

- The Waulsortian Limestone consists mainly of pale grey biomicrite (a limestone consisting of skeletal debris and carbonate mud). The sediments commonly form individual and coalesced mounds with depositional dips of 30-40 degrees.
- The Allenwood Formation comprises peloidal and crinoidal limestone and minor oolite at the base with micrites and minor shales overlying and mainly pelsparite (limestone consisting of peloids and spary-calcite) at the top of the succession. The Edenderry Oolite Member, which is part of the Allenwood Formation, is not distinguished on all locations of the map due to its irregular distribution.
- The Dublin Basin depositional succession and the Portarlinton Trough depositional succession are dominated by the Calp Limestones. The term 'Calp' is used to refer to the various basinal limestone and shales occurring in these successions. The Calp units generally consist of dark grey, fine grained, graded limestone with interbedded black shales. The variation in bed thickness, grain size, colour and proportion of shale is a feature of the depositional environment in which these sediments were deposited in the basin.
- The structural geology of the Carboniferous Limestones is poorly understood and any faults shown on the geological map are considered to be very tentative, as indicated by the Geological Survey of Ireland. The poorly understood tectonics is due to the poor control of the bedrock geology as a result of the lack of outcrop exposure.

2.4.3 Geological information gathered from Site-Specific Investigations

Nature and Extent of Peat Material

Visual assessment of the site indicates that peat deposits occur across the entire site. Peat is a soil that is made up of the partially decomposed remains of dead plants that have accumulated on top of each other in waterlogged conditions over thousands of years. Peat is brownish-black in colour and in its natural state is composed of 90-95% water and 5-10% solid organic material.

Industrial harvesting of the peat deposits has occurred in the past within the site. In order to allow for such harvesting of the peat a network of large drains was opened up across the bog to reduce the moisture content of the material, thus allowing the land to be traversed by specialist plant and machinery. The appearance of the bog is heavily influenced by the drainage network, which divides the bog into a number of compartments. The topography of the site is heavily influenced by the previous industrial activity, where the harvesting has resulted in a relatively flat relief across the site.

The remaining peat deposits within the site have been investigated on a number of occasions using different intrusive and non-intrusive methods.

- Bord na Móna undertook a survey of the site in mid-1980s, using a ground penetrating radar technique, to determine the thickness of peat overlying glacial overburden.
- A peat probe investigation was undertaken in January 2002, based on a 100mx100m grid at a total of 205 locations. The probing exercise indicated that peat thickness varies from 0.4m to 2.3m across the area of land surveyed on Timahoe Bog.
- Additional information regarding the peat thickness was available from the 32 No. trial pits excavated by Fehily Timoney & Co. (FTC) in 2002.
- As part of the site investigation programme undertaken by TOBIN, the peat thickness was further investigated during the excavation of 37 No. trial pits.
- Further pre-construction (of permitted facility) site investigations of the borrow pits and administrative area was undertaken by TOBIN and comprised 42 No. trial pits.
- A further Peat Probing Survey was carried out on behalf of TOBIN by BRG Ltd to test the depth of the peat and soft clay along route of the access road, given in Appendix 2.4.1. The depths of the peat varied from 0.1m – 7.7m with an average of 1.5m.

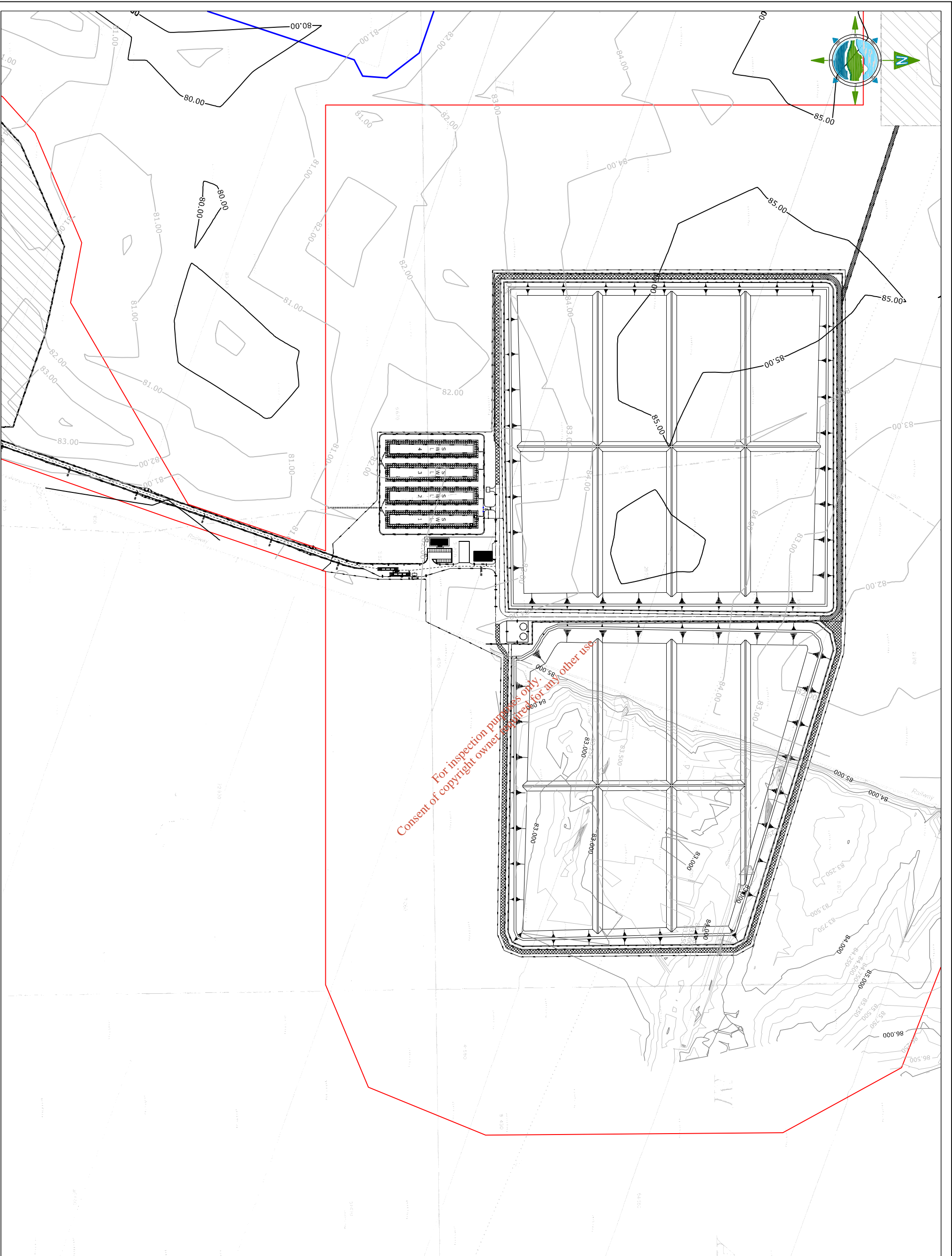
Based on the above sources of information the bottom contours of peat deposits remaining across the site are shown on Figure 2.4.5. The permitted landfill footprint and proposed extension have been positioned to, inter alia, minimise the volume of peat that is required to be removed. The thickness of peat within the landfill footprint extension varies from 0.5m to a maximum of 2.3m.

Subsoil Geology

The quaternary information detailed in this section is based on site investigations undertaken by TES between: December 2002 and March 2003; and, April 2006 and June 2006. Site investigation information was also sourced from the site selection study (2002) undertaken by Fehily Timoney & Co. (FTC) on behalf of Kildare County Council. This information is interpreted to determine the lateral and vertical variations across the site. The sources of site investigation data available from within the site comprise:

- 79 No. trial pit logs undertaken by TOBIN;
- 12 No. boreholes drilled on behalf of TOBIN;
- Geophysical surveys of the site, undertaken in January 2002 and November 2002 by APEX Geoservices Ltd.
- 32 No. trial pit logs undertaken by FTC;
- 9 No. borehole logs drilled on behalf of FTC; and,
- Peat Probe Survey (BRG Ltd) April 2006.

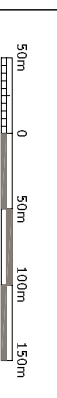
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GENERAL LEGEND
 BORD NA MÓNA
 OWNERSHIP BOUNDARY
 ACTIVITY BOUNDARY
 MAJOR CONTOUR
 MINOR CONTOUR

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD
5. 6" OS SHEET NOS: KILDARE 3, 4, 8, 9 & 13



Issue	Date	Description	By	Check
A	17-04-08	ISSUED FOR TRAINING	JUN	NON

Client:
BORD NA MÓNA

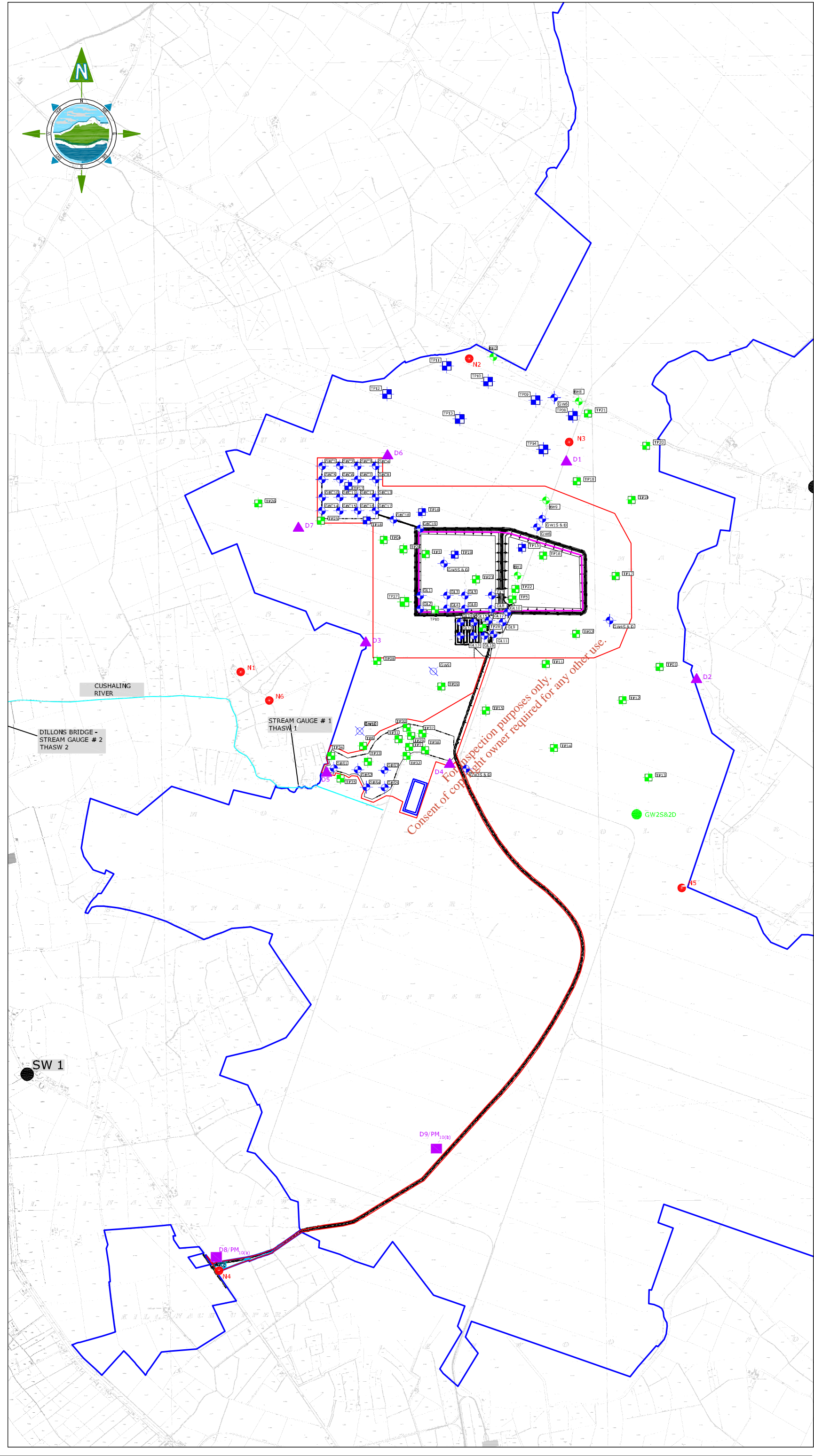
Project:
 EIS FOR EXTENSION TO
 DREDGED WASTE MANAGEMENT
 FACILITY

