
Longitudinal dispersivity (m)	Single		0.1		10% of liner thickness
Non-hazardous Liner					
Clay liner thickness (m)	Single		1		Engineering Planning Report
Clay moisture content (fraction)	Uniform	0.096		0.128	EC guidance
Clay hydraulic conductivity (m/s)	Log uniform	1.00E-10		1.00E-09	Engineering Planning Report
Clay longitudinal dispersivity (m)	Single		0.1		10% of liner thickness
HDPE Pinholes (0.1-5 mm^2)	Log Uniform	25		0	Standard value in LandSim for flexible membrane liners based on Golder research

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
HDPE Holes (5-100 mm^2)	Log Uniform	5		0	Standard value in LandSim for flexible membrane liners based on Golder research
HDPE Tears (100-10000 mm^2)	Triangular	2	0.1	0	Standard value in LandSim for flexible membrane liners based on Golder research
Onset of HDPE degradation (yrs)	Single		150		Standard value in LandSim for flexible membrane liners based on Golder research
Time for area of HDPE defects to double (yrs)	Single		100		Standard value in LandSim for flexible membrane liners based on Golder research
Hazardous Liner					
Design thickness of 'clay' liner (m)	Single		0.08		Engineering eport for Planning (WYG, 2010)
Moisture content (fraction)	Log uniform	0.096		0.128	Do sensitivity analysis
Clay hydraulic conductivity (m/s)	Log uniform	1.00E-15		1.00E-12	Engineering report for Planning (WYG, 2010)
Longitudinal dispersivity (m)	Single		0.008		10% of the thickness of the DAC liner

The inert cells will be lined with a single clay liner. This can be modelled in LandSim as a 'Single Clay EBS' (Engineered Barrier System). This is the simplest type of liner and it allows the physical characteristics of the liner to be inputted. These are outlined in **Table 8.8**.

The non-hazardous cells will be lined with a single clay liner which is overlain by a HDPE liner. This has been modelled in LandSim as a 'Composite EBS'. As with the 'Single Clay EBS', LandSim models the characteristics of the clay, however it also allows the details of the future failure rate of the HDPE liner to be taken into account. The input parameters and their justifications are outlined in **Table 8.8**.

The liner which provides the highest level of protection will be in the hazardous cells. A DAC liner system will be used for the hazardous cells and the composition of this is outlined in section 2.4.2.

There are two liners with different permeabilities incorporated into the DAC system; the upper liner is the DAC liner with an extremely low permeability, while the lower liner is a simple low permeability clay liner. A stabilisation layer, with leak detection system, is present in between these two liners.

The performance of DAC liners are presumed to remain unchanged over time in line with the LandSim manual. LandSim v 2.5 assumes no changes to the physical properties will occur during the simulation if the artificial sealing layer is simulated as a mineral barrier (i.e. a clay). For this reason it is appropriate to treat the DAC liner as a clay barrier in LandSim.

To maintain a conservative approach to the modelling the liner for the hazardous cells, the liner was modelled in LandSim as a ‘Single Clay EBS’ (Engineered Barrier System). This only simulates the thin low permeability DAC liner as the liner for the hazardous cells and does not take account of the second low permeability 0.5 m thick liner which is incorporated into the DAC system.

This indicates that the liner for the hazardous cells will have an additional level of protection for groundwater incorporated into it which is not accounted for in the model and consequently the results will be conservative.

The retardation of contaminants within the liner has been incorporated into the LandSim model. The retardation is calculated from the pathway density and the partition coefficient of each individual contaminant. The input parameters used for retardation in the clay liner, unsaturated zone and aquifer are outlined in **Table 8.10**.

Table 8.10 Retardation Input Parameters

Parameter	Input details				Comment
	Distribution	Max	Likely	Min	
Pathway density for landfill liner (kg/l)	Uniform	1		2.4	ConSim density of clay
Pathway density for unsaturated zone (kg/l)	Uniform	1.6		2.68	ConSim value[9] for sandstone: conservative as the material is a mixture of weathered sandstones & siltstone - as above
Pathway density for aquifer (kg/l)	Uniform	1.74		2.79	ConSim density of limestone

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[9] ConSim is the sister programme of LandSim which was developed for the UK EA with the aim of assessing the risk to groundwater from contaminated land sites. A detailed database was developed as part of this programme development based on an extensive literature search and field values internationally. This data can be used in the absence of site specific data

Parameter	**Input details**				**Comment**
	Distribution	**Max**	**Likely**	**Min**	
Kd: Arsenic (l/kg)	Uniform	117		249.6	LandSim recommends a Kd range of 25-250 for unspecified material. As the liner is being modelled as clay, the ConSim values for a 'unspecified material' (min) and a glacial till (max) were used
Kd: Barium (l/kg)	Log Uniform	0.6		17	ConSim max & min for Barium
Kd: Cadmium (l/kg)	Uniform	222.2		240	Same basis as Arsenic
Kd: Chloride (l/kg)	Single		0		Unretarded parameter (ConSim & LandSim)
Kd: Chromium (l/kg)	Log uniform	35		965.6	Same basis as Arsenic
Kd: Copper (l/kg)	Uniform	126.8		295	Same basis as Arsenic
Kd: Fluoride (l/kg)	Single		0.8		Only value in ConSim
Kd: Lead (l/kg)	Log uniform	27		2.70E+05	LandSim
Kd Mercury (l/kg)	Log uniform	430		3.84E+03	Same basis as Arsenic
Kd: Nickel (l/kg)	Uniform	66		85	Same basis as Arsenic
Kd: Selenium (l/kg)	Single		9.5		ConSim unspecified material
Kd: Sulphate (l/kg)	Single		0		Unretarded parameter (LandSim)
Kd: Zinc (l/kg)	Uniform	20.7		26	Same basis as Arsenic
Kd: Molybdenum (l/kg)	Single		110		ConSim
Kd: Antimony (l/kg)	Single		251		US EPA, 2005[10]

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[10] Allison, J.D. and Allison, T.L. (2005). Partition Coefficients for Metals in surface water, soil and waste. U.S. Environmental Protection Agency, Office of Research and Development, Washington

8.3.2.2 Unsaturated zone

The unsaturated zone is the ground beneath the site which is above the water table. By inputting this horizon into LandSim V.2.5 it allows the natural protection which the site offers for the protection of groundwater to be assessed.

As the natural protection offered by the site can have a large influence on the amount of contaminants which may reach the aquifer and local receptors a very conservative approach was taken to these input parameters. This allowed the highest concentrations of contamination in groundwater to be predicted.

It should be noted, that as outlined in section 2.4.3 an additional 1 m of clay material with a permeability of 6.6 x 10^{-10} m/s will be placed below the base of the liner for the non-hazardous cells to enhance the natural protection. This layer has not been included in the LandSim model and consequently the results from the non-hazardous cells are conservative.

As outlined in section 6.2.1 the groundwater beneath the site is confined. This indicates that there is an upward gradient of groundwater beneath the site and this will limit the movement of contamination downwards. This has not been accounted for in the LandSim model, and the model assumes downward flow to an unconfined aquifer. Therefore the model is not realistic but is highly conservative.

The piezometric head of the aquifer beneath the site lies approximately 1-2 m below the proposed formation level (102.5 mOD which is the lowest point of excavation except for local excavations for sumps to 102 mOD) however as outlined in section 6.2 this does not reflect where groundwater is encountered beneath the site. Examination of water strikes recorded, during drilling, showed no large strikes were encountered shallower than 12 mbgl and the major strikes were encountered after 25 mbgl.

The ground on site will be excavated below its current level by up to 2.5 m in places. In order to take account of this and some minor water strikes which were observed during the site investigation an unsaturated zone thinner than the 12-25 m which was quoted above was used.

In order to assess the infiltration and vertical hydraulic conductivity on the site, soakaway tests were undertaken. The results of these were inputted as a log triangular distribution for the hydraulic conductivity.

The input parameters used are summarised in **Table 8.11**.

Table 8.11 Input parameters for unsaturated zone

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Pathway length (m)	Uniform	6		5	Conservative estimate applied to whole site. On site data indicates this could be increased
Moisture content	Single		0.3		Estimate. Sensitivity analysis to be undertaken
Hydraulic conductivity (m/s)	Log triangular	2.82E-08	1.53E-07	4.54E-07	Infiltration testing
Dispersion	Uniform	0.06		0.05	10% of pathway

Retardation of contaminants can occur within the unsaturated zone and the parameters associated with this are presented in **Table 8.10**.

8.3.2.3 Vertical pathway

A ‘vertical pathway’ zone can be inputted into LandSim V2.5. This is appropriate for use in a situation where a saturated low permeability aquitard overlies the aquifer as is the case beneath the MEHL site. The input parameters used are summarised in **Table 8.12**.

Table 8.12 Input parameters for vertical pathway

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Pathway length (m)	Uniform	60		10	Based on site investigation data
Porosity	Uniform	0.61		0.34	ConSim value for a silt
Dispersivity (m)	Uniform	6		1	10% pathway

The retardation values inputted for the vertical pathway are the same as those used for the unsaturated zone and are presented in **Table 8.10**.

In LandSim V.2.5 the vertical pathway has to apply to the whole site as opposed to discrete areas on the site. In some areas e.g. the inert cells in the southern part of the site there is no vertical pathway present. However, the highest level of risk to groundwater is generated by pollutants from the hazardous cells and for this reason the thickness of the vertical pathway is related to the ground beneath the hazardous cells only.

It should be noted that there will be an upward gradient of water from the aquifer through the aquitard pathway due to the confining conditions on the site. This will limit the movement of leachate downwards from the landfill towards the aquifer but this cannot be represented in the LandSim model.

8.3.2.4 Aquifer

As outlined in section 8.3.2.2 in the LandSim model the aquifer is directly beneath the unsaturated zone at 5-6 mbgl which is a conservative assumption. The aquifer input parameters used in the LandSim model are summarised in **Table 8.13**.

Table 8.13 Aquifer input parameters

Parameter	Value				Comment
	Distribution	Max	Likely	Min	
Hydraulic conductivity (m/s)	Log Triangular	0.0004	0.0001	2.31E-05	K data based on SI results
Regional gradient	Log Uniform	0.019		0.015	Winter and summer gradients
Pathway porosity (fraction)	Log Triangular	0.05	0.025	0.01	Porosity typical of Irish limestones. Range inputted to account for uncertainty.
Aquifer thickness (m)	Uniform	50		30	Aquifer thickness will be less than formation thickness. Range inputted to account for uncertainty.
Longitudinal dispersivity (m)	Uniform	82.5		16.5	10% of longest & shortest distance from furthest & nearest cell to a phantom monitoring well on the ownership boundary
Transverse dispersivity (m)	Uniform	24.75		4.95	30% of longitudinal dispersivity

Retardation of contaminants can occur within the aquifer and the parameters associated with this are presented in **Table 8.10**.

LandSim V.2.5 does not allow the direction of groundwater flow to be adjusted and for this reason the placement of the cells were adjusted. The receptor well was placed immediately down-gradient of the hazardous cells.

Some parameters may already be present in the aquifer and LandSim allows background concentrations to be inputted into the model. This allows any potential leachate generated by the landfill to be loaded on top of the concentrations naturally present in the groundwater.

Groundwater quality monitoring has been undertaken on site since 2003 and all data recorded in the aquifer was used to calculate the background concentrations. The minimum, maximum and average values calculated based on this dataset and the input values are summarised in **Table 8.14**.

