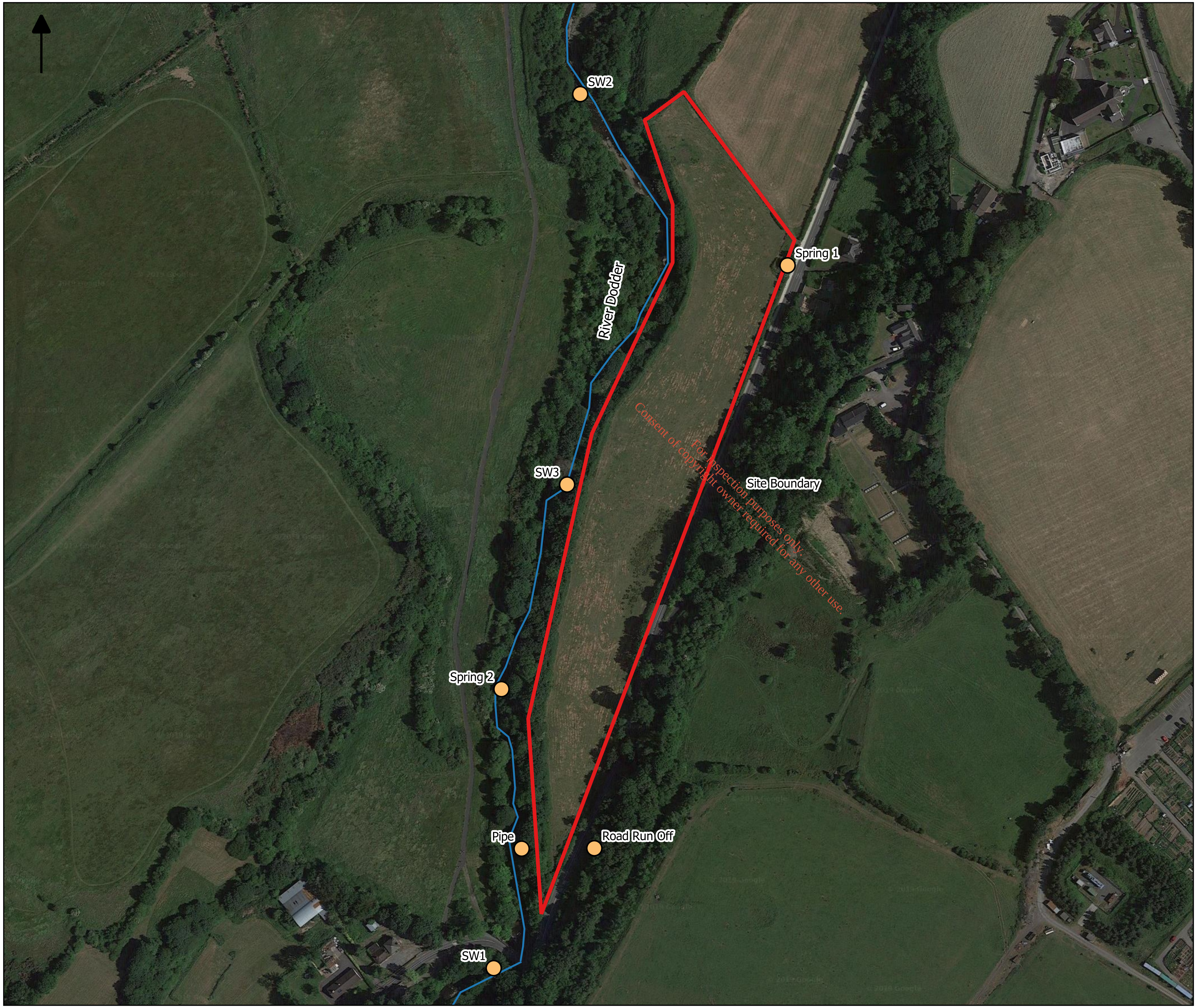
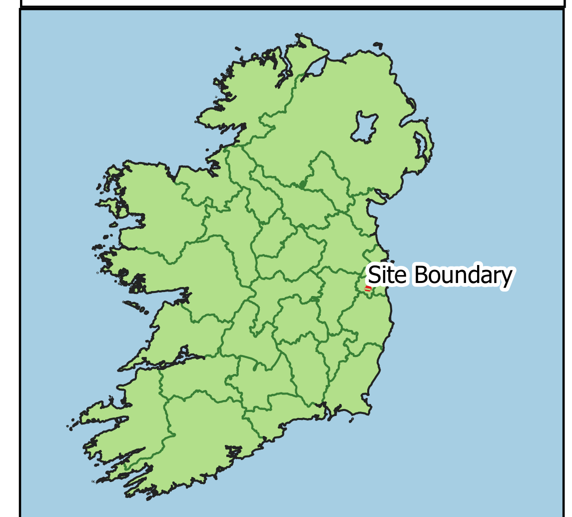