Title:
 PEAT BOTTOM
 CONTOURS
 (mOD)

Scale @ A3: 1:5,000
 Prepared by: M. Nolan
 Checked: P. O'Neil
 Date: April 2008
 Project Director: D. Gleehan

TOBIN
 Patrick J. Tobin & Co. Ltd.
 Consulting, Civil and Structural Engineers,
 Block 10-3, Blanchardstown Corporate Park,
 Dublin 15, Ireland.
 Tel: +353-401-8000406
 Fax: +353-401-8000409
 e-mail: info@tobin.ie
 www.tobin.ie

Drawing No: **Figure 2.4.5**
 Issue: **A**



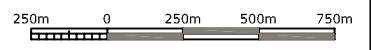
GENERAL LEGEND

BORD NA MÓNA OWNERSHIP BOUNDARY	SITE ACTIVITY BOUNDARY
TOWNLAND BOUNDARY	PERMITTED LANDFILL FOOTPRINT
BORROW AREAS (Clay and sand & gravel)	PROPOSED LANDFILL FOOTPRINT

Legend:

	BORD NA MÓNA OWNERSHIP BOUNDARY
	SITE/ACTIVITY BOUNDARY
	LANDFILL FOOTPRINT
	BORROW AREAS
	BOREHOLES DRILLED BY TES
	TRIAL PITS EXCAVATED BY TES
	BOREHOLES DRILLED BY FEHILY TIMONEY
	TRIAL PITS EXCAVATED BY FEHILY TIMONEY
	SURFACE WATER DRAIN
	STREAM
	RAIL LINE
	NOISE MONITORING LOCATION
	DUST MONITORING LOCATION
	PARTICULATE MATTER
	SURFACE WATER MONITORING LOCATION
	GROUND WATER MONITORING WELLS

- NOTES**
- FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
 - ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
 - ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
 - ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD
 - 6" OS SHEET NO'S: KILDARE 3, 4, 8, 9 & 13



Issue	Date	Description	By	Crk'd.
A	17-04-08	ISSUED FOR PLANNING	MN	PON

Client:
BORD NA MÓNA

Project:
INTENSIFICATION AND EXTENSION TO DREHID WASTE MANAGEMENT FACILITY

Title:
SITE INVESTIGATION AND ENVIRONMENTAL MONITORING LOCATIONS

Scale @ A3: 1:25,000

Prepared by: M. Nolan
Checked: P. O'Neill
Date: April 2008

Project Director: D. Grehan

TOBIN
Patrick J. Tobin & Co., Ltd.
Consulting, Civil and Structural Engineers,
Block 10-4, Blanchardstown Corporate Park,
Dublin 15, Ireland.
Tel: +353-(0)1-8030406
Fax: +353-(0)1-8030409
e-mail: info@tobin.ie
www.tobin.ie

Issue:
Drawing No.: **Figure 2.4.6** **A**

The locations of all trial pits and boreholes, undertaken by TES and FTC are shown on Figure 2.4.6, with the descriptive logs contained in Appendices 2.4.3. The trial pit depths varied within the range of 2.1m to 5.5m below ground level (bgl). Most trial pits were terminated due to collapsing side walls, unstable ground conditions or the compactness of the subsoil material at depth. Bedrock was not encountered in any trial pits excavated within the site. Depth of peat within the proposed extension is typically less than 2 metres below ground level (mbgl).

The contact between the peat deposits and the underlying glacial subsoil is very pronounced, with a sharp change between the two materials.

The subsoils, which underlie the site, are predominantly fine grained. The composition of the subsoil, recorded from each trial pit, was relatively consistent across the site, with some notable exceptions. The subsoils encountered in the trial pits underlying the peat comprise firm to stiff, grey to blue grey, SILTs, CLAYs and SILT/CLAYs with occasional to frequent sub-angular to sub-rounded gravels and cobbles.

To the extreme south of the activity boundary, the peat deposit was almost directly underlain by a lense of Sand and coarse Gravel. The Sand ranges from medium to coarse grained and is quite clean, with a low clay content. The gravel clasts vary from sub-rounded to well rounded, with clasts generally ranging from pebble to cobble size. The extent of the sand and gravel was defined through the excavation of a number of trial pits in this area. The interface between the sand and gravel deposit and the silt/clay appears to be sharp, with a distinctive change over a short lateral distance. The sand and gravel deposit at this location is both horizontally and vertically limited.

In tandem with the trial pitting programme carried out in December 2002 and March 2003, Apex Geoservices Ltd. was contracted to carry out a geophysical survey of the site. The objective of the non-intrusive geophysical survey, in terms of Quaternary characterisation, was to indicate the type and thickness of overburden and determine any lateral variation of overburden type. The geophysical survey was issued to TES Consulting Engineers in November 2002, which included recommendations for borehole drilling within the site to provide control points to calibrate the geophysical results.

Site Investigation data from 11 No. boreholes and 21 No. trial pits were issued to APEX, along with the previous FTC site investigation data (32 No. trial pits and 9 No. boreholes) and existing geophysical surveys, for the purpose of calibrating their results and issue of a final report. The results of the geophysical survey were good in extrapolating the coverage within the site where intrusive investigations were not undertaken. A full copy of the geophysical report is included in Appendix 2.4.2.

A good correlation was observed between the 2D Resistivity survey and the intrusive

site investigation data, with respect to overburden thickness. The resistivity values and seismic refraction values (velocities) recorded during the survey were typical for the Peat/Clay/Silt upper layer and the underlying, stiff, gravelly clay layer.

Based on the findings of previous drilling within the site and deep penetrating geophysical surveys a steeply incised valley was delineated within the site. Investigations undertaken as part of the Kildare Landfill Site Selection study terminated drilling within the valley feature at approximately 60m bgl, without encountering bedrock. As part of the environmental baseline assessment undertaken on behalf of Bord na Móna, a borehole was drilled to a depth of 128.3m bgl before bedrock was encountered. The depth to bedrock either side of the valley feature is relatively constant, i.e. in the range of 11m bgl to 17m bgl. The depth to bedrock under the proposed landfill extension is between 11mbgl and 14mbgl.

Based on the findings of the deep borehole drilling and other pertinent information collected during the site investigation programme, the valley feature is not considered to result from dissolution of the bedrock, i.e. not karstic in nature. The borehole drilling on the edge of the valley feature (Ref. BH1 & BH9 – FTC logs and GW6PW, GW1D, GW3D – TES logs) recorded competent rock, with relatively low permeability characteristics. The unconsolidated material recorded within the valley feature would also disagree with the hypothesis that the valley is a dissolution feature.

In order to define the actual depth to bedrock within this channel and determine the nature of the bedrock Briody Aquadrom Ltd., under the joint supervision of TES and the Geology Department of Trinity College Dublin, were contracted to drill a borehole (Borehole GW7) towards the centre of the deep channel, to the north of the site. This borehole was completed in June 2003. The borehole continued through 128.3m of unconsolidated material before encountering bedrock. The unconsolidated material recorded during drilling was recovered and logged. The borehole log is included in Appendix 2.4.3.

Grey Sandy Clay and Gravelly Clay was recorded to a depth of 8.25m bgl. A lense of granular material, which was interbedded with the gravelly Clay was recorded from 8.25m bgl to 21m bgl. From 21m bgl to 63.7m bgl grey Clay and gravelly Clay was noted.

A distinctive interface between the Quaternary unconsolidated material and older unconsolidated material was noted at 63.7m bgl. The older deposits comprised orange, yellow and brown Clays from 63.7m bgl to 100.3m bgl and thereafter white siliceous silcrete, with white, pale grey, orange and pinks clays were noted to a depth of 115.8m bgl. A very compact, grey/purple/yellow Clay was recorded from 115.8m bgl to 128.3m bgl, at which depth bedrock was encountered.

The Edenderry Member of the Allenwood Formation was recorded at the base of the borehole, based on description of the rock chippings recovered.

The occurrence of the deep overburden channel within the site is not unique. Aeromagnetic data for Central Ireland identifies a remarkable pattern of northeast to southwest trending linear magnetic and negative gravity anomalies some of which are considered to be related to tectonic and volcanic activity during the Tertiary period (65 million years to 1.6 million years ago) (Williams and Brown, 1986). Many of the gravity anomalies correlate with zones of anomalously high depth to bedrock, some of which are considered to be fault related. The main features identified on the aeromagnetic data are up to 3km wide and 165m deep. The faulting along these linear features would have created catchment boundary conditions and controlled the palaeo-drainage from the Tertiary landscape.

The Tertiary Period (65 to 16 millions years ago) in the British Isles was marked by a distinct pattern of erosion and deposition. Due to tectonic activity, east Scotland and northeast Ireland were uplifted, with this area commonly termed the Thulean High. As outlined above, this uplifted area was transected by high energy river channels and underwent very rapid river erosion, with large rivers then crossing the midlands of Ireland before depositing their load in the faulted basins off the west coast of Ireland such as the Erris Trough and Porcupine Basin.

The steeply incised valley does not appear to be of sufficient width to concur with the major faults identified on the aeromagnetic data. Such a feature is considered to have resulted from powerful fluvial erosion (i.e. river erosion) forces resulting in progressive deepening of the valley floor. These deep river channels flowed across arid plains similar in appearance to modern arid environments. In later times, perhaps when subsidence of a fault block resulted in a lowering of the level of the terrain, the fluvial system stagnated and lakes resulted. These lakes would have resulted in the deposition of great thickness of clays.

During this period there was large scale volcanic activity in the north of Ireland and Scotland associated with the Antrim Plateau Basalts. This released large quantities of volcanic ash, which were deposited as far down as the midlands of Ireland. When this alkaline volcanic ash fell on water bodies such as lakes, it not only resulted in the deposition of Jasper (mineral), but also resulted in an increase in the pH of the water, on which the ash was deposited as fall-out. This increase in pH to levels above 8.6 resulted in a very unusual occurrence; conditions suitable for silica to come out of solution and be deposited as Silcrete. These Silcrettes often formed in stagnant lakes and so are often interbedded with tertiary clays which have distinct colours such as orange and very light browns. As the Tertiary period progressed this entire landscape may again have been buried in further sediment deposited over the whole area.

Later in the quaternary period global temperatures fell and the landscape would have been covered in glaciers which would have advanced and retreated several times eroding all soil and stripping the terrain surface down to bare rock, which it then eroded. All evidence of the Tertiary arid landscape was obliterated from the entire island of Ireland except for a few isolated protected pockets. Deep buried river gorges would have been too deep for the glacial action to reach and so isolated pockets of the Tertiary deposits survived. The retreating glaciers deposited a layer of clay dominated till over the whole area, with bog later forming on top of this as the glaciers retreated and the climate warmed.