Table 8.14 Background groundwater quality concentrations

Parameter	Distribution	Concentration (mg/l)		
		min	Likely	max
Arsenic	Log Triangular	0.00026	0.00503065	0.025
Barium	Log Triangular	0.006	0.02655294	0.06
Cadmium	Log Triangular	0.00003	0.0011075	0.0039
Chloride	Triangular	18	32.6462264	57
Chromium	Log Triangular	0.0009	0.0068	0.0237
Copper	Triangular	0.001	0.00266667	0.005
Fluoride	Triangular	0.1	0.25714286	0.4
Lead	Triangular	0.001	0.00288889	0.006
Mercury	Single		0.0005	
Nickel	NA			
Selenium	Triangular	0.0012	0.00248	0.005
Sulphate	Log Triangular	5.08	49.0798148	244.77
Zinc	Log Triangular	0.002	0.0196875	0.169
Molybdenum	Log Triangular	0.0002	0.01048	0.043
Antimony	Triangular	0.003	0.0034	0.004

8.3.3 Receptors

8.3.3.1 Relevant European Legislation

The original Groundwater Directive (80/68/EEC) defined two lists of substances that were deemed to pose the greatest risk to groundwater quality, referred to as List I and List II. The Water Framework Directive (WFD, 2000/60/EC) and the Groundwater Daughter Directive (2006/118/EC) identify a wider range of potential pollutants and refer to them as ‘hazardous substances’ or ‘non-hazardous pollutants’.

Hazardous substances are defined in the WFD as “substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern.” A non-hazardous pollutant is any substance capable of causing pollution that has not been classified as a hazardous substance.

Of those contaminants potentially present in leachate at the site only Cadmium and Mercury are classed as hazardous substances, with the remaining substances classed as non-hazardous pollutants.

A requirement of the WFD is that the member states must ensure that all reasonable measures are taken that are required to avoid the entry of hazardous substances into groundwater and, for non-hazardous pollutants, to limit input into groundwater so as to avoid pollution or significant and sustained upward trends or deterioration in status of the groundwater body. The purpose of a risk assessment is to validate whether the proposed measures will meet the requirements of the WFD.

8.3.3.2 Modelled Compliance Points and Assessment Limits

Concentrations of hazardous substances at the base of the unsaturated zone are assessed in the model.

Concentrations of non-hazardous pollutants are assessed in groundwater at the site boundary, by modelling a phantom monitoring well placed directly down gradient on the land-ownership boundary. The modelled concentrations in groundwater at the site boundary are compared to appropriate drinking water standards, as presented in **Table 8.16**. As the hazardous cells are those which pose the highest level of risk to groundwater, the receptor well was placed down-gradient of the cell at the shortest distance between the landownership boundary and the nearest hazardous cell in the direction of groundwater flow. This distance was approximately 270 m.

8.3.4 Primary Model Results

8.3.4.1 Model Outputs

The primary model results are presented in the following sections including information on the sensitivity analysis.

The model was run for 1000 iterations. This means that the model re-ran the Monte Carlo simulation 1000 times, each time randomly selecting parameters from those defined. This ensures that the results from the model are not a single selection of results but are results from multiple runs.

Five fixed time slices were chosen for the model runs and these were concentrations after 30 years, 100 years, 300 years, 1000 years and 20,000 years (i.e. infinity).

8.3.4.2 Statistical & graphical results

The statistical results from the LandSim model are presented in **Appendix A1.2**.

LandSim V 2.5 calculates concentrations of each parameter at the set time slices.

It is accepted best practice to consider the concentrations at the 95th percentile.

LandSim V2.5 allows the concentrations at different percentiles to be displayed graphically as reverse-cumulative plots. This data displays each time slice separately on the same graph and the 95th percentile concentration can be read from these graphs also.

The only hazardous substances (as defined by the Water Framework Directive and Groundwater Daughter Directive) with the potential to be present are Cadmium and Mercury and their concentrations at the base of the vertical pathway are summarised in **Table 8.15**.

Reverse cumulative plots for the concentrations of each 'hazardous substance' at the base of the unsaturated zone and the vertical pathway are presented in **Appendix A1.3**. From these, the 95th percentile concentrations at the base of the unsaturated zone and vertical pathway are presented in **Table 8.15**.

Table 8.15 Summary 95th percentile concentration of 'hazardous substances' at the base of the unsaturated zone and vertical pathway

Parameter	Drinking Water Standard (mg/l)	Cell number	Concentration at the base of the unsaturated zone		Concentration at the base of the vertical pathway	
			95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Cadmium	0.005[1]	Existing	0	NA	0	NA
		IN1	0	NA	0	NA
		IN2	0	NA	0	NA
		IN3	0	NA	0	NA
		NH1a	0	NA	0	NA
		NH1b	0	NA	0	NA
		NH2	0	NA	0	NA
		H1a	0	NA	0	NA
		H1b	0	NA	0	NA
		H2a	0	NA	0	NA
		H2a	0	NA	0	NA
		H3a	0	NA	0	NA
		H3b	0	NA	0	NA
Mercury	0.001[1]	Existing	0	NA	0	NA
		IN1	0	NA	0	NA
		IN2	0	NA	0	NA
		IN3	0	NA	0	NA
		NH1a	0	NA	0	NA
		NH1b	0	NA	0	NA
		NH2	0	NA	0	NA
		H1a	0	NA	0	NA
		H1b	0	NA	0	NA
		H2a	0	NA	0	NA
		H2a	0	NA	0	NA
		H3a	0	NA	0	NA
		H3b	0	NA	0	NA

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

These results show that after 20,000 years concentrations of the ‘hazardous substances’ do not exceed Drinking Water Standards. These results illustrate that groundwater is not at risk from ‘hazardous substances’ from the proposed development.

The cumulative frequency plots of the concentrations of each contaminant at the phantom receptor well placed on the site boundary are presented in **Appendix A1.4**. The 95th percentile concentrations of these are summarised in **Table 8.16.** If the contaminant was detected in more than one time slice then the data from all the time slices will be presented.

In order to allow the contribution of contamination caused by the landfill to be differentiated from the background concentrations, a separate version of the model was created. This model was run with no background concentrations of any parameter present.

The print out of the LandSim model summarising the input parameters are presented in **Appendix A2.1**. The concentrations at the phantom well from this model are presented in **Appendix A2.2** and are summarised in **Table 8.16.** This allows a comparison of the results from the models with and without background concentrations. It highlights how much of the predicted concentrations are due to background concentrations rather than due to the proposed development.

Table 8.16 Summary 95th percentile concentration of all parameters at the phantom receptor well.

Contaminant	Drinking Water Standard (mg/l)	Model which includes background concentrations of parameters in groundwater		Model which does not include background concentrations of parameters in groundwater	
		95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Arsenic	0.01[1]	**0.014**	All	9.9x10^{-5}	20,000
Barium	0.7[2]	0.04	All	0.0001	300
				0.018	1,000
				0.007	20,000
Cadmium	0.005[1]	0.002	All	8.6 x 10^{-6}	20,000
Total chromium	0.05[1]	0.015	All	0.0001	20,000
Copper	2[1]	0.004	30, 100, 300, 1000	0.0006	20,000
		0.005	20,000		
Mercury	0.001[1]	0.0005	All	0	All
Molybdenum	0.07[2]	0.02	All	0.0005	20,000
Nickel	0.02[1]	0	03, 100, 300, 1000	0.0003	20,000
		0.0003	20,000		
Lead	0.025[1]	0.005	All	0	All
Antimony	0.005[1]	0.004	All	2.5 x 10^{-5}	20,000
Selenium	0.01[1]	0.004	All	6.5 x 10^{-5}	1,000
				0.0002	20,000
Zinc	5[3]	0.08	All	0.003	20,000
Chloride	250[1]	51	All	7.6 x 10^{-5}	30
				1.59	100
				1.37	300
				0.92	1,000
				0.03	20,000
Fluoride	1[1]	0.35	30, 100, 20,000	0.001	100
				0.02	300
		0.36	300, 1000	0.009	1,000
				0.001	20,000
Sulphate	250[1]	136	30, 20,000	0.0003	30
				5.42	100
		141	100, 300	5.23	300
				4.42	1,000
		138	1000	0.103	20,000

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

[2] WHO Health

[3] UK Drinking Water Standard

The results presented in **Table 8.16** illustrate that arsenic is the only contaminant to exceed the Drinking Water Standard in the phantom receptor well when the model includes background concentrations of contaminants. The maximum concentration of arsenic modelled was 0.014 mg/l which is 0.004 mg/l above the drinking water standard.

As outlined in previous sections a large element of conservatism has been built into the model as it does not account for the confining nature of the aquifer, the second low permeability layer within the hazardous liner etc.

The model run without the background concentrations shows that the concentration of arsenic will not exceed the drinking water standard for arsenic, indicating that the modelled result is due to the background concentration. This result is confirmed by the results presented in **Table 8.18** when the liner in one cell is modelled to represent a significant defect resulting in much greater leakage, the concentration of arsenic does not increase.

Furthermore the partition coefficient of arsenic used is relatively low compared to values obtained in a wider literature search. If a higher value for retardation was used the model would not fail for arsenic.

These results demonstrate that resulting arsenic concentrations will not be present down-gradient above background levels.

8.3.4.3 Sensitivity Analysis

A sensitivity analysis was undertaken to assess the impact that changing certain parameters would have on the model. The model was shown to be sensitive to changes in the parameters outlined below:

- **Management control period:** The management control period was set to the length of time which the cells are operational (active filling), i.e. 35 years (from 2003). Beyond this the model assumes the landfill would not be maintained (i.e. leachate removal would cease and leachate levels would rise etc). As expected the results of the model are sensitive to the length of the management control period. If the management control period is increased then the modelled concentrations of contaminants at the receptors are lower. A conservative approach was undertaken with assigning this parameter and as such the values generated are conservative. The management control period could reasonably be increased.
- **Aquifer parameters:** The model is sensitive to the aquifer parameters such as the aquifer thickness, porosity, gradient and permeability values. These values influence the amount of dilution which takes place in the aquifer. The values assigned were based on extensive experience on working in the Irish context and as such are reasonable.
- **Vertical pathway:** the presence of the saturated vertical pathway serves to reduce the amount of leachate which reaches the aquifer. The presence of saturated aquitard overlying the aquifer that is modelled as the vertical pathway, was confirmed during the site investigation. BH16 in the northern part of the site, beneath H2a, was drilled to a depth of 60 mbgl and only reached the top of the Balrickard Formation. For this reason, the parameters chosen can be justified.
- **Retardation:** Contaminants were allowed to be retarded as they moved through each pathway. Conservative contaminant-specific retardation parameters were chosen (the lowest of quoted ranges).

The model was also slightly sensitive to changes in other parameters such as the moisture content of the unsaturated zone. However, the changes did not have a significant influence on the results of the model.

Some parameters were highlighted as uncertain (e.g. the size of the sump for the internal drainage layer in the DAC, dry density of inert waste). The sensitivity analysis illustrated that the model output was not significantly influenced by these parameters.

The sensitivity analysis indicated that the parameters chosen for the model are the most appropriate and in some cases are highly conservative.

8.3.4.4 Discussion

The results of the primary model indicate that with all the mitigation measures in place, no significant impact will be observed at a phantom receptor well placed on the site boundary. No exceedances of appropriate drinking water standards in groundwater in the Loughshinny aquifer at the site boundary are predicted. With respect to 'hazardous substances' concentrations are non-detectable after 1000 years and are only detected in the 20,000 year time slice.

It should be noted that the model can be considered highly conservative for the following reasons:

- Groundwater in the Loughshinny aquifer is confined beneath overlying Namurian strata in the area of the hazardous cells, however it is modelled as unconfined. The confining strata will limit the movement of leachate from the hazardous cells downwards to the aquifer.
- The non-hazardous cells are located on the aquifer. For this reason an extra 1 m of material with a permeability of 6.6×10^{-10} m/s is to be placed beneath the liner of the non-hazardous cells. This liner has not been modelled as LandSim cannot represent this type of lining system. For this reason, the results from the non-hazardous cells are conservative as they do not reflect the extra protection provided by this liner.
- The modelling of the hazardous cell liner is conservative as is does not incorporate the second low permeability clay liner built into the DAC system.
- The management control period has been modelled as 35 years, the period of active filling of the cells. The model assumes that after this period there is no leachate management and leachate head can rise within the cells resulting in greatly increased leakage.
- It will be a requirement of the waste licence that the closure, restoration and aftercare management plant be implemented. Surrender of the licence will only be accepted by the EPA when it has been demonstrated that there will be no risk of significant pollution from the site.
- Conservative input parameters have been used throughout the model and the 95th percentile results have been assessed.