Legend

- RPS_Sample Leachate Location
- River Dodder
- Site Bondary
- Sea_Background
- County Boundary_NoDetails

Google Map

Map shows the locations for leachate sampling



Title: **Figure 3.3 SW Sampling Locations**

Project: Bohernabreena Landfill

Client: South Dublin County Council

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Issue Details

Drawn by: Scott graydon	Project No: MDR1489
Checked by: xxx	File Ref.: MDR1489QGIS0001D01
Approved by: xxx	
Scale: 1:4,000@A3	Drawing No.: QGIS0001
Date: 24/06/2019	

3.7.6 Soil Geotechnical Sampling

During leachate well drilling 5 No. disturbed soil samples; LW01 (5.0 mbgl), LW02 (4.0 mbgl), LW03 (1.0 mbgl), LW04 (5.0 mbgl) and LW05 (0.1 mbgl) were collected. Samples were taken to test for soil type, particle size, permeability and strength, to assess for ground vulnerability and for any horizontal or vertical pathway. Undisturbed samples (U100 samples) from LW01 (0.2 mbgl) and LW03 (0.3 mbgl) were taken to assess the permeability of any capping layer. Samples were taken by GII and sent to the National Materials Testing Laboratory Ltd., Tullow Industrial Estate, Bunclody Road, Tullow, Co. Carlow. The locations of the samples are show in **Figure 3.2** and the full technical report is presented in **Appendix I**.

3.7.7 Gas Monitoring

Landfill gas monitoring was undertaken on 5 No. occasions, on 16th, 19th October 2018 and 5th, 8th, 14th November 2018. A handheld gas analyser (GFM436) was utilised to monitor gas concentrations and flow rate. The gas analyser was calibrated by the manufacturer prior to use.

3.8 INVESTIGATION LIMITATIONS

- The thickness of waste in some locations was not identified as it extended below the maximum reach of the excavator (4m).
- Insufficient sample volumes could not be recovered from all installed leachate monitoring boreholes.
- Only 1 No. groundwater well was installed on site due to the presence of waste across the site.
- The duration of gas monitoring was limited due to restrictions in the project timeframe. The geophysical survey was completed post intrusive works due to time constraints.

3.9 TIER II EXPLORATORY SITE INVESTIGATION RESULTS

3.9.1 Geophysical Survey

The elevated EM conductivity readings show the waste to be present in approximately 2.16 Ha of the survey area. This zone coincides with the waste recorded on the borehole and trial pit logs. The average thickness of the waste from the combined geophysical and borehole/trial pit data is approximately 5.0m. The quantity of waste calculated using the extents and thicknesses was calculated as 151,200 tonnes (21,600m^2 area x 5m average depth = 108,000m^3 x 1.4t/m^3 = 151,200 tonnes). The waste was characterised as:

- Topsoil over waste (predominately organic) with clay – lower resistivity; and
- Topsoil over mixed organic/inert waste with clay – higher resistivity.

All of the ERT profiles indicate between 4m and 6m of leachate beneath the waste body extending into the underlying sandy gravelly clay and gravel. The average S-wave velocity for the waste from M4 is 120m/s indicating that it is soft to very soft. The underlying sandy gravelly clay material is firm-stiff. The bedrock resistivity range of 240-1300 Ohm-m indicate a siltstone/greywacke type bedrock rather than a shale. Combined waste and underlying soil thicknesses (depth to bedrock) ranges from 10m to 12m.