There is evidence that the above scenario occurred within the site. During the early Tertiary period Ireland was an arid area, with very low rainfall, however the area was transected by a number of deep river gorges, which were very prone to flash flooding, which resulted in the very rapid incision of the gorge into the landscape, which was probably undergoing tectonic uplift at the time. The waters flowing through the gorge flowed from the uplands of west Scotland and north-eastern Ireland, carrying large amounts of sediment to the ocean basins to the west. Due to the flashy nature of the river, which scoured out the bed, there was very little deposition of rivers sediments, on the contrary the area was one of rapid erosion; hence there are no sediments to record this period in the channel's history. However the shape of the channel very clearly indicates the very rapid erosion which cut down into the arid plane. However at some point the drainage in the area changed dramatically. Perhaps the entire plain on which the river flowed subsided due to faulting, or sea levels rose, resulting in a decrease in the elevation head of the river. The entire river flow slowed, very dramatically, with the area rapidly becoming a low energy environment and deposition site, with deposition of fine coloured clay sediments, often with a volcanic influence. The clays deposited are distinctive bright oranges and light browns, typical of the Tertiary clays. Jasper and Silcrete bands in the clay near the base of GW7, as well as reworked clasts of Silcrete in the deposits further up the succession also indicate that there was a volcanic content and influence on the clays which were deposited.

As with any fluvial system, especially in a rapidly eroding area, the presence of minor channels and tributary canyons as well as hanging river valleys is to be expected. It is therefore not surprising that mineral exploration drilling has located several deep anomalies in depth to bedrock in the surrounding area, as detailed on the GSI depth to bedrock map suite for the Kildare Groundwater Protection Scheme, which records some dramatic changes in depth to bedrock in places.

The depth, width and very sharp edges of the feature, as well as the thickness of the clay deposits, is of a scale that is unusual in Ireland and would be considered very unusual for a karst feature. The level at which rock was encountered either side of the feature and rock quality shown by the 2-D Resistivity sections show no evidence of

karstification in the bedrock. It is highly improbable that the channel feature could be due to karstification on such a scale and that the adjacent bedrock would not show any indication of karstification.

Again it must be pointed out that the GSI, who has compiled the depth to bedrock maps and Groundwater Protection Scheme for the area, has no record of any karst feature in the Waulsortian Limestone in Kildare, with only 3 No. features (all in the Calp Limestone) being recorded for the county.

In summary, from the evidence of the geophysical survey and the drilling of the site, the clay filled, weathered-out valley feature identified within the site is not believed to be karstic in nature. The feature is thought to be an unusual Tertiary fluvial feature, which is filled with clay, with possible tributaries to this channel present in the area. There is no indication of karstification at the site, which is in agreement with the Geological Survey of Ireland's assessment of the Waulsortian Limestone in County Kildare. The presence of this feature, while interesting from a geological point of view, has no negative impact on the suitability of the site. In fact the presence of such a thickness of low permeability clay means the site has one on the most protective layers overlying any bedrock aquifer in Ireland.

Bedrock Geology

The bedrock encountered within the site was generally in accordance with the GSI geologic map. Waulsortian limestone, which comprises pale grey, fine grained limestone, was encountered throughout most of the site (boreholes GW1D, GW4D and GW6). To the south of the site, where boreholes GW2D and GW3D were installed, dark argillaceous limestone was encountered. This rock is considered to be consistent with the description of the Boston Hill Formation.

The bedrock material encountered at the base of the deep borehole (GW7) was classified as the Edenderry Oolite Member of the Allenwood Formation based on material recovered during drilling. Bedrock was not encountered to a depth of 27.5m bgl in borehole GW5, which is located close to the centre of the deep unconsolidated feature.

The site specific borehole information suggests that the contact between the Boston Hill Formation and the Waulsortian Limestone extends further to the east than shown on the GSI geology map. As the bedrock at the base of the deep borehole is the Edenderry member, the lithological divide between the Waulsortian and the Allenwood Formation extends further west than shown on the GSI geology map. Notwithstanding the difference in the lithological divides between the Waulsortian Limestone and the Boston Hill Formation/Allenwood Formation, the borehole drilling is generally consistent with the GSI geology map.

The geophysical survey of the site, undertaken by APEX Geoservices Ltd. did not find evidence of high permeability zones in the bedrock. The geophysical report recommended that the significance of dolomitisation, in terms of increased permeability, should be investigated. As part of the drilling and hydraulic testing programme, undertaken as part of the environmental baseline assessment, the significance of dolomitisation was assessed.

Dolomitisation of limestone bedrock can commonly lead to enhanced porosity of the rock, through chemical reaction. Hence, the presence of dolomitisation is an indicator that permeability may potentially be higher than an undolomitised rock.

The geophysical report did not state that the dolomitisation of the bedrock had occurred or that the survey had detected high permeability zones in the site area. The report stated that the possibility should be investigated, due to the data recorded. The report states that “*Waulsortian Limestone would typically have a higher range of resistivity values than those interpreted from November 2002 2D Resistivity Profile 1 (250-1600ohm-m). This may be due to the effect of dolomitisation especially in the upper 5-10 m of interpreted bedrock. The significance of this dolomitisation in terms of increased bedrock permeability should be investigated*”.

The results of the initial geophysical survey were used in order to target borehole drill locations, so that control points could be used by APEX Geoservices Ltd. to refine their report. Slight dolomitisation was encountered during drilling of GW6 and the pump testing of this well showed the bedrock to have a low transmissivity (permeability). Therefore, dolomitisation of the limestone bedrock has been investigated and has not shown any zones of high permeability.

The drilling records do not indicate any large groundwater strikes and the drill returns did not indicate any zones of notable weathering or solution, with the exception of borehole GW6 and GW7.

The bedrock encountered in GW6 was weathered and possibly dolomitised, however the borehole is located on the side wall of the incised unconsolidated valley feature. It could reasonably be expected that the erosion of the bedrock would have resulted in a degree of weathering on the side walls. The extent of the weathering does not continue laterally in the bedrock, as no weathering or solution of the bedrock was noted in borehole GW1, located close to GW6.

During the drilling of GW7 groundwater inflow was observed from the gravel material encountered between the interval 9.75m bgl to 21m bgl. The inflow was estimated to comprise 110-220m³/day (1,000-2,000gph), however the sustainability of such a yield is unknown due to the possible limited extent of the granular deposit. A significant groundwater inflow was recorded at the base of this borehole, where rock

was encountered in the interval of 128.3m bgl to 129.8m bgl. It is estimated that a yield of greater than 1,100m³/day (>10,000gph) was encountered at this interval that was under considerable confining pressure. The confining pressure was not unexpected at such depth as the overlying unconsolidated material has a very low permeability. The static water in this borehole was measured in July 2003 at 3.77m bgl, which is relatively similar to the piezometric head observed elsewhere within the site.

2.4.4 Geotechnical analysis of subsoil material

Samples of the Quaternary material encountered within the site were obtained during site investigations. A total of 27 No. disturbed samples were obtained to determine the particle size distribution (PSD) of the unconsolidated material (10 in the 2002-2003 programme; 17 in the 2006 programme) from trial pits TP2, TP5, TP8, TP11, TP16, TP18, TP32, TP33, TP35 and TP36, GBS2, GBS3, GBS4, GBC3, GBC10 (2 Samples), GBC13, GBC16, GBC20, GL1, GL2, GL4, GL9, GL11, GL14, GL15 and GL16. They are considered to be representative of the fine grained subsoil (SILT, SILT/CLAY, CLAY) that dominates within this site. Disturbed bulk samples were obtained from trial pits TP32, TP33, TP35, TP36 and GBS2, GBS3, GBS4 excavated within the Sand and Gravel deposit delineated to the south of the site

The grading of the disturbed bulk samples was determined by wet sieving, in accordance with Test 9.2 and 9.3 of BS1377: Part 2, 1990. All peat material was excluded from the sample. The results of the PSD laboratory tests are included in Appendix 2.4.4.

The PSD laboratory results from trial pits TP2, TP5, TP8, TP11, TP16, TP18, GBC3, GBC10 (2 Samples), GBC13, GBC16, GBC20, GL1, GL2, GL4, GL9, GL11, GL14, GL15 and GL16 confirm the field descriptions of Gravelly SILT/CLAY, gravelly SILT, and gravelly CLAY, as described in the trial pit logs based on on-site visual assessment. Gravelly SILT/CLAY is the dominant subsoil type. A summary of the laboratory testing is detailed below:

Table 2.4.1: Particle Size Distribution of fine grained Samples

Sample ID	% Clay	% Silt	% Sand	% Gravel
TP2	16	50	16	18
TP5	14	45	28	13
TP8	13	37	26	24
TP11	11	29	29	31
TP16	9	24	24	43
TP18	16	32	23	29
GBC3	6	36	24	34
GBC10	8	56	25	14
GBC10	10	41	22	28
GBC13	6	33	25	36
GBC16	7	56	21	16
GBC20	8	37	24	31
GL1	9	42	19	30
GL2	8	42	26	24
GL4	12	38	21	29
GL9	8	17	55	18
GL11	5	15	35	35
GL14	5	11	20	59
GL15	14	14	22	41
GL16	8	37	33	21
Average	10	35	26	29

The PSD laboratory results from trial pits TP32 (*Sample Ref. THGV1**), TP33 (*Sample Ref.: THGV2*), TP35 (*Sample Ref.: THGV4*) and TP36 (*Sample Ref.: THGV3*) confirm the field description of Sand and Gravel, as described in the trial pit logs. A summary of the laboratory testing is detailed below:

Table 2.4.2: Particle Size Distribution of Sand and Gravel Samples

Sample ID	% Silt/Clay	% Sand	% Gravel
TP32	2	38	60
TP33	2	51	47
TP35	1	39	60
TP36	1	45	54
GBS2	5	29	66
GBS3	2	19	52
GBS4	6	50	42
Average	3	39	58

To determine the vertical permeability of the glacial deposits 10 No. undisturbed soil samples were obtained for tri-axial constant head permeability analysis. The samples were obtained from the glacial subsoil material in the vicinity of the landfill footprint

* Sample Refs given in this instance for cross reference with copy of PSD results from laboratory included in Appendix C-VI

and the clay borrow area, however the permeability values are considered representative of the grey gravelly SILT/CLAY which dominates within the entire site.

The laboratory test sheets of the tri-axial constant head permeability analysis are included in Appendix 2.4.5, with the results summarised below.

Table 2.4.3: Results of Triaxial Constant Head Permeability Analysis

Sample Ref.	Trial Pit Ref.	Vertical Permeability (m/sec)	Mean Effective Stress (kPA)
TH1	TP22	6.3×10^{-10}	24
TH2	TP23	5.4×10^{-10}	25
TH3	TP24	6.0×10^{-10}	25
TH4	TP25	6.3×10^{-10}	24
TH5	TP26	7.1×10^{-10}	26
TH6	TP27	1.1×10^{-9}	25
TH7	TP28	1.5×10^{-9}	25
3-1	GBC3	4.5×10^{-10}	80
10-1	GBC10	2.2×10^{-10}	80
16-1	GBC16	4.0×10^{-10}	80
	K_v Average	6.78×10^{-10}	41.4

The visual description of the material by Glovers Site Investigation Ltd. generally concurs with the description noted by TES. The test results indicate that the in-situ natural vertical permeability of the quaternary overburden varies between 2.2×10^{-10} metres/second (lower limit) to 1.5×10^{-9} (upper limit), with an average vertical permeability of 6.78×10^{-10} metres/second. Permeability values in this range are considered to be low permeability and in the lower range of permeability values for Irish Tills.

2.4.5 Hydrogeology Data

Aquifer Classification

The Geological Survey of Ireland has prepared a Groundwater Protection Scheme for County Kildare (2004). The aquifer classification for the bedrock units underlying the site application are obtained from the GSI website (2007) and an extract from the groundwater web mapping is provided in Figure 2.4.7 and in Appendix 2.4.6.

The Boston Hill Formation and the Waulsortian Limestone are classified as Locally Important Aquifers, which are moderately productive only in localised zones (L1), see Figure 2.4.7 .