8.4 Supplementary Models

Following consultation with the Environmental Protection Agency (EPA) supplementary models were created. The details of these are outlined below.

8.4.1 Supplementary Model 1 - Major defect in DAC liner

The first supplementary model was created to assess the impact to groundwater if there was a fault in the liner of one of the hazardous cells. This was simulated in LandSim V2.5 by allowing a single cell to leak at a significantly higher rate by increasing the permeability of the DAC liner.

H3b was chosen as the cell that should be allowed to leak at a higher rate as it is the largest cell and will produce the most leachate.

All the input parameters outlined in section 8.3 were used for the supplementary model except for the permeability of the DAC liner in cell H3b. The permeability of the liner for this cell was increased to range from 1 x 10^{-4} - 1 x 10^{-6} m/s.

The print out from the LandSim model are summarised in **Appendix A3.1**.

8.4.1.1 Results & Discussion

The model was run for the same time slices and number of iterations as the primary model as outlined in section 8.3.4.1.

The statistical results from the LandSim model are presented in **Appendix A3.2**.

Reverse cumulative plots for the concentrations of each 'hazardous substance' at the base of the unsaturated zone and the vertical pathway are presented in **Appendix A3.3**. From these, the 95th percentile concentrations at the base of the unsaturated zone and vertical pathway are presented in **Table 8.17**.

Table 8.17 Summary 95th percentile concentration of 'hazardous substances' substances at the base of the unsaturated zone and vertical pathway when the liner of cell H3b leaks

Parameter	Drinking Water Standard (mg/l)	Cell number	Concentration at the base of the unsaturated zone		Concentration at the base of the vertical pathway	
			95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Cadmium	0.005[1]	H3b	0.00025	300	0.58	1000
			2.71	1000		
Mercury	0.001[1]	H3b	0.012	1,000	0.0096	20,000

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

These results indicate that if a hazardous cell starts to leak at a significantly increased rate that hazardous substances would enter the groundwater beneath the site at concentrations exceeding drinking water standards.

The cumulative frequency plots of the concentrations of each contaminant at the phantom receptor well placed on the site boundary are presented in **Appendix A3.4**. The 95th percentile concentrations of these are summarised in **Table 8.18.** If the contaminant was detected in more than one time slice then the data from all the time slices is presented. If a time slice is not listed below for any parameter then that parameter was not detected at that time slice (i.e. its concentration was 0 mg/l).

Table 8.18 Summary 95th percentile concentration of all parameters at the phantom receptor well with a significant defect in the liner of cell H3b

Contaminant	Drinking Water Standard (mg/l)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Arsenic	0.01[1]	0.014	All
Barium	0.7[2]	0.043	30
		0.343	100
		0.678	300
		0.066	1,000
		0.044	20,000
Cadmium	0.005[1]	0.002	All
Total chromium	0.05[1]	0.015	30, 100, 200
		0.016	1,000
		0.017	20,000
Copper	2[1]	0.003	30, 100, 300, 1000
		0.005	20,000
Mercury	0.001[1]	0.0005	All
Molybdenum	0.07[2]	0.025	All
Nickel	0.02[1]	0.013	1,000
		0.0003	20,000
Lead	0.025[1]	0.005	30, 100, 300, 1,000
		0.013	20,000
Antimony	0.005[1]	0.004	All
Selenium	0.01[1]	0.004	30, 100, 20,000
		0.02	300
		0.005	1,000
Zinc	5[3]	0.084	30, 100, 20,000
		0.134	300
		0.438	1,000
Chloride	250[1]	51	30, 1,000, 20,000
		678	100
		115	300
Fluoride	1[1]	0.35	30, 20,000
		3.8	100
		2.3	300
		0.43	1,000
Sulphate	250[1]	146	30, 20,000
		841	100
		304	300
		152	1,000

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

[2] WHO Health

[3] UK Drinking Water Standard

These results indicate that if the DAC liner fails the contaminants with low retardation (e.g. chloride, sulphate) will be detected at a phantom monitoring well at concentrations above drinking water standards.

However, it should be noted that as outlined in section 8.3.2.1 there are two low permeability liners built into the DAC system and the lower of these has not been taken into account.

In reality if the DAC liner starts to leak, there will still be the second low permeability liner present. A leak detection and collection system will be incorporated in the drainage layer between the two low permeability liners. This will ensure that any leaks in the upper DAC liner will be detected and leachate leakage controlled.

8.4.2 Supplementary Model 2 - No liners in place

The second supplementary model simulates the impact to groundwater if the waste is placed directly on the geological formation and no engineered barrier system (liner) is constructed.

This is clearly an unrealistic scenario; however it demonstrates the level of protection which the proposed engineered liners provide for the protection of groundwater.

The inputs for this model are the same as those for the primary model however no Engineered Barrier System (EBS) is selected. The input parameters for this model are presented in **Appendix A4.1**.

It should be noted that LandSim V2.5 still requires the head of the liner to be fixed in this simulation. It is a highly unrealistic scenario that the leachate head would be maintained where there is no liner in place.

8.4.2.1 Results and Discussion

The model was run for the same time slices and number of iterations as the primary model as outlined in section 8.3.4.1.

The statistical results from the LandSim model are presented in **Appendix A4.2**.

Reverse cumulative plots for the concentrations of each 'hazardous substance' at the base of the unsaturated zone and the vertical pathway are presented in **Appendix A4.3**. From these, the 95th percentile concentrations at the base of the unsaturated zone and vertical pathway are presented in **Table 8.19**.

Table 8.19 Summary 95th percentile concentration of 'hazardous substances' at the base of the unsaturated zone and vertical pathway when there is no landfill liner

Parameter	Drinking Water Standard (mg/l)	Cell number	Concentration at the base of the unsaturated zone		Concentration at the base of the vertical pathway	
			95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Cadmium	0.005[1]	Existing	0		0	
		IN1	0		0	
		IN2	0		0	
		IN3	0		0	
		NH1a	0		0	
		NH1b	0		0	
		NH2	0		0	
		H1a	0		0.0038	20000
		H1b	0		0.0039	20000
		H2a	0		0.0048	20000
		H2a	0		0.0047	20000
		H3a	1.52-8	1000	0.0062	20000
		H3b	0.00047	300	0.051	1000
Mercury	0.001[1]	Existing	0		0	
		IN1	0		0	
		IN2	0		0	
		IN3	0		0	
		NH1a	0		0	
		NH1b	0		0	
		NH2	0		0	
		H1a	0.0014	20000	0.014	20000
		H1b	0.0014	20000	0.022	20000
		H2a	0.0013	20000	0.019	20000
		H2a	0.0017	20000	0.021	20000
		H3a	0.0021	20000	0.026	20000
		H3b	0.0045	1000	0.00033	1000
			0.0022	20000	0.049	20000

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

These results indicate that if no landfill liners are used the groundwater beneath the site will be impacted by ‘hazardous substances’. The landfill liners are therefore an essential measure required to achieve compliance with the Water Framework Directive. It should be noted that in the MEHL facility every cell will have an appropriate liner.

However, it should be noted that the concentrations at the base of the vertical pathway are higher than those at the base of the unsaturated zone. This would not be expected and indicates that the model is unstable for this scenario.

The cumulative frequency plots of the concentrations of each contaminant at the phantom receptor well placed on the site boundary are presented in **Appendix A4.4**. The 95th percentile concentrations of these are summarised in **Table 8.20.** If the contaminant was detected in more than one time slice then the data from all the time slices will be presented.

Table 8.20 Summary 95th percentile concentration of all parameters at the phantom receptor well when there is no landfill liner

Contaminant	Drinking Water Standard (mg/l)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
Arsenic	0.01[1]	0.014	30, 100, 300, 100
		0.015	200000
Barium	0.7[2]	0.044	30
		0.11	100
		0.8	300
		0.22	1000
		0.044	200000
Cadmium	0.005[1]	0.002	All
Total chromium	0.05[1]	0.015	30, 100, 300
		0.016	1000
		0.017	200000
Copper	2[1]	0.004	30, 100, 300, 1000
		0.018	200000
Mercury	0.001[1]	0.0005	All
Molybdenum	0.07[2]	0.025	All
Nickel	0.02[1]	0	30, 100, 300
		0.006	1000
		0.0003	200000
Lead	0.025[1]	0.005	30, 100, 300, 1000
		0.006	200000
Antimony	0.005[1]	0.004	All
Selenium	0.01[1]	0.004	30, 100, 20,000
		0.019	300
		0.02	1000
Zinc	5[3]	0.084	30, 100
		0.098	300
		0.37	1000

Contaminant	Drinking Water Standard (mg/l)	95th percentile conc. (mg/l)	Time period after which the concentration is detected (years)
		0.084	200000
Chloride	250[1]	50.48	30
		769.62	100
		176.62	300
		54.73	1000
		49.88	200000
Fluoride	1[1]	0.35	30
		3.14	100
		2.66	300
		0.81	1000
		0.35	200000
Sulphate	250[1]	141.71	30
		991.68	100
		372.23	300
		165.70	1000
		140.35	200000

[1] S.I. 278/2007 European Communities (Drinking Water) (No.2) Regulations 2007

[2] WHO Health

[3] UK Drinking Water Standard

These results indicate that if no engineered barriers are used on the site then groundwater at the site boundary would exceed drinking water standards. However, these results are lower than would be expected, only 3 time drinking water standards (with the exception of selenium).

As outlined in section 8.4.2 the head of leachate still has to be fixed in this simulation despite there being no liner system in place. This is highly unrealistic and for this reason it is likely that the results presented are un-conservative and explains why they are lower than expected.

8.5 Further Work

Further work related to groundwater protection at the site is outlined below:

- A Groundwater and Surface Water Monitoring Plan, incorporating levels and quality will be a consultation requirement of the waste licence.
- Site investigation boreholes drilled in the centre of the site will be grouted up carefully to ensure that no vertical pathways exist beneath the proposed cells.
- A Closure Restoration and Aftercare Management Plan (CRAMP) will be developed and submitted to the Environmental Protection Agency for approval. Following the cessation of operation at the site the CRAMP will be implemented to the Environmental Protection Agency satisfaction.

9 Conclusions

A detailed hydrogeological investigation was undertaken on the MEHL site in order to develop a conceptual model for the site using site specific data that describes the groundwater system in the vicinity of the site.

Based on this information a detailed quantitative risk assessment (QRA) modelling exercise was undertaken as part of this assessment using the program LandSim v2.5. This model was used to quantify the potential risk to groundwater and groundwater based receptors from the proposed development.

The primary model developed used the landfill design criteria as provided by the landfill designer and all site specific geological and hydrogeological data collected during this assessment. The primary model is designed to represent the impact on the environment of leachate leaking from the landfill on the environment. The primary model assumes that the landfill will be constructed as described in the Engineering Planning Report (WYG, 2010).

A summary of the results of the primary model are presented below:

- No 'hazardous substances' (List 1) predicted to be in groundwater beneath the site (and therefore none detected at the phantom receptor well);
- 'Non-hazardous pollutants' (List 2), metals, chloride and sulphate predicted to be present in groundwater beneath the site above Drinking Water Standards after 20,000 years;
- No contaminants at concentrations above Drinking Water Standards predicted to be present at the phantom well receptor.

The results of the LandSim modelling indicate the risk to groundwater quality at wells down gradient of the site will be insignificant.