The results of the geophysical survey are presented in **Figures 3.4 to 3.6**.

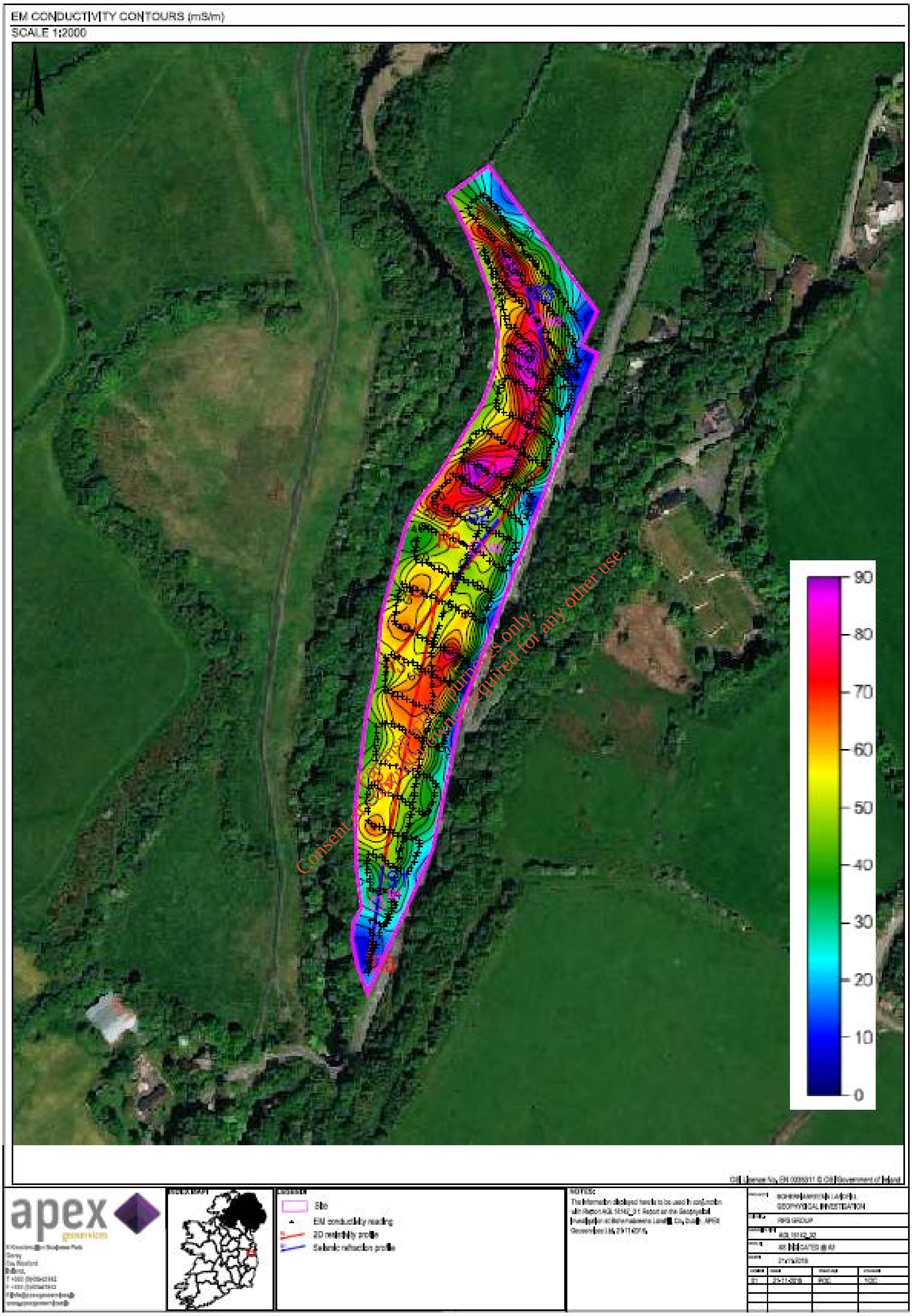

Figure 3.4 Geophysical Survey – Map 1

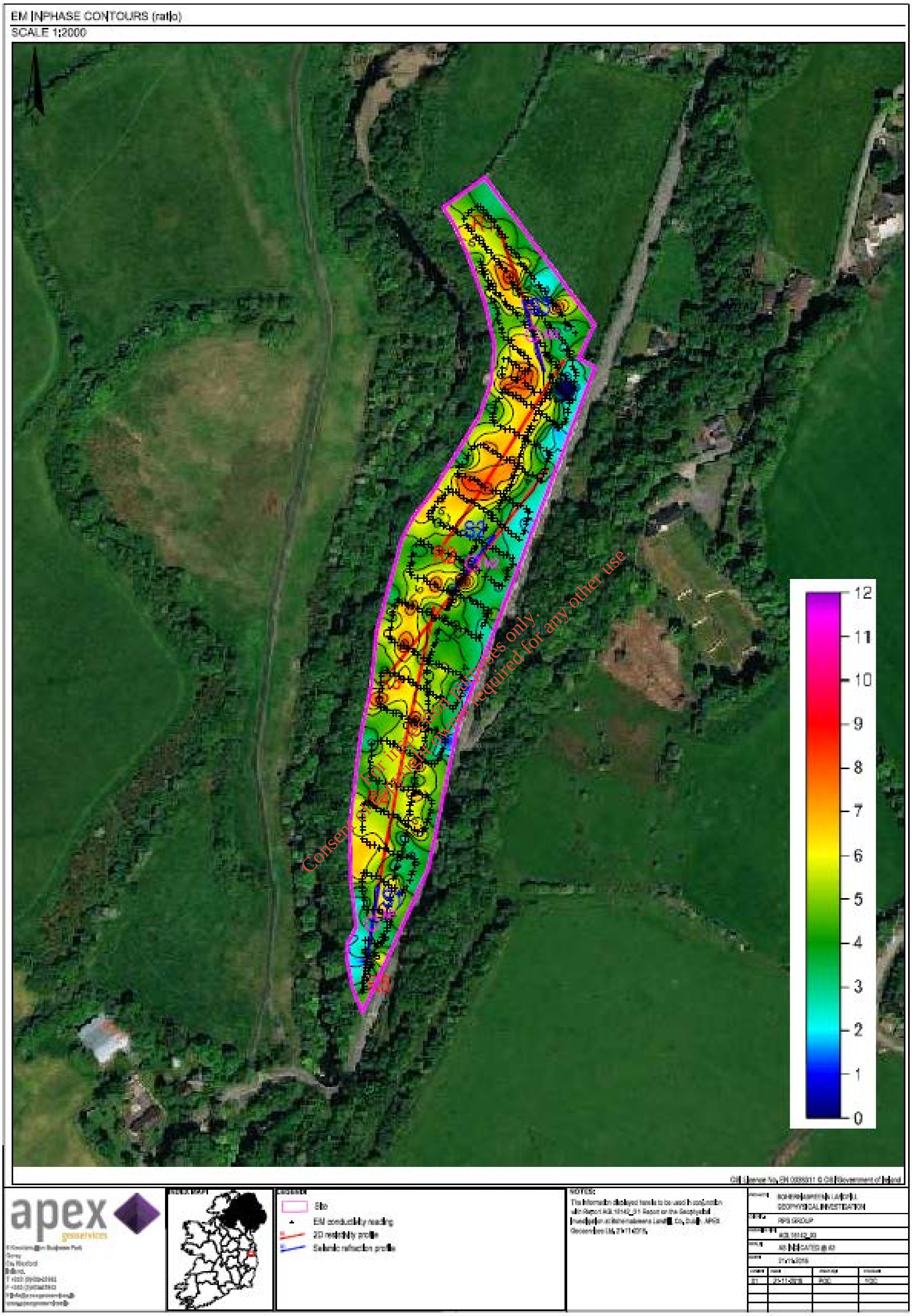

Figure 3.5 Geophysical Survey – Map 2

Figure 3.6 Geophysical Survey – Map 3

3.9.2 Topographical Survey

The site is located within a river valley with the Dodder terraces either side of the river valley. The site rises gently from 111mAOD at the north of the site to 118mAOD at the southern boundary. To the eastern boundary there is a steep slope to the River Dodder level (100mAOD). The topographical survey is included in **Appendix E.**