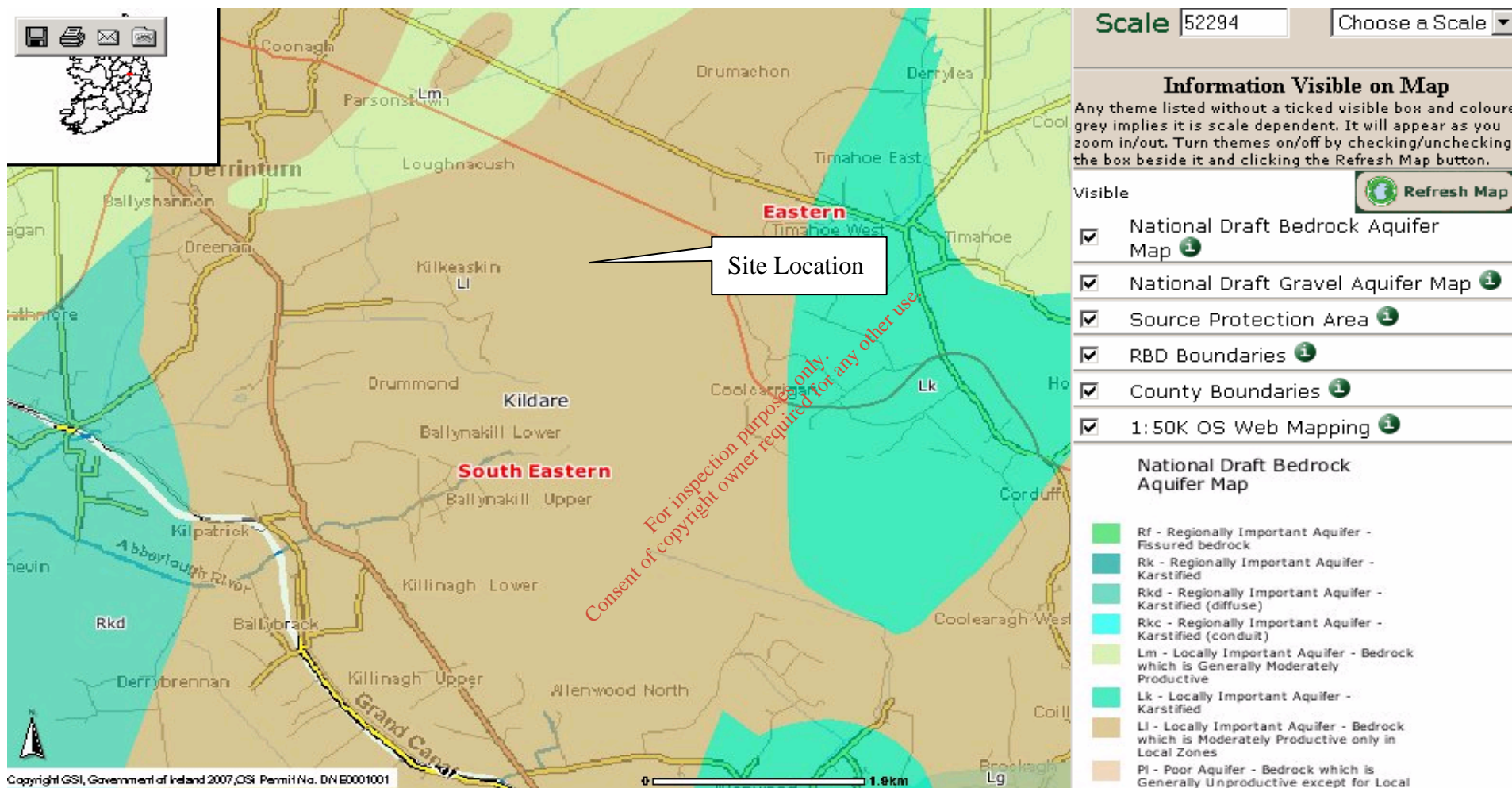


Figure 2.4.7 Groundwater Web Mapping- GSI Website 2007

The Calp limestones located to the north of the site is classified as a Locally Important Aquifer generally moderately productive (Lm). The Allenwood Formation and the Ballydams are located to the east and west of the site. The Allenwood Formation and the Ballydams located to west of the site are classified as a Regionally Important Karst Aquifer (Rkd), while the Allenwood Formation located to the east of the site is classified as a Locally Important Karst aquifer (Lk). Based on extensive site investigation works conducted on the site it has been shown that these bedrock units do not underlie the site application boundary.

Aquifer Potential

The groundwater flow characteristics within the limestones underlying the site are dominated by secondary permeability, i.e. fissure flow. There is effectively no primary permeability (inter-granular permeability) in these rocks.

As part of this hydrogeological investigation of the aquifer potential a 72 hour pump test was carried out to determine the characteristics of the aquifer close to the landfill footprint. The pump test was undertaken on borehole GW6, which is approximately 200m from the landfill footprint. Before the pump test began the static water level (SWL) in all monitoring boreholes was recorded to act as a datum for measurement during the test. The water levels in all boreholes were measured periodically to determine if the pumping was resulting in a radial cone of depression as a result of drawdown from the pumped borehole.

The pump test was undertaken by pumping from GW6, which was drilled to a finished 150mm diameter borehole. The other boreholes installed at the site were monitored during the course of the pump test to observe any water level fluctuations. The discharge drawdown data from the pump test are included in Appendix 2.4.7.

The only water level fluctuation in the observation wells was recorded in monitoring wells BH1D and BH1S, which are approximately 35m from the pumping well. A drawdown of 1.53 m was achieved in BH1D with a drawdown of 0.6 m being achieved in borehole BH1S indicating the pumping and drawdown only had a very localized effect.

The peak pump rate measured during the test was 56m³/day. The pump rate of 43m³/day was used for calculations as an average pump rate maintained during the log cycle in which the data was interpreted (i.e. 10 to 100 minutes), due to slight fluctuation in discharge during the test. These fluctuations in pumping rate are discussed below.

Due to slight variation in the pumping rates observed during the test, the pumping rate used in the Jacob Calculation was correlated with the pumping rate observed during a full log cycle. A value of 43m³/day was used for the calculation of the aquifer

transmissivity in the 10 to 100 minutes log. The drawdown per log cycle during the 10 to 100 minutes log cycle was 37.2m (with actual observed drawdown between 25 and 27 m, however as per the Jacob Method the drawdown per log cycle is used). Therefore, the figures used for calculating the Transmissivity are a drawdown per log cycle of 37.2m and the pumping rate of 43m³/day, giving a calculated transmissivity of 0.215 m²/day (See Calculation Appendix 2.4.8).

Following 100 minutes of pumping the drawdown in the well began to vary, making the determination of a straight line slope for calculation difficult. A similar slope (and hence Transmissivity value) is noted from 1709 minutes to 2909 minutes. Notwithstanding the slight variation, the drawdown in the pumped well was at a relatively steady-state (though oscillating) at a level between 23m and 27m (with an approximate average value of 25m).

A Logan Approximation calculation which relates transmissivity to the pumping rate and steady-state drawdown in a well was applied to this data for pumping after 100 minutes. The Logan Approximation was deemed an appropriate method to approximate the aquifer transmissivity due to the slight variation in drawdown in the pumped well. The values used were a pumping rate 48.5 m³/day (an average pumping rate over the 100 to 4349 minute period) and a drawdown of 25 m. This Logan calculation gave a transmissivity result of 2.37 m²/day, presented as a rounded value of 2 m²/day in the EIS (See Calculation Appendix 2.4.8). The calculated specific capacity of the pumping well is 1.94 m³/day/m, using the above values of the average mid to late pumping rate of 48.5 m³/day and an average drawdown of 25 m. This means the well would be classified as Well Productivity Class V (the lowest classification), as per the Geological Survey of Ireland well classification system.

An additional analysis of the pump test data was undertaken using a simplified Thiem Equation formula. This simplified Thiem equation was derived by Aslibekian (1998) and is normally applied to steady radial flow in a confined aquifer in typical Irish Aquifers. The simplified Thiem Equation gave a transmissivity result of 2.31 m²/day, confirming the values obtained through other methods of data interpretation. (See calculation, Appendix 2.4.8).

The values for Transmissivity calculated from drawdown data from GW6 are presented below in Table 2.4.4

Table 2.4.4: Transmissivity Values from Drawdown Data from GW6PW

Analytical Method used	Jacob Straight Line (10 to 100 minutes)	Logan Approximation (100-4349 minutes)	Aslibekian (simplified Thiem Equation)	Arithmetic Mean
T (m²/day)	0.215	2.37	2.31	1.7

The recovery period of the aquifer pump test was monitored and the data interpreted using the Jacob Straight Line Method using a semi-log plot of residual drawdown (s') vs. t'/t (time since cessation of pumping divided by time since commencement of pumping). The recovery period was 210 minutes long with water levels recovering from a drawdown of 25.93 m to within 1.37 m of zero drawdown (the SWL prior to the test).

Monitoring of the data ceased after continuous monitoring of the data curve showed there was sufficient data to allow an analysis to be carried out and due to the incrementally slower recovery which always occurs in the final metre of any recovery test, but which is more due to well effects than aquifer response.

Analysis of the graphs showed three subtly different slopes for late, mid and early points in the recovery (highest values of t'/t are early time, lowest values are late time). Values of transmissivity were calculated using the highest pumping rate observed of 56m³/day and also the average pumping rate over the 72 hours of 49m³/day. The calculated values of transmissivity for the recovery data are presented below in Table 2.4.5. The transmissivity data from the recovery data is in agreement with the values determined from the pump test drawdown data, with transmissivity values of approximately 2m²/day (See Graph and Calculations in Appendix 2.4.8).

Table 2.4.5: Transmissivity Values from Recovery Data from GW6PW

Pumping Rate	Late	Mid	Early	Average
m ³ /day	T (m ² /day)	T (m ² /day)	T (m ² /day)	T (m ² /day)
56.68	3.84	1.7	0.72	2.09
49.14	3.3	1.47	0.62	1.81

Analysis of drawdown data from observation well GW1D gave calculated transmissivity of 16 m²/day. Analysis of recovery data using the two pumping rates resulted in transmissivity values in general agreement with the values calculated using drawdown data, with values of 16.06 and 18.5 m²/day being calculated, as presented in Table 2.4.6.

Table 2.4.6: Transmissivity values from recovery data at observation well GW1D

Pumping Rate	Average
m ³ /day	T (m ² /day)
56.68	18.5
49.14	16.06

A distance drawdown analysis was carried out by plotting the two data points on a semi-log plot (using 25 m as the steady drawdown for the pumping well and 1.53m as

the maximum drawdown for GW1) the straight line intercepts the zero drawdown line at 19.6 m from the pumping well. This indicates that the zone of depression induced by pumping extends approximately 20m. While this is a correctly calculated value, it is most likely not a valid number given the very low drawdowns achieved. It does however demonstrate that the cone of depression is quite restricted in area due to the low Transmissivity of the bedrock aquifer.

When a Jacob Straight Line analysis is applied, using the distance drawdown method using the maximum and averaged pumping rates over the test, the calculated transmissivity values of 0.76 and 0.88 m²/day (as presented in Table 2.4.7) are in general agreement with values calculated with the Jacob Drawdown and Recovery and Aslibekain Calculations above.

Table 2.4.7: Transmissivity Values from Distance Drawdown Analysis

Pumping Rate	Average
m ³ /day	T (m ² /day)
56.68	0.88
49.14	0.76

No appreciable drawdowns were detected in the other monitoring boreholes. While minor water level fluctuations occurred these cannot logically be related to the pumping well, with SWLs actually increasing (GW5D) and one well (GW4S) showing a decrease in water levels of 0.19 m and then an increase in water levels after 2000 minutes, halfway through the pumping period (see graphs in Appendix 2.4.8).