Although the primary model is designed to represent the landfill and surrounding environment it should be noted that these results are considered conservative for the following reasons:

- The main aquifer unit beneath the site (the Loughshinny Formation) is observed to be confined, and locally artesian, and therefore downward movement of leachate will be limited by the lower permeability overlying horizons. However the model assumes the aquifer is unconfined.
- Lower liner (0.5 m of material with a hydraulic conductivity of $1x10^{-9}$ m/s) within the DAC system has not been modelled.
- The additional low permeability layer to be installed beneath the non-hazardous cells has not been modelled.
- The additional low permeability bentonite enhanced soil (BES) layer to be installed beneath the liner for the non-hazardous cells has not been included in the model.
- The management control period has been modelled as unrealistically short. The actual management control period will be determined by the EPA.

Supplementary models were created following consultations with the EPA. The first supplementary model was developed to simulate the impact of the proposed development on groundwater if there was a significant defect in the liner of the hazardous cells. The second supplementary model was developed to simulate the impact of the proposed development on groundwater without any landfill liners. The supplementary models represent highly unrealistic scenarios and have been developed to assess the level of protection the engineered liners provide.

The results of the supplementary models are summarised below:

- 'Hazardous substances' and 'non-hazardous pollutants' (List 1 and List 2) predicted to be present in groundwater beneath the site;
- 'Hazardous substances' and 'non-hazardous pollutants' (List 1 and List 2) predicted to be present in a phantom well receptor placed on the down-gradient boundary of the MEHL site.

A Groundwater and Surface Water Monitoring Plan, incorporating level and quality monitoring, will be a requirement of the waste licence.

A Closure Restoration and Aftercare Management Plan (CRAMP) will be developed and submitted to the Environmental Protection Agency for approval. Following the cessation of operation at the site the CRAMP will be implemented to the satisfaction of the Environmental Protection Agency.

References

[1] Environmental Protection Agency (EPA, 2002). 'Guidelines on the Information to be Contained in Environmental Impact Statements'.

[2] Environmental Protection Agency (EPA, 2003). 'Advice Notes on Current Practice in the Preparation of Environmental Impact Statements'.

[3] Environmental Protection Agency (EPA, 2006). EPA Landfill Manuals. Manual on site selection, draft for consultation.

[4] Geological Survey of Ireland (GSI). Groundwater Protection Responses for Landfills

[5] Geological Survey of Ireland 1:100,000 scale Bedrock Series geology Map Sheet 13 (1999)

[6] Geological Survey of Ireland 1:10,560 scale Bedrock Series geology Map Sheet Dublin 14/2 (19th Century)

[7] Geological Survey of Ireland 1:63,360 scale Bedrock Series geology Map Sheet 102 (1901)

[8] Geological Survey of Ireland National Draft Bedrock Aquifer map

[9] Geological Survey of Ireland Groundwater Database

[10] Geological Survey of Ireland Quaternary Geology map of Dublin

[11] Institute of Geologists of Ireland (September 2002). 'Geology in Environmental Impact Statements – a Guide'.

[12] IGSL (2010) Ground Investigation Factual report on MEHL Integrated Waste Management Facility.

[13] Jantzen, C.M. (2006). Fluidized bed steam reformer (FBSR) product: Monolith formation and characterization. Savannah River National Laboratory. Prepared for the U.S. Department of Energy

[14] Jones, G.Ll (2009). Report on the geology of the landfill site Hollywood, Naul, Co. Fingal.

[15] Jones, G.Ll (2010). Micropalaeontology report on sample MEHL – 18, 15.2-15.8 m, The Naul, Co. Fingal.

[16] Kreith, F. And Tchobanoglous, G. (2002) Handbook of solid waste management. McGraw-Hill Professional, 2002-950 pp.

[17] Leach, B. and Nikitas, C. Waste management capacity in the South East Region. A report to SEERA

[18] McConnell, B., Philcox, M. And Geraghty, M. 2001 Geology of Meath: A geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 13, Meath. Geological Survey of Ireland.

[19] Minerex (2010) Well survey report.

[20] National Roads Authority (NRA, 2009). 'Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes'.

[21] Rübner, K., Haamkens, F. And Linde, O. (2007). Use of municipal solid waste incinerator bottom ash as aggregate in concrete. European Geosciences Union General Assembly 2007.

[22] Simons, D-J, Bleijerveld, R. and Humez, N. (2006).. solidification/Stabilisation of Hazardous Waste. Sustainable Landfill Foundation

[23] Staub, M., Galietti, B., Oxaranglo, L., Khire, M.V. and Gourc, J.-P. (2009). Porosity and hydraulic conductivity of MSW using laboratory-scale tests. Third Internation Workshop "Hydro-Physcio-Mechanics of Landfills", Braunschweig, Germany; 10-13 March 2009

[24] Water Framework Directive (2005). Working group on groundwater guidance document No. 5. Guidance on the assessment of the impact on groundwater abstractions.

[25] White Young Green (2010). Engineering Report for Planning. Proposal for an Integrated Waste Management Facility for Non Biodegradable Waste including Hazardous Waste

Figures

0 metres 5000

Scale 1:125,000

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Legend

- 🟧 MEHL Proposed Planning and Waste Licence Boundary
- ✈ Dublin Airport
- — Motorway
- — National Road
- — Regional Road
- ☐ County Boundary
- ▨ Urban Area

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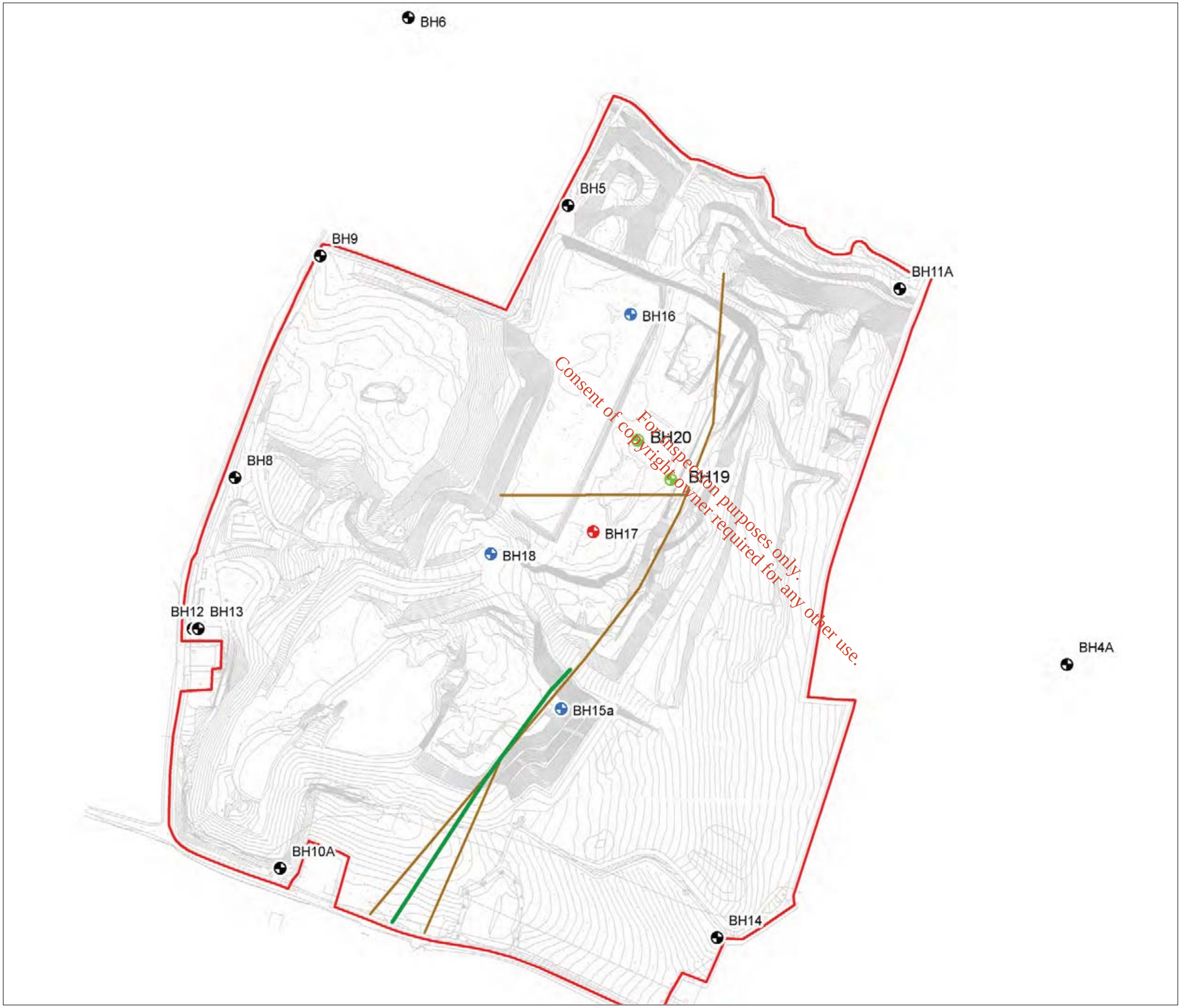
Site Location Map (1:125,000)

December 2010 Figure **1**



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Scale 1:3,500

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Legend

- ▭ MEHL Proposed Planning and Waste Licence Boundary
- — Apex Fault/Fracture
- — Mapped Fault
- ● EPA Licence W0129-02 Monitoring Boreholes
- ● Cored Monitoring Wells *
- ● Monitoring Wells *
- ● Pumping Wells *

Note.
* These wells will be decommissioned.

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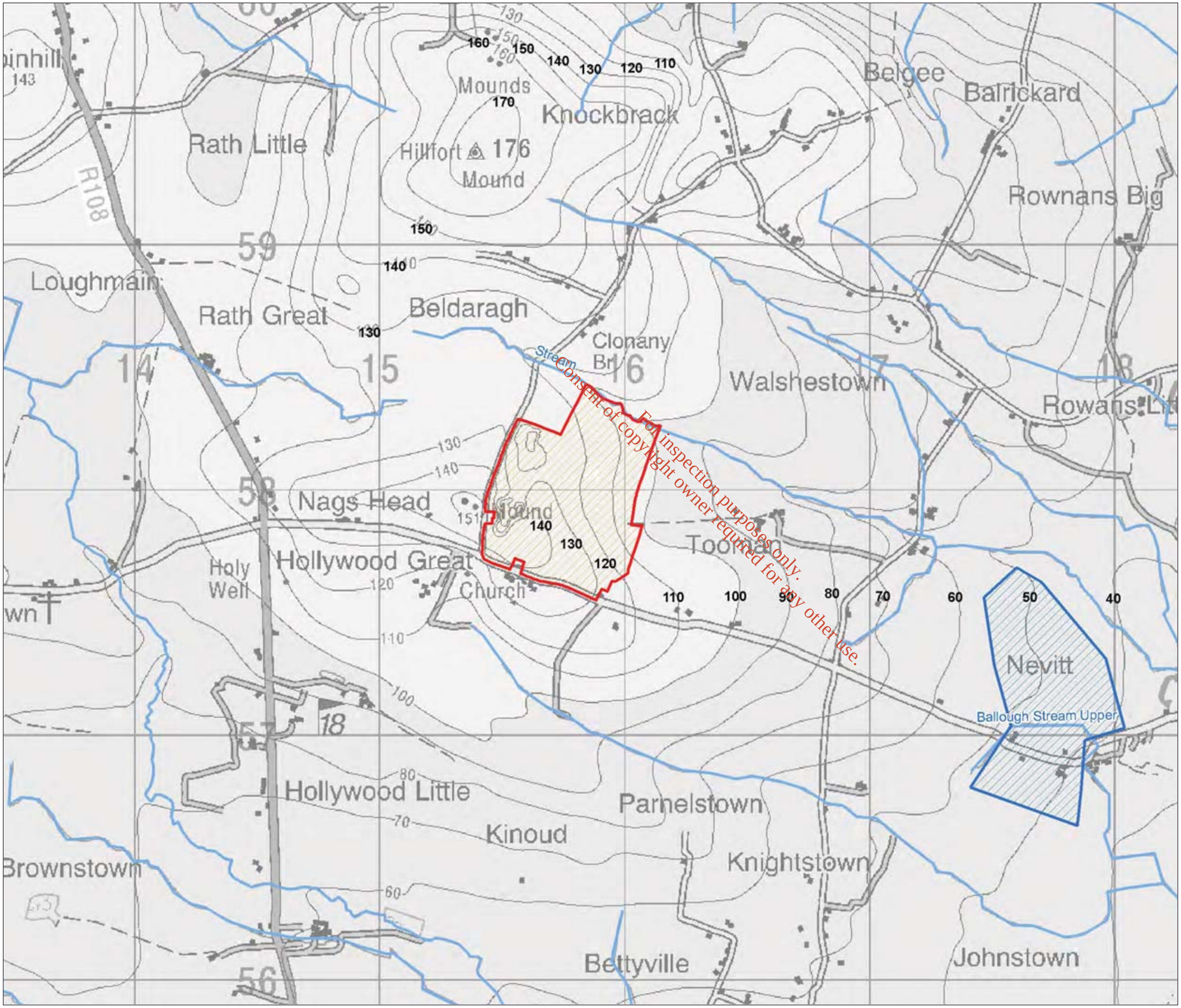
Groundwater Monitoring Network