3.10 OBSERVED GROUND CONDITIONS

3.10.1 Ground Observations

There were no visual or olfactory observations of contamination across the site. The site was covered in grass which was used for pastural grazing. In areas across the site there were patches of marshy uneven ground. The site was surrounded by overgrown hedgerows. On the eastern boundary there was a steep slope to the River Dodder.

During a walkover along the River Dodder, tufa deposits were noted along both sides of the river banks, adjacent and downstream from the site boundary (**Plates 3.1**). General rubbish (plastic bottles, litter) was noted along the river.

Plate 3.1 Tufa deposits along the River Dodder

3.10.2 Trial Pits

Trial pit observations detailing the subsurface conditions include the presence of any waste, superficial deposits are presented in **Table 3.3** with a series of photos in **Plates 3.2 and 3.3.** Detailed trial pit logs are presented in **Appendix F**. Grass and an overlying layer of topsoil (sandy silty clay) was encountered across the site. The depth of the topsoil varied from 0.2-1.0 mbgl. Underlying the topsoil waste was encountered at all trial pit locations across the site. Bedrock was not encountered at any location.

Plate 3.2 Trial Pit excavation

Plate 3.3 Trial Pit material extracted

Table 3.3 Trial Pit Description Summary

Trial Pit ID	Total Depth (mbgl)	Depth of Waste (mbgl)	Description of Waste	Notes
TP01	3.2	0.7 – 3.2	Waste composed of decomposed organic matter, clay, plastic, partially degraded paper	Strong organic odour
TP02	3.0	1.0 – 3.0	Black clay mixed with plastic	Strong organic odour
TP04	3.6	0.8 – 3.6	-	Slight hydrocarbon, bitumen odour
TP05	2.6	0.2 – 2.6	Grey clay, municipal waste, plastic bags	-
TP06	3.8	0.8 – 3.8	Grey/black, mixed municipal waste	Depth of waste could not be determined
TP07	4.5	0.8 – 4.5	-	-
TP08	4.4	0.3 – 4.4	-	-

3.10.3 Waste Volumes and Composition

Waste is present across most of the site and was encountered from depths of 0.3 – 4.5 mbgl, however the depth of the waste in TP06 could not be ascertained. The waste was distributed to the site boundary, with the exception of the southern boundary. The waste generally consisted of black clays with varying amounts of municipal waste which generally included plastics and brick. A strong organic odour was noted. During trial pitting paper waste was identified which dated to 1974.

Based on the site investigation logs and the geophysical survey the volumes of waste calculated using the extents and thicknesses was calculated at a quantity of 151,200 tonnes.

3.11 SOIL GEOTECHNICAL RESULTS

Soil laboratory testing on 5 No. disturbed samples indicated that the majority of samples mainly consisted of brown slightly sandy gravelly silty clay. A summary of the results is presented in **Table 3.4**. A summary of the results of the U100 samples is presented in **Table 3.5**. The full geotechnical results are presented in **Appendix I**.

Table 3.4 Soil Geotechnical Results Summary

Location		LW01 (5.0 mbgl)	LW02 (4.0 mbgl)	LW03 (1.0 mbgl)	LW04 (5.9 mbgl)	LW05 (0.1 mbgl)
Soil Type		Sandy very silty GRAVEL with high cobble content	Silty very sandy GRAVEL	Very silty very sandy GRAVEL with high cobble content	Silty sandy GRAVEL with medium cobble content	Slightly sandy slightly gravelly SILT with medium cobble content
Particle Size	Cobbles	27.0	0.0	25.0	17.0	16.0
	Gravel	42.0	58.0	43.0	56.0	29.0
	Sand	14.0	24.0	14.0	14.0	22.0
	Silt	13.0	12.0	10.0	9.0	20.0
	Clay	5.0	7.0	7.0	4.0	13.0
Moisture (%)		78	14	54	33	26