Discussion of Results

Although on-paper there is an order of magnitude difference between the calculated transmissivity values for Mid and Late pumping time values the numbers are only important in that they express that the transmissivity is low. The calculated transmissivity values for the pumping well of 0.2 m²/day (for drawdown) to 2 m²/day (for recovery) at GW6 and 16 m²/day (for drawdown) and 18.5m²/day (for recovery) at observation well GW1D are typical of the Waulsortian Limestone in the northern half of Ireland. These values concur with transmissivity values ranging from 0.3 to 115m²/day with a 50th Percentile value of 10m²/day (Aslibekian 1998) for the Waulsortian elsewhere in the Midlands. The consistency of the results allows for a high degree of confidence in the Transmissivity value presented in the EIS as being in the region of 2 to 16 m²/day, with the transmissivity value of 2m²/day from the pumping well being the most representative of the aquifer.

Permeability Calculation

The estimation of Permeability (K) from Transmissivity values in fractured or fissured aquifers is very difficult, as interpretive hydraulic methods are based on the assumption that the aquifer is a homogenous porous medium. Permeability is

normally determined by dividing the Transmissivity by the aquifer thickness. In unconfined aquifers, where drawdown results in a decrease in the saturated thickness of the aquifer, the estimation is further complicated.

Permeability calculations using three different values for the aquifer thickness are given in Appendix 2.4.9.

1. The length of the well screen in the pumping well.
2. The saturated thickness of the borehole (distance between the static water level and the base of the borehole).
3. The top 50m of the aquifer. This is a reasonable value to assume for the Waulsortian Limestone aquifer as higher permeability values are generally found in the upper section of the aquifer.

The values of Transmissivity have been demonstrated to be in the range of 2 to 16 m²/day, with the lower value being more representative.

These Permeability values range from

- $K = 4.6 \times 10^{-7}$ to 2.6×10^{-6} m/s using a T value of 2 m²/day; and
- $K = 3.7 \times 10^{-6}$ to 2.1×10^{-5} m/s using a T value of 16 m²/day.

Caution needs to be applied to these values, as shown by the pump test, the interconnectivity of pores, fissures or any conduits are very limited - demonstrated by the very narrow cone of depression generated by the ca. 25 m drawdown in the pumping well. The in-situ hydraulic testing of the aquifer within the site is consistent with the GSI classification of the aquifer. The localized nature of the cone of depression demonstrates the poor and localized nature of the permeability in the bedrock underlying the site, which is consistent with the GSI aquifer classification.

With respect to the hydraulic information for the unconsolidated material, the site investigation programme across the site indicates that the dominant subsoil material comprises grey, gravelly SILT/CLAY.

The in-situ vertical permeability of the subsoil underlying the landfill footprint has been tested and the permeability values, which vary between 5.4×10^{-10} metres/second (lower limit) to 1.5×10^{-9} (upper limit), demonstrate that the material exhibits very low permeability. The natural permeability of the subsoils impedes percolation of rainwater to the bedrock aquifer.

To the south of the site a lense of Sand and Gravel was delineated. The extent of this lense does not extend to the landfill footprint. Borehole GW5, which is located close to the landfill footprint, continued to a depth of 27.5m bgl without encountering any Sand and Gravel material or bedrock material. The edge of the Sand and Gravel lense is 650m to the south of the landfill footprint. The extent of the Sand and Gravel lense

was delineated during the site investigation programme. The lense appears to trend in an east to west direction. The Cushaling River originates from the discharge of groundwater to the surface at the bog margin. The particle size distribution indicates that the material is coarse in size and very clean (Clay and Silt content is less than 2%).

Sand and Gravel material was also encountered in the Quaternary deposits during the drilling of deep borehole GW7. A significant groundwater inflow was recorded in this deposit. Fehily Timoney & Co. also encountered this granular material during the installation of borehole BH8. The exact lateral extent of this granular lense has not been delineated, however other boreholes drilled by both TOBIN and Fehily Timoney & Co. did not encounter similar granular material to the south or west of the site. It is therefore concluded that this granular lense is a localised feature and is bound by the grey gravelly SILT/CLAY. No sand and gravel material was encountered in the environs of the landfill footprint.

Aquifer Throughput

The aquifer throughput beneath the landfill footprint was determined using the formula:

$$Q = wTi$$

Where:

Q is the flow (or throughput) in m³/day;

w is the width of the footprint (taken at its maximum, a diagonal section, 652 m);

T is the transmissivity (taken as ranging from 2 – 16 m²/day from the TES pump test);

and,

i is the horizontal hydraulic gradient interpreted from the piezometric map in the footprint area.

The calculations and methodology used are presented in Appendix 2.4.10. As is expected the hydraulic gradient varies across the site and is effected by the topography, with higher gradients experienced on the fringes of the site where there is a change in level and the lowest gradients experienced on the flatter parts of the site, such as the footprint area. The hydraulic gradient in the area of the footprint is estimated to be in the order of 0.0012 to 0.0005. However, to apply a conservative approach and apply a high factor of safety, the gradient used in the calculations was doubled to 0.0025

The calculations estimate that the aquifer flow beneath the footprint is in the order of 3.26 – 26.08m³/day, with the flow probably in the lower range as, while the Transmissivity ranges from 2 – 16m²/day, it is more probable that it is closer to the figure of 2m²/day rather than the higher ranges.

2.4.6 Groundwater Vulnerability

Groundwater protection is based on the concept of groundwater contamination risk and risk management. The conventional hazard-pathway-target model for environmental management can be applied to groundwater risk management. The risk of contamination of groundwater depends on three elements.

Firstly, the hazard in this case is represented primarily by the landfill and to a lesser extent by the composting facility, the designs of which are detailed in Section 3 of this EIS. The high specification design criteria are not accounted for in the groundwater protection scheme, however it is an implicit requirement that the risk of potential contamination is minimised. Secondly, the target is represented in this case as the top of the bedrock aquifer. The GSI have classified the bedrock aquifers underlying the site as Locally Important and no beneficial users of groundwater (groundwater abstractions) have been identified within 1km (closest domestic dwelling is in excess 1km to the landfill footprint).

The final part of the model is the potential pathway linking the hazard to the target, in this case the low permeability Silt/Clay overburden (average vertical permeability is 4.48×10^{-10} metres/sec).

Groundwater vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. The vulnerability category is based on the relative ease with which infiltrating water and potential contaminants may reach groundwater in a vertical or sub-vertical direction. The permeability and thickness of the subsoil, which influences the attenuation capacity, are important elements in determining the vulnerability of groundwater.

A groundwater vulnerability map for County Kildare has been prepared by the GSI as part of the Groundwater Protection Scheme. According to the information available at present from the GSI, the vulnerability rating for the site is classified as Low over the majority of the site, which is the rating that affords greatest natural protection against contamination.

The borehole records for the site indicate that rockhead varies from 9m to the south of the property (close to the Sand and Gravel lense to the south) to 128m to the north of the property (adjacent to the L5025 road). Rockhead was encountered in the borehole drilled within the proposed landfill footprint (borehole BH1), where drilling continued to a finished depth of 21m bgl reaching bedrock at 18 mbgl and encountered the grey gravelly Silt/Clay (10 metres thick). Testing conducted on the gravelly silt/clay indicated the subsoil material has a low permeability (4.48×10^{-10} metres/sec). The deep unconsolidated channel (128m) is located to the west of the landfill footprint. Therefore based on the site specific information the vulnerability rating for landfill

activity boundary is Low Vulnerability.

In areas further to the south of the proposed extension where Sand and Gravel directly underlie the peat deposits, the vulnerability is assessed as Moderate Vulnerability. It is proposed to utilise the sand and gravel in the construction of the landfill, as in the case of the previous decision, however it should be noted that the landfill footprint (including its proposed extension) will be entirely underlain by the low permeability gravelly Silt/Clay. Sand and Gravel deposits do not underlie the permitted/proposed landfill footprint.

2.4.7 Groundwater Protection Response Matrix

The Groundwater Protection Response Matrix for Landfills (GSI, 1999), included in Appendix 2.4.11, has defined hydrogeological situations, which are considered suitable or unsuitable for landfill facilities. The groundwater protection responses outline the likely acceptability of landfills in each groundwater protection zone and the recommended level of response/restriction, which depends on the groundwater vulnerability, the value of the groundwater environment and the contaminant loading. Using the aquifer classification, in association with the vulnerability rating, a groundwater resource for the particular site is determined. With regard to the landfill facility the existing groundwater resource underlying the landfill is determined as LI/L (locally important aquifer with a vulnerability rating of Low), which is assigned a R1 rating, as per the response matrix for landfills. The response matrix deems that the development of a landfill is acceptable, subject to guidance outlined in the EPA design manual or conditions of a Waste Licence.

As discussed in Section 2.4.3, the geophysical survey was undertaken by APEX Geoservices Ltd. across the landfill footprint to check for the presence of any anomalies within the bedrock. The geophysical report is included in Appendix 2.4.2. Interpretation of the geophysical survey data did not detect any anomalies in the bedrock strata, other than the deep unconsolidated channel, which affords the aquifer greater protection. From the site investigations and surveys carried out there is no evidence of high permeability zone across the site.

2.4.8 Water Abstractions

During the course of the environmental baseline assessment information was collated regarding the provision of services to the community surrounding the facility.

Kildare County Council operates two large water distribution networks in County Kildare. The water provision centres are located at the Hill of Allen and the Hill of Carbury, two topographically elevated sites, whereby water falls by gravity to the distribution network.

The Hill of Allen reservoir is fed from the Ballymore Eustace Treatment Works, whose source of supply is the River Liffey. This reservoir supplies Newbridge, Naas and the surrounding environs in County Kildare.

The Hill of Carbury network supplies much of north Kildare. The reservoir supplies water to distribution networks in the vicinity of the site, Drehid Association Group Water Scheme (GWS), Johnstown Bridge GWS, Timahoe GWS.

The Hodgestown GWS is in operation to the east of the development, approximately 5km east of the landfill footprint.

Kildare County Council has adopted a water strategy to meet the water requirements for the county up to the year 2020. The Council intend to develop groundwater sources in the Carboniferous Limestones to augment the current supply network. The two groundwater well fields to be developed which are closest to the facility are located near Johnstown Bridge (approximately 8km to the northeast of the landfill) and near Robertstown (approximately 6.5km southeast of the landfill) respectively. A detailed Environmental Report was compiled for each well field and related infrastructure. A brief summary of each well field is detailed below.

The Johnstown Bridge well field envisages abstracting 3,750m³/day from 7 No. production wells drilled into the Calp Limestone aquifer. The production wells are located in Dunferth Wood (WW2), Coolree (WW23), Dysart (WW17), Clonagh (WW20), Clonagh (WW21) and Hortland (WW24) and Hortland (WW25). The location of the wells are shown on Figure 2.1, contained in Appendix 2.4.12, which is an extract from the Environmental Report. The source protection zones for the scheme are also included in Appendix 2.4.12.

The Johnstown Bridge well field is located in the River Boyne catchment area. The water abstracted from the Johnstown Bridge well field will be treated and pumped to a new reservoir to be constructed on the Hill of Carbury. With reference to the Source Protection Scheme for the Johnstown Bridge well field, the landfill is approximately 5km to the south of the outer protection zone for the scheme. Therefore the development will not impact upon the quantity or quality of water abstracted during the operation of the scheme.

The Robertstown well field envisages abstracting 6,500m³/day from 9 No. production wells drilled into gravel deposits, which constitute an important potential groundwater resource in the Robertstown area. All production wells are located on Council property or adjacent agricultural land approximately 750m east of Robertstown Village. The location of the wells is shown on Figure 2.1, contained in Appendix 2.4.12, which is an extract from the Environmental Report. The source protection

zones for the scheme are also included in Appendix 2.4.12.