December 2010 Figure **2**



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Scale 1:15,000

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Legend

- 🟥 MEHL Proposed Planning and Waste Licence Boundary
- ▨ Licensed Fingal County Council Landfill (approx boundary as not yet constructed)
- — Rivers

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Area Topography Map

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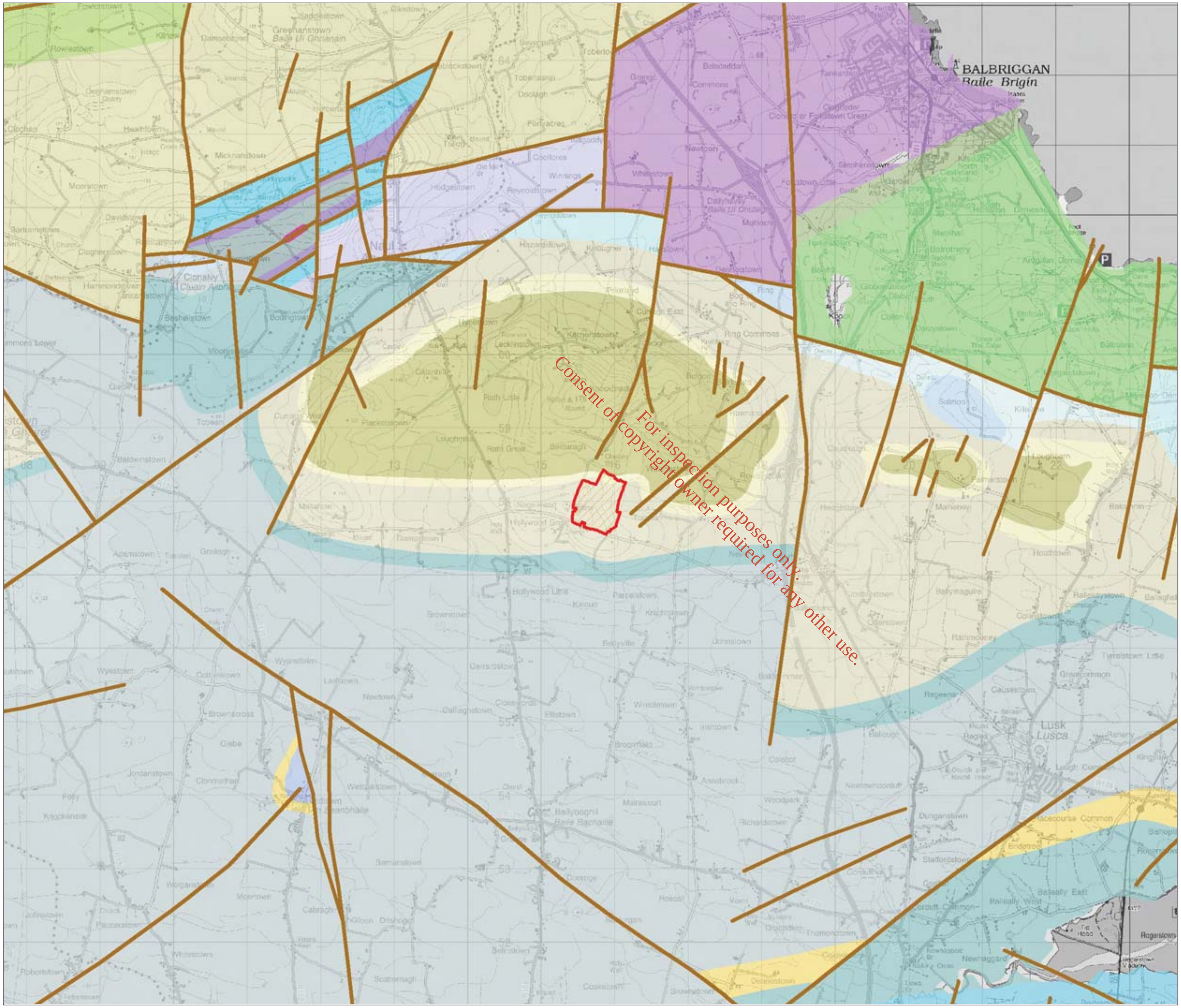
Figure **3**



0 metres 600

Scale 1:15,000

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Legend

🟥	MEHL Proposed Planning and Waste Licence Boundary
—	Faults

GSI Bedrock Geology (1:100,000)

🟩	WL - Walshestown Formation
🟨	BC - Balrickard Formation
▨	LO - Loughshinny Formation
🟦	NA - Naul Formation
▨	LU - Lucan Formation

Note:
GSI geological boundaries are subject to revision with site specific data (as shown on Figure 14.6)

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GSI Geology Map

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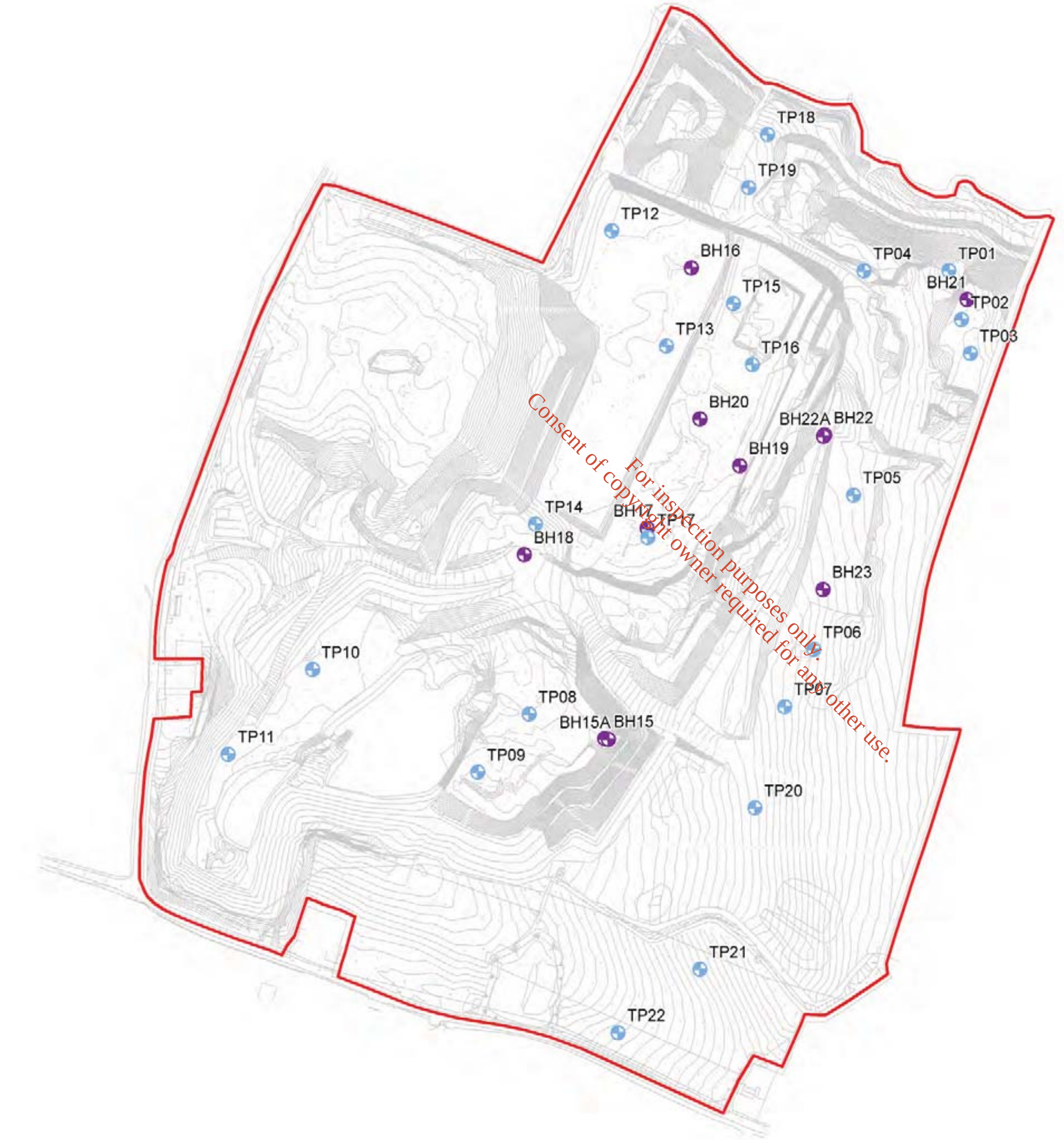
Figure **4**



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Scale 1:3,500

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Legend

▭ MEHL Proposed Planning and Waste Licence Boundary

Site Investigation Locations

● Boreholes

● Trial Pits

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Site Investigation Locations

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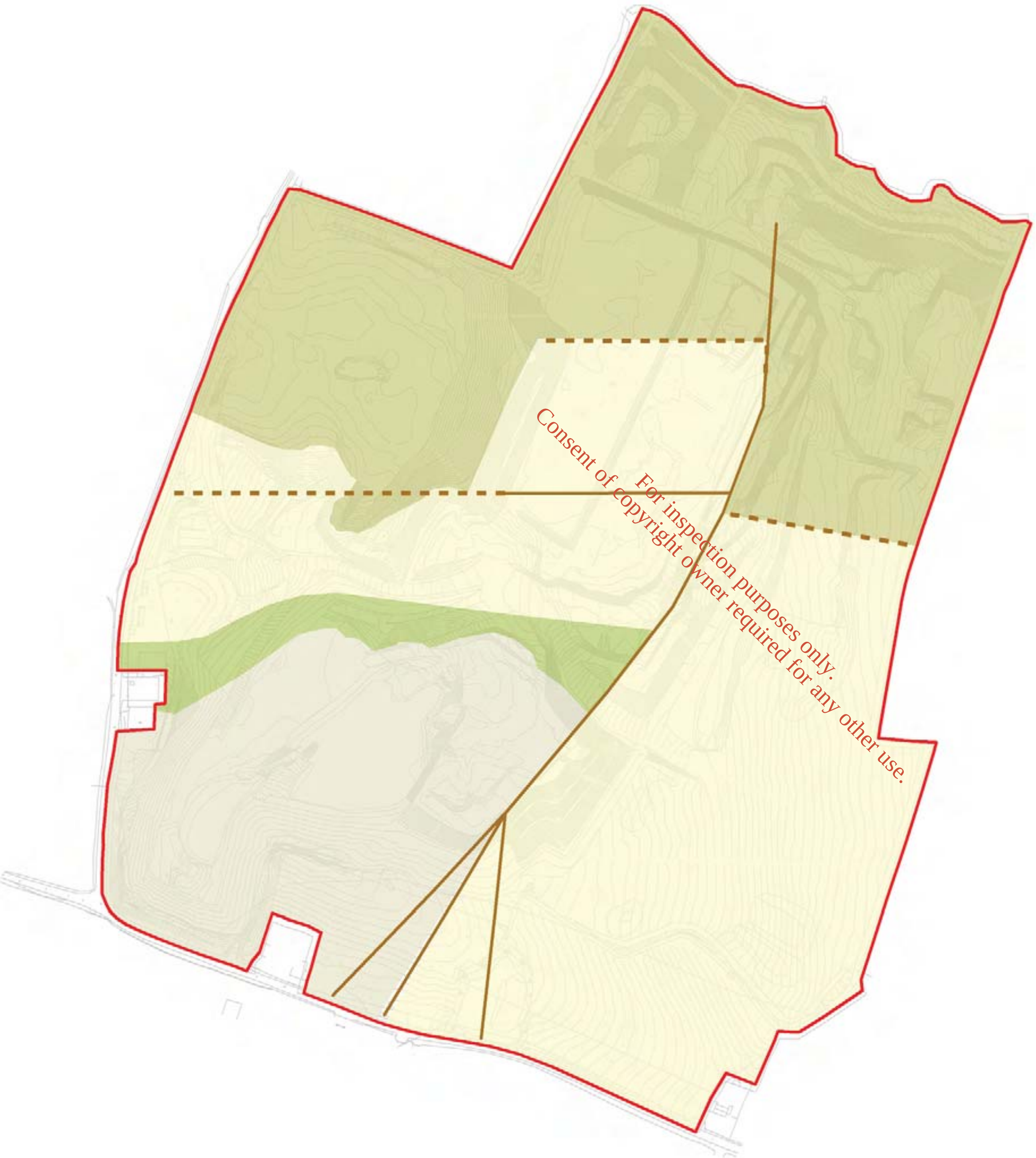
Figure **5**



0 metres 140

Scale 1:3,500

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Legend

- 🟥 MEHL Proposed Planning and Waste Licence Boundary
- - - Possible Faulted Contact
- — Interpreted Fault/Fracture
- 🟫 WL - Walshestown Formation
- 🟨 BC - Balrickard Formation
- 🟩 DR - Donore Formation
- ▨ LO - Loughshinny Formation

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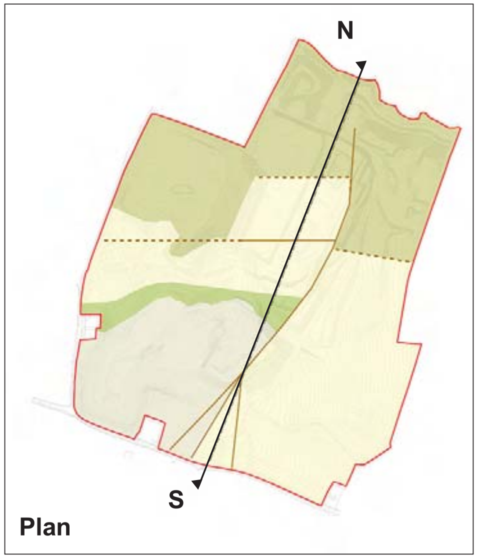
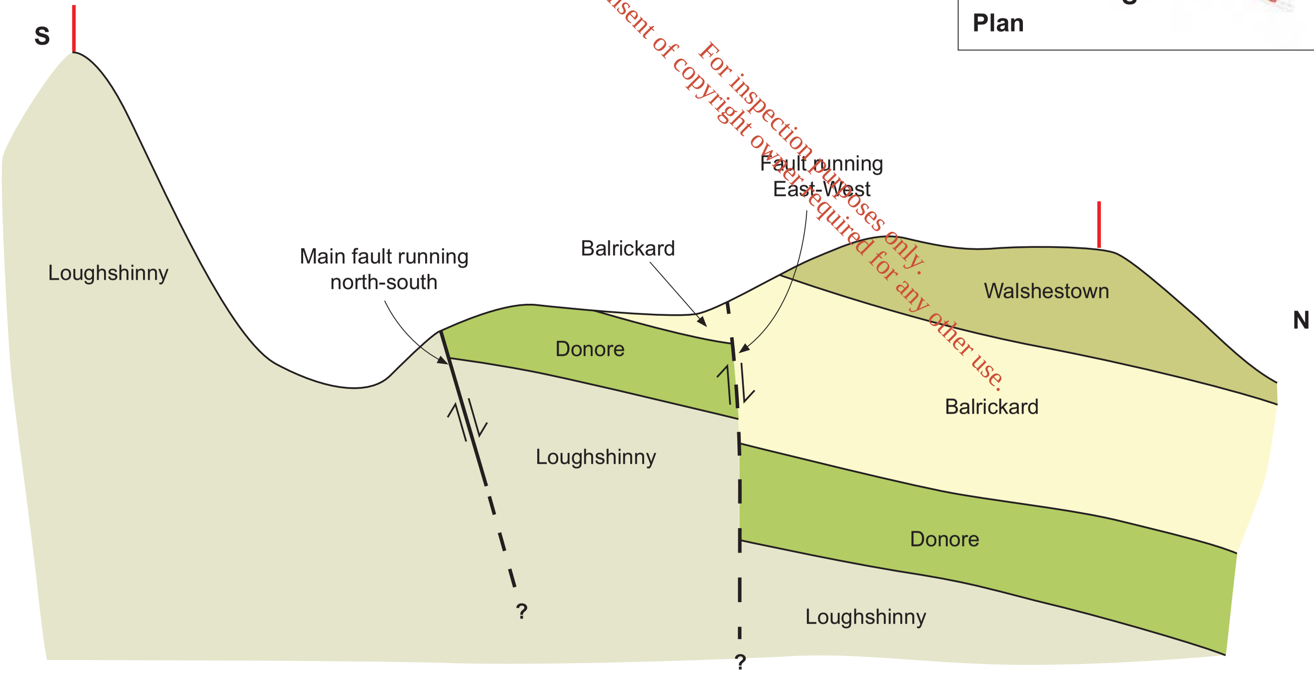
Site Geological map

December 2010 Figure **6**





Cross Section

0 metres 140

Scale 1:3,500

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Legend

- 🟥 MEHL Proposed Planning and Waste Licence Boundary
- - - Possible Faulted Contact
- — Interpreted Fault/Fracture
- ▨ WL - Walshestown Formation
- ▨ BC - Balrickard Formation
- 🟩 DR - Donore Formation
- ▨ LO - Loughshinny Formation

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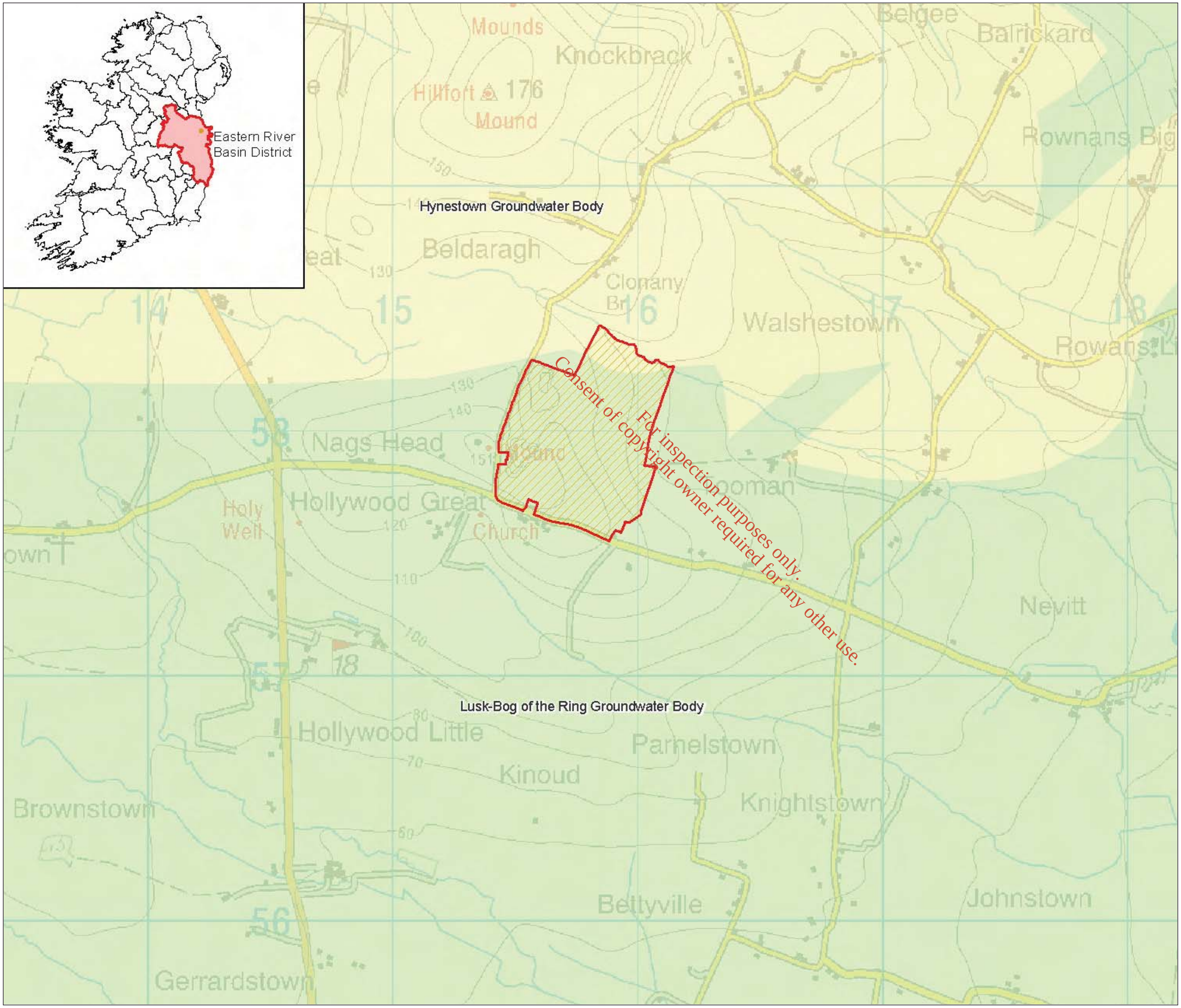
Indicative North-south Cross Section

December 2010 Figure **7**



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Legend

- ▨ MEHL Proposed Planning and Waste Licence Boundary
- 🟥 Eastern River Basin District
- 🟨 Hynestown GWB
- 🟩 Lusk-Bog of the Ring GWB

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River Basin District Boundaries and Groundwater Bodies