The Robertstown well field lies in the headwaters of the River Slate catchment, which is a sub-catchment of the River Barrow catchment. The well field is positioned close to the watershed with the River Boyne and the River Liffey. The groundwater flow direction in the environs of the Robertstown well field is from a southeast/east direction towards the northwest/west. Therefore the development will not impact upon the quantity or quality of water abstracted from the gravel aquifer during the operation of the scheme.

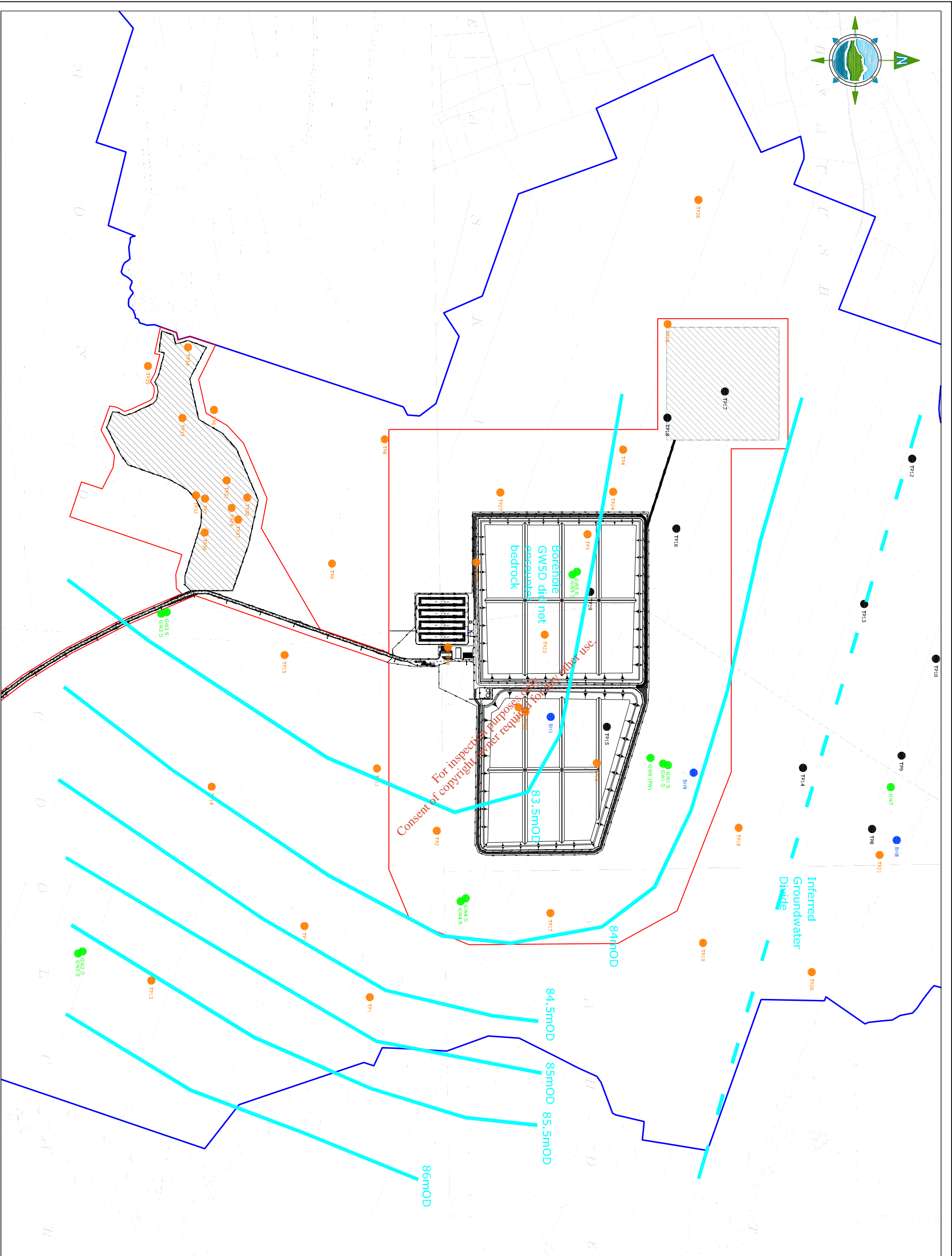
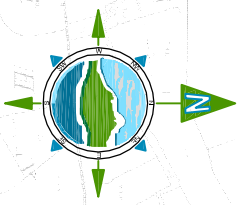
The landfill footprint is in excess of 1km from the nearest domestic dwelling and the extremely low permeability and thickness of the subsoil material underlying the site would inhibit infiltration to the bedrock aquifer. The water distribution network from public supply and group water schemes is extensive in this area; however some households may have retained private wells to meet their own water requirements. These wells will not be impacted by the development.

2.4.9 Groundwater Piezometry

In order to determine the groundwater flow direction and the groundwater gradients within the site, the topographic elevation of all monitoring points was established. Based on the water level monitoring and the topographic elevation it was possible to establish the piezometric head at each monitoring point.

Paired monitoring boreholes / piezometers in the bedrock and overburden were drilled at five different locations within the Timahoe site which provided for monitoring of the shallow and deep groundwater levels. These boreholes are designated a number and the letter “D” if the borehole is screened only in the bedrock (e.g. GW1D); or the letter “S” if it is a shallow overburden borehole screened only in the Till (e.g. GW1S). These boreholes are generally within 15 to 20 m of each other and so it is possible to monitor the water level in the overburden and bedrock at approximately the same point. The pumping borehole GW6 is within 16m of GW1S and so this represents a 6th pairing.

All levels were measured relative to Ordnance Datum (Malin Head). The elevation and piezometric head of all measured points are tabulated on Table 2.4.8. The piezometric data and inferred groundwater contours are shown on Figure 2.4.8.



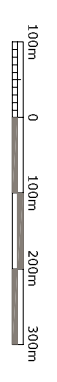
GENERAL LEGEND

- BORD NA MÓNA OWNERSHIP BOUNDARY
- - - SITE ACTIVITY BOUNDARY
- GROUND WATER CONTOURS
- BOREHOLES DRILLED BY FEIHLY TIMONEY (SEPTEMBER 2007)
- BOREHOLES DRILLED BY T&S (DECEMBER 2002)
- TRIAL PITS EXCAVATED BY FEIHLY TIMONEY (SEPTEMBER 2007)
- TRIAL PITS EXCAVATED BY T&S (DECEMBER 2002)

Sources of Information:
 T&S Consulting Engineers Site Investigation Programme
 Feihly Timoney Consulting Engineers Site Investigation Programme

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD
5. 6" OS SHEET NOS: KILDARE 3, 4, 8, 9 & 13



Issue	Date	Description	By	Chk'd
A	17-04-08	ISSUED FOR TRAINING	JUN	NON

Client:
BORD NA MÓNA

Project:
 EIS FOR EXTENSION TO
 DREHD WASTE MANAGEMENT
 FACILITY

Title:
 BEDROCK PIEZOMETRIC LEVELS
 & INFERRED GROUNDWATER
 CONTOURS

Scale @ A3:
 1:10,000

Prepared by: M. Nolan
 Checked: P. O'Neill
 Date: April 2008

Project Director: D. Gleehan

Patrick J. Tobin & Co. Ltd.
 Consulting, Civil and Structural Engineers,
 Block 103, Blanchardstown Corporate Park,
 Dublin 15, Ireland.
 Tel: +353-401-8000406
 Fax: +353-401-8000409
 e-mail: info@tobin.ie
 www.tobin.ie

Drawing No.: **Figure 2.4.8**
 Issue: **A**

Table 2.4.8: Location and Elevation of Groundwater Monitoring Points and Piezometric Head

Reference	Grid Reference	Ground Elevation (mOD)	Static Water Level (m OD) on 16/01/03	Static Water Level (m OD) on 03/02/03	Static Water Level (m OD) on 18/07/03	Static Water Level (m OD) on 18/01/07
GW1D	E274767, N232294	84.886	83.856	83.951	84.586	83.922
GW1S	E274773, N232292	84.852	83.727	83.812	83.457	84.286
GW2D	E275305, N230640	87.862	85.857	85.952	85.522	-
GW2S	E275312, N230650	87.37	86.32	86.42	85.96	86.07
GW3D	E274349, N230902	85.115	83.505	83.59	83.245	82.178
GW3S	E274354, N230907	85.018	82.998	83.068	82.778	82.695
GW4D	E275153, N231756	84.612	83.932	84.012	83.632	-
GW4S	E275159, N231740	84.213	83.413	83.433	83.133	-
GW5D	E274236, N232062	85.85	84.895	85.01	84.57	85.35
GW5S	E274246, N232059	85.799	85.154	85.224	85.724	84.919
GW6	E274765, N232278	84.737	83.782	84.242	83.827	83.497
GW7	E274784, N232999	86.5 (approx)	Not drilled until Jun 03	Not drilled until Jun 03	82.73	-

It is not possible to accurately tell the natural piezometric level of the bog prior to the drainage and harvesting of peat. Historical data for raised bogs suggests that the water level fluctuation in raised bogs varies by no more than 30cm, which is considerably less than fluctuations that would occur in mineral soil/subsoil and exposed bedrock environments.

The shallow subsoil piezometric levels and the deep bedrock piezometric levels differ across the site. The shallow piezometric levels are considered to be heavily influenced by the artificial drains traversing the site. These drains are excavated to the level of the mineral subsoil across the site. Shallow flows are considered to discharge to the drains, with very short flowpaths. The fluctuation in water levels varies from 0.3m to 0.5m in the shallow subsoil environment.

The bedrock piezometry is not considered to be as heavily influenced by the artificial drainage of the site. The piezometric levels, which vary from 85.852m OD (GW2D) to 83.59m OD (GW3D) on the 03rd March 2003, suggest that the groundwater flow is

from an east and northerly direction towards the west of the applicant's property. The summer piezometric levels vary from 85.522m OD (GW2D) to 83.245m OD (GW2D), which is similar to the gradients observed during the winter surveys. The flow direction is consistent with the surface water drainage from the site, which is towards the west/southwest and the Cushaling River and the Abbeylough River. The Cushaling emerges as a surface flow within the property and continues to flow and gain groundwater baseflow further to the west of the property.

The piezometric head measurement for GW7 suggests that the groundwater flow pattern is different in this area. Although surface water collected in the drainage ditches is culverted to the south in this area, the groundwater flow appears to be to the north, towards the Fear English River, and ultimately to the River Boyne. Based on existing topographic maps for the area and site investigation data, the watershed between the River Boyne and the River Barrow occurs in the lateral distance between boreholes GW7 and GW1D, which are separated by approximately 725m. No activities associated with the landfill will occur within the catchment of the River Boyne.

Groundwater Gradients

The vertical groundwater gradients across the site can therefore be assessed by calculating the vertical gradients between the observed Static Water Levels (SWLs) at these locations with borehole pairs.

Monitoring of the groundwater levels from these boreholes was undertaken on a number of occasions during the environmental baseline assessment. Based on the groundwater monitoring surveys it is possible to determine the hydraulic gradients at these locations on a number of dates. The mean hydraulic gradients for these locations are presented in Table 2.4.9, with positive values representing an upward gradient (indicating a potential for flow from the bedrock to the overburden) and negative values representing a downward gradient (indicating potential for flow from the overburden to the bedrock).

The calculated hydraulic gradients are quite low with the recorded gradients on the site ranging in magnitude from 0.129 to 1.154. The maximum upward gradient recorded is 1.129 and the maximum downward gradient recorded is -1.154. The presence of vertical gradients demonstrates that the overburden is low permeability and that the flow of water from the surface to the bedrock or from the bedrock to the surface is impeded (but not wholly prevented) by the low permeability till. Given that the gradients are low however, it would not be accurate to describe the bedrock aquifer as confined. Modest upward gradients are observed at the locations of: GW1D & GW1S (confirmed by GW6 and GW1S), GW3D & GW3S and GW4D & GW4S. However a term such as "semi-confined" or "leaky" would best describe the hydrogeology of the site. SWLs, calculation sheets and graphs for each of the

borehole pairs are presented in Appendix 2.4.13.

Table 2.4.9: Vertical Groundwater Gradients

Borehole Pair	Date				Mean
	16/01/2003	03/02/2003	18/07/2003	10/01/2007	
GW1D					
GW1S	0.129	0.139	1.129	0.364	0.44
GW2D					
GW2S	-0.463	-0.468	-0.438	-	-0.455
GW3D					
GW3S	0.507	0.522	0.467	0.517	0.503
GW4D					
GW4S	0.519	0.579	0.499	-	0.519
GW5D					
GW5S	-0.259	-0.214	-1.154	-0.431	-0.515
GW6	0.055	0.43	0.37	-	0.285

2.4.10 Groundwater Chemistry

As part of the first sampling round, 11 No groundwater samples were obtained from the monitoring borehole network on the 4th February 2003 to establish background groundwater quality. Monthly and annual monitoring has been carried out subsequently and results are presented Tables 2.4.10, Table 2.4.11 and Table 2.4.12. A brief interpretation of the chemistry is provided below. The locations of where the samples were taken are shown on Drawing 3369-2407.

Prior to the water sampling survey, each borehole was purged to expel any groundwater standing within the standpipe and gravel pack. The purging of the standpipes was undertaken for over 90 minutes using an air compressor and a ½-inch air-line. The air-line was lowered gradually to the base of each borehole to expel the standing groundwater and to develop and clean the gravel pack surrounding the screened section of the borehole. The samples were obtained from the borehole standpipe immediately following the purging using a disposable bailer.

General Chemistry

The groundwater signature is calcium bicarbonate type. The pH of the groundwater varies within the range of 6.93 to 8.08. There does not appear to be any difference in the pH between the shallow boreholes (range 7.6 to 8.0) and the deeper boreholes (range 7.7 to 8.0).

Electrical Conductivity recorded at all monitoring locations were within the EPA Interim Guideline Value of 1000 µS/cm for groundwater with the exception of GW1S in March

2007 (1014 $\mu\text{S}/\text{cm}$). The electrical conductivity of the deeper groundwater (range 286 to 776 $\mu\text{S}/\text{cm}$) is lower than the shallow groundwater (range 577 to 1014 $\mu\text{S}/\text{cm}$).

The impact of the water infiltrating through the peat to the boreholes is considered to have impacted both the pH and the conductivity.

The reported Total Alkalinity is greater than the Total Hardness in GW1D, GW1S, GW2D, GW2S, GW4S, GW5D, GW5S and GW6PW. These are an indication of natural ion-exchange and confirm the semi-confined nature of the groundwater.

The dissolved oxygen concentration is considered low, but the deeper groundwater is more depleted than the shallow groundwater. This suggests that the oxygen saturation is depleted as the water percolates to the bedrock. The COD varies within the range of 87-178mg/l O_2 . There does not appear to be any discernable trends in the concentration, however the chemical oxygen demand appears to be higher in the shallow groundwater.

The total solids concentration is high for all samples, however the suspended solids concentration appears to be the dominant factor. This is not unexpected as the wells are only periodically pumped and the sediment content would take a long time to clear.

Ammonia

Ammonia concentrations are significantly elevated above normal background levels within all of the boreholes (deep and shallow), ranging from 0.4 mg/l as N (GW2S) to 8.1mg/l and 8.7mg/l as N in GW-1S, and GW-1D respectively. See Table 2.4.12.

The reduction of free nitrogen occurs due to the reducing environment of the peat, where there is a deficiency of available oxygen. The fact is borne out by the generally low concentration of Nitrite and Nitrate. The Drehid Waste Management Facility is located within a cut-away peat land. Groundwater beneath peatlands has been found to be naturally high in nitrogen and, due to the nature of the peatlands (reducing conditions) the nitrogen is present in the reduced form (ammonia). The ammonia concentrations remain elevated as it is not oxidised to nitrite or nitrate. The nitrate concentrations are low in all of the boreholes, similar to previous results, with none detected above the limit of detection in the deeper boreholes (<0.05 mg/l as N), and nitrate only detected in GW2S within the shallow boreholes at a level of 0.21 mg/l as N. This concentration is significantly lower than that detected in the baseline monitoring (5.8 mg/l as N) at this borehole.

Chloride

Concentrations detected on 11th August 2006 (12.5 – 16.6 mg/l) are generally lower than the concentrations recorded on the 4th February 2003 (21 – 68 mg/l) with concentrations

significantly lower in GW7 (68 to 14.1 mg/l). The concentrations appear to be slightly higher in the shallow boreholes (14.4 – 16.6 mg/l) compared to the deeper boreholes (12.5 – 14.4 mg/l). Monthly monitoring in 2007 indicates chloride concentrations are typically less than 15 mg/l.

Sulphates

The sulphate concentration varies significantly between monitoring points and between monitoring events. The recorded concentrations from 2006 are low across the site with no concentrations detected in the deeper boreholes and the highest concentration recorded at 14.9mg/l in GW-2S. These concentrations show a significant reduction from those recorded in 2003 when levels ranged from <3 mg/l to 59 mg/l in GW1D.

Fluoride

The concentration of fluoride is below the detection limit of the laboratory.

Phosphorous & Phosphates

The levels of Total P recorded on 11th August 2006 were consistently low across the site showing only minor fluctuations between boreholes. With the exception of GW1D (0.57 mg/l), results were generally lower in the deeper boreholes (<0.05 to 0.14 mg/l), in comparison to the shallower boreholes (0.31 to 0.57 mg/l). Total Phosphorous was not analysed for in the 2003 monitoring event. Phosphates were not detected above the limit of detection at any of the sampling locations during the 2003 monitoring event. This is a reduction when compared to the 2006 monitoring event where levels ranged from 0.2 to 1.2 mg/l P04.

Cations

The concentrations of sodium, potassium and magnesium vary significantly and there do not appear to be any discernable trends, and the high concentrations are likely to be naturally occurring.

Concentrations of potassium, magnesium, calcium and sodium are comparable between monitoring events with concentrations varying greatly between the boreholes over the site and showing no discernible trend between the shallow and deep boreholes. The concentration of calcium are within normal ranges for groundwater within carbonate based subsoil and bedrock.

Calcium concentrations in the shallow boreholes exceeded the IGV in two of the monitoring locations (namely GW2S (202 mg/l) and GW3S (203 mg/l) in the 2006 monitoring event. Both these concentrations show an increase from 2003. An increase was also noted in GW4S (108 to 156 mg/l) while concentrations remain constant in GW1S. There were no exceedances of the IGV's in concentrations of potassium, magnesium, and sodium. Potassium concentrations are low, ranging from 0.8 mg/l to 4.2

mg/l. Magnesium concentrations recorded for 2003 and 2006 are similar, while reductions were noted in GW1S (44 to 7.4 mg/l) and GW2S (34 to 23 mg/l). Sodium concentrations (range 9.9 to 40 mg/l).

Calcium concentrations in the deeper boreholes there were no exceedances of the IGV's for any of the cations. Calcium levels generally remain similar to previous results with the exception of GW6 where an increase was noted (43.5 to 112 mg/l). Levels of potassium generally showed a decrease from previous levels (average 2 mg/l (2003) to 1.5 mg/l (2006)) with the exception of GW7 (1 to 2.9 mg/l) which showed a slight increase.

Metals

The concentration of trace metals are generally low for all boreholes however some isolated spikes are noted in certain boreholes. The occurrence of elevated concentration of trace metals in the groundwater is considered to result from the mobilisation of metals in the groundwater in a reducing environment. The concentration of manganese seems to be endemic to groundwater in this area.

There were no concentrations of aluminium, beryllium, chromium, cadmium, copper, tin, antimony, silver, or selenium detected in any of the groundwater monitoring boreholes during 2006. This is similar to the 2003 monitoring event with the exception of trace concentrations of copper (29 µg/l) and selenium (9 µg/l) detected GW7, and copper in GW1S (7 µg/l). Only trace concentrations of cobalt were detected in GW1D (8 µg/l) and GW6 (7 µg/l). Zinc, mercury and boron concentrations are generally low.

Elevated concentrations of arsenic were detected in 2006 in GW1S (25 µg/l), GW1D (142 µg/l), GW3D (24 µg/l), GW4D (15 µg/l) and GW6 (27 µg/l). These concentrations have all increased from the 2003 monitoring event and lie above the IGV level of 10 µg/l. All remaining boreholes lie between the IGV ranging between 3 and 8 µg/l. In the 2003 monitoring event elevated concentrations of arsenic were detected in GW1D (19 µg/l), GW3D (22 µg/l), and GW6 (22 µg/l). The source of the arsenic is unknown however it is noted that "*concentrations in groundwater in some areas are sometimes elevated as a result of erosion from natural sources*" (EPA 2001; Parameter of Water Quality). A literature review reveals several studies, which attribute arsenic concentrations to reducing conditions associated with peat deposits. Waste has not been deposited at the facility at the time of sampling and as such these results represent the natural geochemistry beneath the peatland.

Barium concentrations vary greatly over the site, however are generally higher within the shallow boreholes. Concentrations from 11th August 2006 recorded in GW1S (343 µg/l), GW4S (521 µg/l), GW1D (327 µg/l) and GW6 (123 µg/l) all lie above the IGV of 100 µg/l. These concentrations are similar to that detected in the 2003 monitoring event

where concentrations ranged from 60 to 270 $\mu\text{g/l}$ in the deeper boreholes and from 130 to 520 $\mu\text{g/l}$ in the shallow boreholes and (as with arsenic concentration), are believed to be representative of the natural geochemistry beneath the peatlands.

Elevated concentrations of nickel were detected in GW1S (27 $\mu\text{g/l}$), GW2S (30 $\mu\text{g/l}$), GW1D (27 $\mu\text{g/l}$) in 2006. These results show an increase from 2003 where concentrations of 11 $\mu\text{g/l}$, <10 $\mu\text{g/l}$ and <10 $\mu\text{g/l}$ were recorded. The remaining boreholes record concentrations below 20 $\mu\text{g/l}$.

VOC's, SVOC's and Pesticides

There were no concentrations of VOC's, SVOC's or pesticides detected in the 2006 monitoring round. In the 2003 monitoring round diesel range organics and mineral oil were detected. The interpretation of the compounds detected indicates that they are related to lubricant oil used in the drilling of the boreholes. Polycyclic aromatic hydrocarbons were also recorded in GW2S and GW6, which are also related to the lubricant oil used in the drilling. The presence of microbial organisms in the groundwater is an external factor related to the drilling. The boreholes were not disinfected prior to sampling.

The chemistry of the deep groundwater encountered in GW7 is significantly different to the other samples obtained within the site. The water has a low level of mineralisation, which is often less than 50% of the average of the other samples. The concentration of calcium, sodium, potassium, chloride and bicarbonate are low. An explanation of the lower than expected level of dissolved minerals is to suggest a flow system through weathered rock from which all the readily soluble minerals have been leached. The concentration of iron and manganese is elevated with respect to the low mineralisation of other parameters; however this could be natural to the groundwater at depth. The water appears to be older than the shallower groundwater and occurs in an environment with very low free oxygen.

Coliforms

There were no concentrations of coliforms (total or faecal) detected in the groundwater monitoring boreholes during the 2006 monitoring event. These concentrations show a significant reduction from the previous baseline monitoring event where concentrations ranged from 28 to 34,480 no. 100 ml total coliforms. This may be as result of the groundwater sampling procedure.