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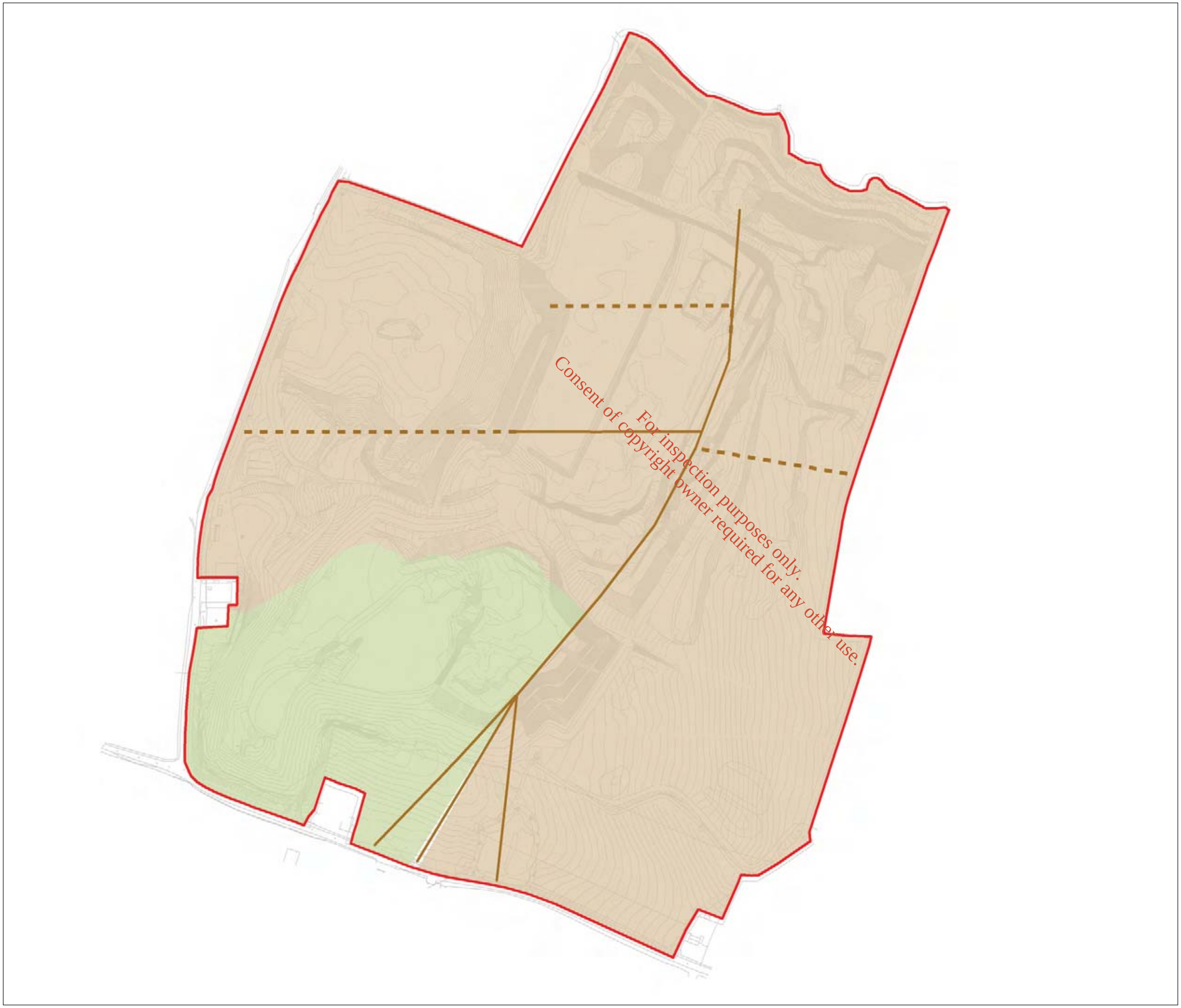
Figure **8**



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Site specific Aquifer Classification

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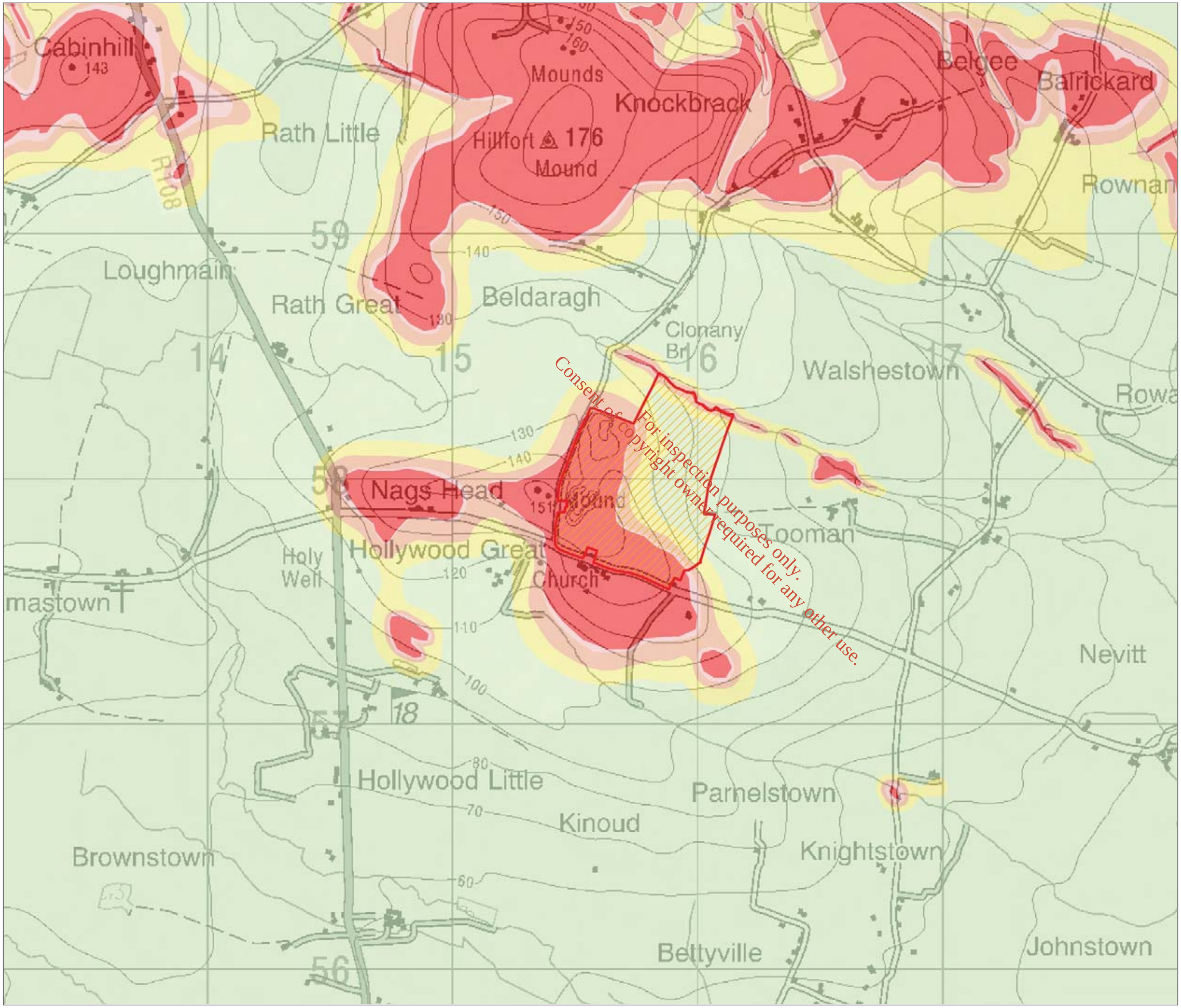
Figure **9**



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Scale 1:15,000

Legend

- ▨ MEHL Proposed Planning and Waste Licence Boundary

Groundwater Interim Vulnerability

- 🟥 X (Rock near Surface or Karst)
- ▨ E - Extreme
- 🟧 H- High
- 🟨 M - Moderate
- 🟩 L - Low

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GSI Groundwater Vulnerability

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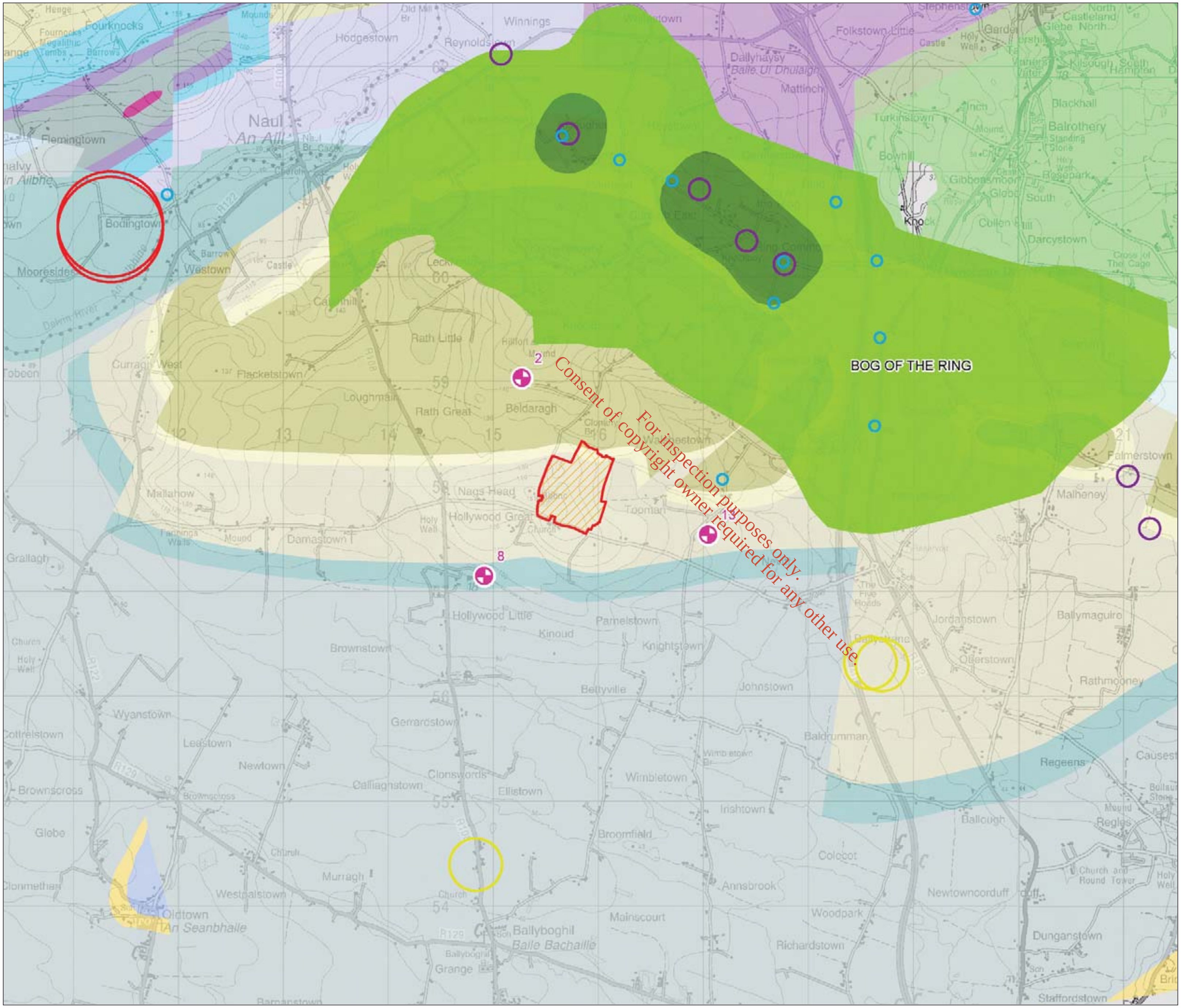
Figure **10**



0 metres 1400

Scale 1:35,000

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Legend

- ▭ MEHL Proposed Planning and Waste Licence Boundary
- ● Well Survey Boreholes
- ▭ GSI Groundwater Wells whose location known to within 100m
- ▭ GSI Groundwater Wells whose location known to within 200m
- ▭ GSI Groundwater Wells whose location known to within 500m
- ▭ GSI Groundwater Wells whose location known to within 1km

Source Protection Areas

- 🟩 SO: Outer Source Protection Zone
- 🟩 SI: Inner Source Protection Zone

GSI Bedrock Geology (1:100,000)

- MF, Mullaghfin Formation
- GG, Balbriggan Formation
- SS, Skerries Formation
- BP, Belcamp Formation
- HO, Holmpatrick Formation
- LUmk, in Lucan Formation
- DD, Denhamstown Formation
- mk - Mudbank limestone
- SW - Snowtown Formation
- HB - Herbertstown Formation
- FK - Fournocks Formation
- Di - Diorite
- RU - Rush Conglomerate Formation
- WA - Waulsortian Limestones
- CF - Clashford House Formation
- WL - Walshestown Formation
- BC - Balrickard Formation
- LO - Loughshinny Formation
- NA - Naul Formation
- LU - Lucan Formation