Table 2.4.10: Groundwater Chemistry from Samples obtained on 04/02/2003

Parameter	Units	M.A.C.	Detection Limit	GW 1D	GW 1S	GW 2D	GW 2S	GW 3D	GW 3S	GW 4D	GW 4S	GW 5D	GW 5S
pH			0.01	7.51	7.17	7.46	6.93	7.66	7.16	7.75	7.55	7.56	7.53
Electrical conductivity EC	m S/cm	6.5 < pH < 9.5	0.014	0.835	1.043	0.755	0.983	0.319	0.936	0.493	0.722	0.9	0.71
Dissolved oxygen (DO)	mg/l	2500	0.1	4.9	6.1	7.6	6.8	5.4	6.6	8.8	7.5	7.9	8.4
Redox potential	mV	n/a		121	14	120	124	102	126	110	119	128	128
COD	mg/l	n/a	10	178	176	166	193	87	167	95	133	107	114
Total solids	mg/l	n/a	1	18579	34946	8693	48647	3152	16635	1557	22710	80762	14169
Total suspended solids	mg/l	n/a	10	16476	31904	10616	43392	2916	15050	1270	18930	73980	11390
Total hardness (as CaCO ₃)	mg/l	60 MRC	5	320	520	266	478	300	312	366	258	300	220
Total alkalinity (as CaCO ₃)	mg/l	30 MRC	1	380	570	460	520	210	240	290	380	370	350
Ammonia as NH ₄ -N	mg/l	0.3	0.2	8	1.9	2	2.1	0.5	6.6	0.8	6.1	3.2	7.6
Nitrate NO ₃	mg/l	50	0.3	0.3	0.3	2.6	25.6	0.05	0.3	<0.3	<0.3	<0.3	<0.3
Nitrite NO ₂	mg/l	0.5	0.05	0.07	0.18	0.39	0.68	0.18	0.1	<0.05	0.11	<0.05	0.3
TOTN	mg/l	n/a	0.3	<0.3	<0.3	0.7	6.1	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride Cl	mg/l	250	1	31	21	44	37	20	39	36	31	37	41
Fluoride F	mg/l	1	0.01	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sulphate SO ₄	mg/l	250	3	59	31	14	45	10	4	4	13	<3	55
ortho-Phosphate PO ₄	mg/l	5	0.03	0.2	0.3	0.2	0.2	0.2	0.2	0.3	1.2	0.2	2.6
Potassium K	mg/l	12	0.2	3.2	0.8	1.8	4.1	1.3	2.9	1.4	2.4	3	2.1
Sodium Na	mg/l	200	0.2	39.5	9.2	32	16.8	12.4	17	15.5	40	64	12.2
Calcium Ca	mg/l	200	0.05	124.9	156	128	152	48.51	161.7	81.74	108.5	117.8	119.1
Magnesium Mg	mg/l	50	0.05	11.11	44.06	11.11	34.72	7.56	11.33	13.68	17.14	11.81	9.64
Aluminium Al	mg/l	0.2	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc Zn	mg/l	1	0.005	0.007	0.011	0.005	0.008	0.017	0.006	<0.005	<0.005	0.006	0.006
Iron Fe	mg/l	0.2	0.001	0.008	0.023	0.005	0.02	0.003	0.014	0.002	0.002	0.003	0.004
Manganese Mn	mg/l	0.05	0.001	0.006	0.022	0.084	0.409	0.082	0.151	0.006	0.142	0.383	0.26
Barium	mg/l	0.5	0.05	0.12	0.1	0.27	0.18	0.09	0.52	0.17	0.13	0.1	0.4
Boron	mg/l	1	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead Pb	µg/l	10	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Copper	µg/l	2000	5	<5	7	<5	<5	<5	<5	<5	<5	<5	<5
Mercury Hg	µg/l	1	0.05	0.12	0.11	<0.05	<0.05	0.1	0.05	0.23	0.11	0.08	0.27
Nickel Ni	µg/l	20	10	<10	11	<10	<10	14	14	<10	<10	18	13
Arsenic	µg/l	10	5	19	<5	<5	<5	22	6	8	<5	<5	<5
Cyanide CN	µg/l	50	50	60	<50	<50	<50	<50	<50	<50	<50	170	<50
Cadmium Cd	µg/l	5	0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium Cr	µg/l	50	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Silver Ag	µg/l	10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium	µg/l	10	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Phenols (HPLC)	mg/l	0.0005	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Diesel Range Organics (DRO)	µg/l	10	10	<10	<10	<10	3303	<10	4441	<10	1649	5533	2731
Mineral Oil	µg/l	10	10	<10	<10	<10	1486	<10	1776	<10	<10	1383	956
Petrol Range Organics C4-C10	µg/l	10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Petrol Range Organics C10+	µg/l	10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BTEX (MTBE) Compounds	µg/l	10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PAH (16 EPA Compounds)	ng/l	100	10	<10	<10	<10	1332	<10	<10	<10	<10	<10	<10
Semi-Volatile Organic Compounds	µg/l		1	<1	<1	<1	<1	<1	<1	<1	7	<1	<1
Volatile Organic Compounds	µg/l		1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Coliforms	c.f.u./100ml	0	1	1450	2880	4130	34480	1480	81640	28	310	4590	1460
Faecal Coliforms	c.f.u./100ml	0	1	6	2	<1	<1	<1	<1	<1	<1	<1	1
Ionic Balance	%			4.22%	14.14%	5.10%	9.19%	0.19	37.97	8.43	15.97	26.72	2.21

Legend

M.A.C = Maximum Admissible Concentration under S.I. No. 439, 2000 (European Communities Drinking Water Regulations).

< = Less than

Table 2.4.11: Results of Chemical Analysis of Groundwater (11/7/2006)

Parameter	Component	Units	M.A.C	Detection	GW-1S	GW-1D	GW-2S	GW-3S	GW-3D	GW-4S	GW-4D	GW-6	GW-7
pH	-	pH units	≥ 6.5 & ≤ 9.5	-	7.7	7.8	8	7.6	8	7.7	7.8	7.9	7.7
Conductivity @ 25°C	-	µS/cm	1000	-	722	742	820	577	313	782	489	615	286
Ammonia (NH3-N)	-	mg/l	0.3	<0.02	8.1	8.7	2.7	5.6	0.41	7.2	0.74	7	1.19
Total Phosphorous	-	mg/l	-	<0.05	0.57	0.57	0.31	0.56	0.14	0.46	0.1	<0.05	0.08
Anions	Chloride	mg/l	250	<0.5	14.4	14.4	15.6	16.6	12.5	15.1	13	14.1	14.1
	N03-N	mg/l	11.3	<0.05	<0.05	<0.05	0.21	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	P04-P	mg/l	-	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16
	SO4	mg/l	250	<0.5	<0.5	<0.5	14.9	1.4	<0.5	1.1	<0.5	<0.5	<0.5
Boron (Dissolved)	-	µg/l	1000	<2	3	18	28	25	17	23	22	18	13
Comb Pesticide Suite	All Components	µg/l	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	-	µg/l	1	<1	<1	<1	<1	<1	<1	<1	<1	15	<1
Metals (Dissolved)	Arsenic	µg/l	10	<2	25	142	3	8	24	5	15	27	5
	Silver	µg/l	10	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Aluminium	µg/l	200	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Beryllium	µg/l	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Barium	µg/l	500	<2	343	327	521	471	53	206	65	123	29
	Chromium	µg/l	50	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Cadmium	µg/l	5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Cobalt	µg/l	-	<2	3	8	5	<2	<2	<2	<2	7	<2
	Copper	µg/l	2000	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Manganese	µg/l	50	<2	118	72	307	221	88	330	91	59	213
	Tin	µg/l	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Nickel	µg/l	20	<2	27	27	30	10	4	5	4	16	<2
	Lead	µg/l	25	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Antimony	µg/l	-	<2	2	<2	<2	<2	<2	<2	<2	<2	<2
	Selenium	µg/l	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Zinc	µg/l	100	<2	<2	3	34	81	2	<2	2	10	9
Metals Scan	Calcium	mg/l	200	<0.1	151	151	202	203	50	156	78	112	38
	Iron	mg/l	0.2	<0.1	0.1	0.1	0.3	0.3	<0.1	0.1	0.1	0.1	<0.1
	Potassium	mg/l	12	<0.1	1.3	1.4	1.1	1.6	0.6	1.9	1.1	1.7	2.9
	Magnesium	mg/l	50	<0.1	7.4	7.6	23	12	7.8	16	<2	9	7.1
	Sodium	mg/l	200	<0.1	9.9	13	12	14	9.1	12	<2	17	13
SVOC's	All Components	µg/l	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
VOC's USEPA 524.2 µg/l	All Components	µg/l	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
VOC's by GC-FID	All Components	mg/l	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Coliforms	-	MPN/100mls	0/100mls	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
e.Coli	-	MPN/100mls	0/100mls	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

M.A.C = Maximum Admissible Concentration under S.I. No. 278, 2007 (European Communities Drinking Water Regulations).

Table 2.4.12: Results of Chemical Analysis of Groundwater for monthly monitoring of ammonia, chloride and conductivity

Conductivity ($\mu\text{S/cm}$) 2007													
	Aug-06	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
GW-1S	722	836	934	1017	1029	768	768	1018	912	860	808	833	823
GW-1D	742	726	750	328	1132	802	719	718	725	722	741	735	735
GW-2S	820	905	887	942	1050	897	897	202	946	900	994	896	1027
GW-2D													
GW-3S	577	774	787	851	975	832	821	220	840	820	829	845	855
GW-3D	313	322	327	350	375								
GW-4S	782						486						
GW-4D	489						759						
GW-5S		686	792	863	900	766	753	163	786	779	756	743	791
GW-5D		776	683	703	526	618	608	138	873	785	766	733	736
GW-6	615	615	628	675	966	602	618						
Ammonia (mg/l) 2007													
	Aug-06	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
GW-1S	8.1	0.87	2.25	2.3	3.36	0.49	6.2	0.75	4.1	5.2	5.6	6.3	6.2
GW-1D	8.7	6.4	7.9	5.1	8.4	0.42	8.1	8	7.86	8.3	8.2	8.6	8.4
GW-2S	2.7	0.5	0.4	0.63	0.97	2.03	1.58	0.89	0.9	2.2	1.93	2.54	1.23
GW-2D													
GW-3S	5.6	3.09	4.53	5.3	5.4	5.3	5.1	2.09	4.37	4.88	5.1	5.4	3.04
GW-3D	0.41	0.42	0.41	0.43	0.37								
GW-4S	7.2						8						
GW-4D	0.74						0.58						
GW-5S		7.2	7.5	6.9	7.4	6.9	6.4	7	6.91	7.3	7.3	6.9	7.4
GW-5D		2.49	1.88	2.14	2.62	2.25	2.38	3.61	2.93	2.21	5.9	4.67	4.67
GW-6	7	6.6	7.2	4.04	7.2	0.54	7						
Chloride (mg/l) 2007													
	Aug-06	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
GW-1S	14.4	13	13	12	12	13	13	7	17	13	13	14	14
GW-1D	14.4	14	14	13	12	13	13	12	15	19	13	19	14
GW-2S	15.6	15	23	15	14	15	14	12	17	15	15	15	12
GW-2D													
GW-3S	16.6	21	16	16	15	17	15	17	17	17	18	15	17
GW-3D	12.5	11	11	11	11								
GW-4S	15.1						14						
GW-4D	13						12						
GW-5S		10	11	10	9.9	11	10	9.7	11	11	13	11	11
GW-5D		8.9	11	3.59	10	13	11	9.4	11	9.4	14	12	9.5
GW-6	14.1	13	13	13	12	14	13						