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Groundwater Abstractions

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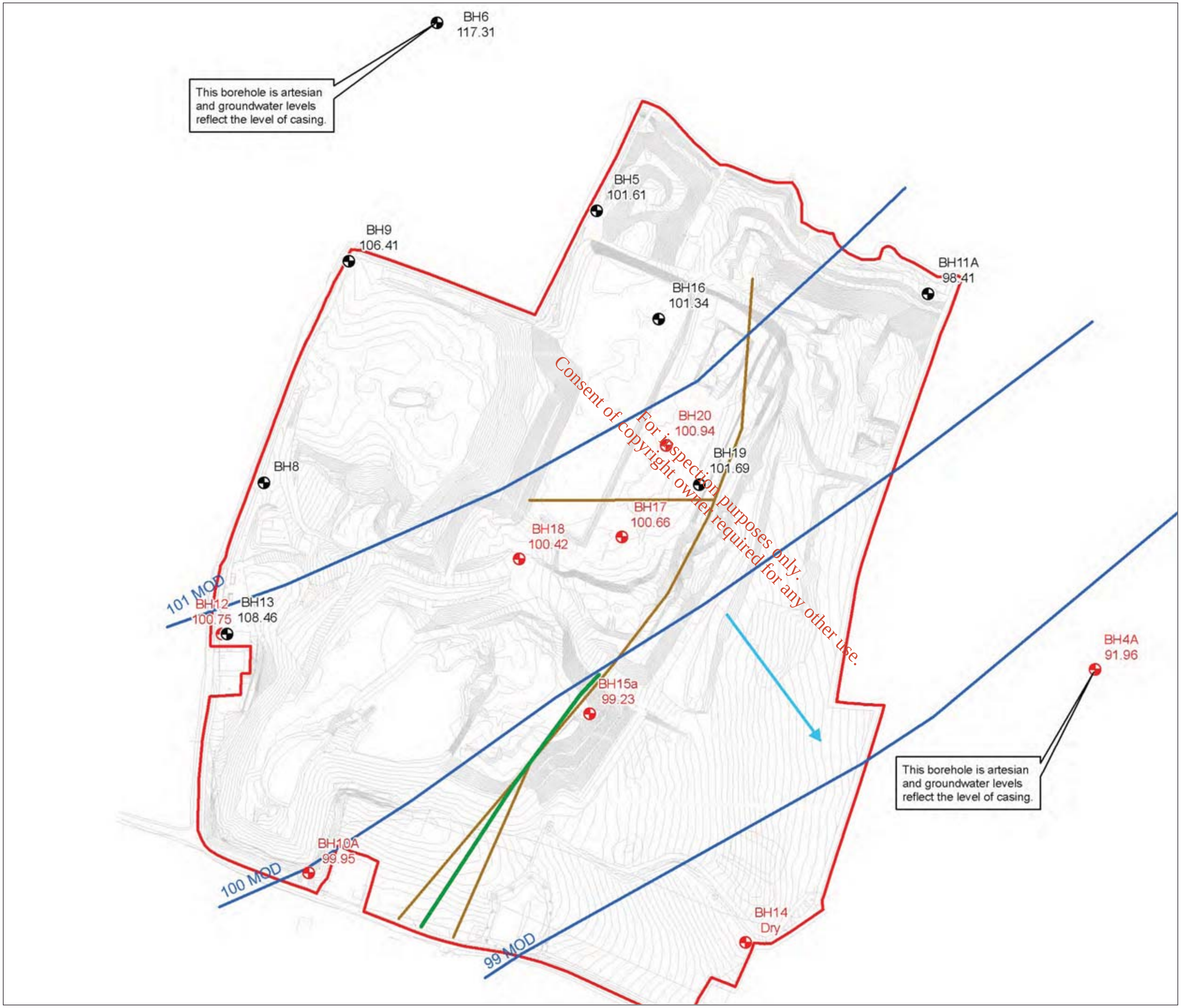

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Scale 1:3,500

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Legend

- ▭ MEHL Proposed Planning and Waste Licence Boundary
- ● Namurian Monitoring Installations
- ● Loughshinny Monitoring Installations
- → Loughshinny Flow Direction
- — Loughshinny Approximate Groundwater Level Contours
- — Mapped Fault
- — Apex Fault/Fracture

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Groundwater Levels from 20/05/2010 and Schematic contours

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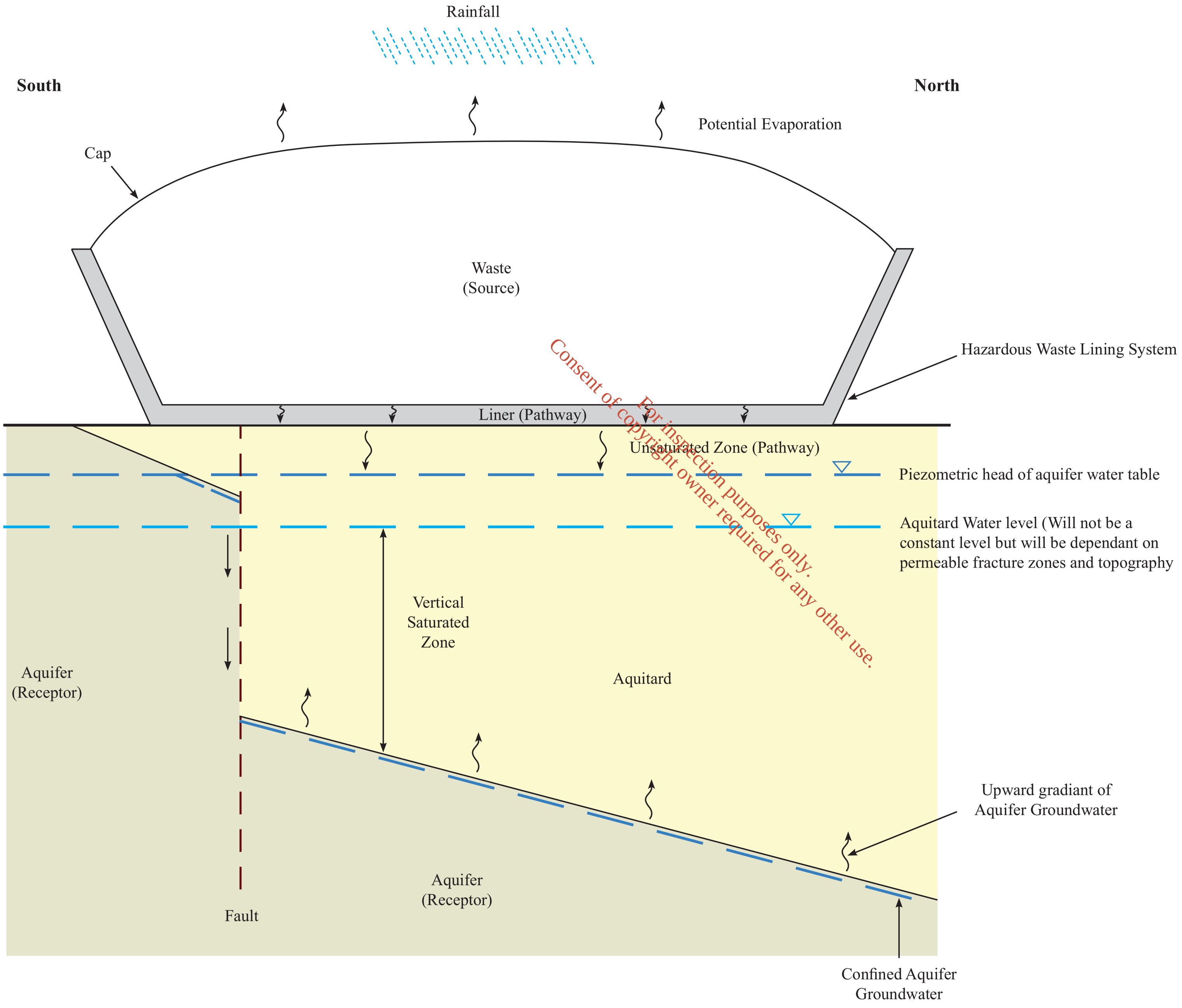
Figure **12**



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Schematic Conceptual Model

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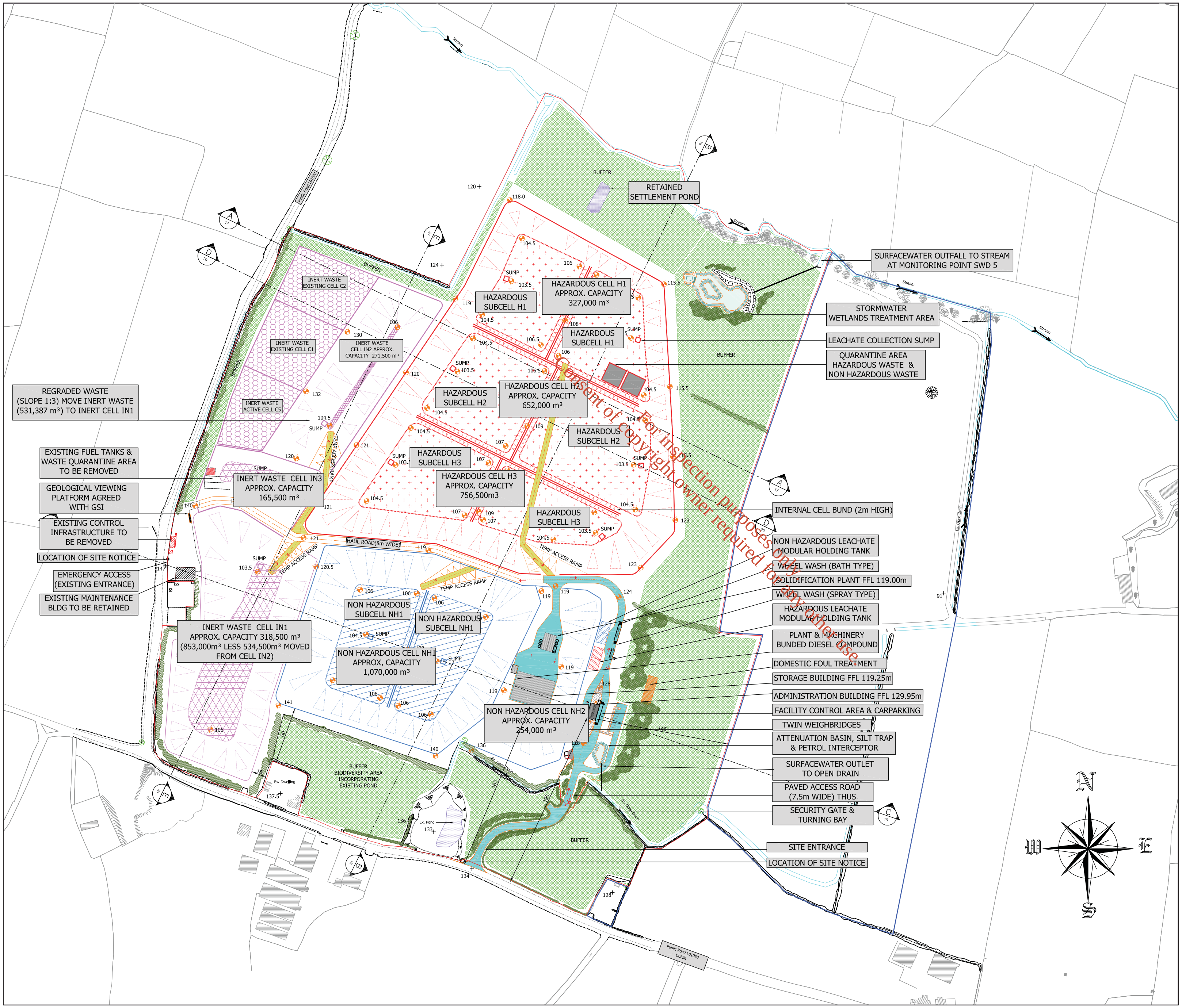

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Scale 1:4,000

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Legend

―	Adjoining Lands in control of MEHL
―	MEHL Proposed Planning and Waste Licence Boundary
🟦	Proposed Paved Hardstanding
▨	Proposed Location for Hazardous Cells
▨	Proposed Location for Non-Hazardous Cells
▨	Existing Inert Cells
▨	Proposed Location for Inert Cells
🟩	Buffer Zone

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Proposed Site Layout

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Figure 14