*Strength tests were completed during SPT during additional gas/leachate installations

Table 3.5 Soil Permeability Results

Location	Description	Mean Effective Stress (KPa)	Hydraulic Gradient	Coefficient of Permeability (K_v) (m/s) @ 20°C
LW01 (0.2 mbgl)	Brown fine-course gravelly slightly sandy slightly silty stiff CLAY	125	145.71	9.28×10^{-11}
LW03 (0.3 mbgl)	Brown fine-course gravelly slightly sandy slightly silty stiff CLAY	125	145.71	1.07×10^{-10}

3.12 SOILS

3.12.1 Soil Human Health

Soil results to assess potential human health risk have been compared to guideline values within the following legislation and guidelines:

- The LQM/CIEH S4ULs for Human Health Risk Assessment (2nd Edition 2015) Copyright Land Quality Management Limited reproduced with permission Publication Number S4UL3680. All rights reserved;
- Contaminated Land: Applications in Real Environments (CL:AIRE), December 2009: The Soil Generic Assessment Criteria for Human Health Risk Assessment; and
- DEFRA and Environmental Agency (EA) Soil Guideline Values (SGVs).

Reported concentrations of soil results did not exceed any guideline values for human health. therefore, there is no risk from soil vapours to human health. Tabulated soil results are presented within **Appendix J**.

3.12.2 Soil Leachate Samples

Soil leachate results have been compared to guideline values within the following legislation and guidelines:

- European Communities Environmental Objectives (Groundwater) Regulations, 2010 (SI No. 9 of 2010); and
- The EPA interim report "Towards Setting Guideline Values for the Protection of Groundwater in Ireland" (2003).

3.12.3 Soil Leachate Results - Inorganics

Inorganic concentrations were all below the relevant groundwater guidelines with the exception of the following:

- Dissolved Arsenic which exceeded the guideline value of 7.5ug/l in samples TP1 (2.5mbgl) at 8.7µg/l and TP7 (4.5mbgl) at 9.0µg/l.
- Dissolved Iron which exceeded the guideline value of 0.2 mg/l in sample TP1 (2.5mbgl) at 2.794mg/l.
- Dissolved Manganese which exceeded the guideline value of 0.05mg/l in samples TP1 (2.5mbgl) at 151mg/l.
- Dissolved Nickel which exceeded the guideline value of 20µg/l in samples TP1 (2.5mbgl) at 30 ug/l.
- Dissolved Potassium which exceeded the guideline value of 5mg/l in samples TP1 (2.5mbgl) at 44.6mg/l, TP7 (4.5mbgl) at 13.5mg/l and TP8 (2.5mbgl) at 8.1mg/l.
- Ammoniacal Nitrogen as N which exceeded the guideline value of 0.175mg/l in samples TP1 (2.5mbgl) at 37.35mg/l and TP7 (4.5mbgl) at 23.21mg/l.
- Electrical Conductivity which exceeded the guideline value of 800-1875 µS/cm in samples TP7 (4.5mbgl) at 362 µS/cm and TP8 (2.5mbgl) at 685 µS/cm.

3.12.4 Soil Leachate Results - Organics

Reported organic concentrations (volatiles or semi-volatiles) were all below the relevant groundwater guidelines with the exception of;

- Benzo(a)pyrene which exceeded the guideline value of 0.0075µg/l in samples TP1 (2.5mbgl) at 0.188µg/l, TP7 (4.5mbgl) at 0.027µg/l and TP8(2.5mbgl) at 0.058µg/l.
- PAH 16 Total which exceeded the guideline value of 0.1µg/l in samples TP1 (2.5mbgl) at 5.023µg/l, TP7 (4.5mbgl) at 0.784µg/l and TP8(2.5mbgl) at 0.483µg/l.
- Di-n-butyl phthalate which exceeded the guideline value of 2µg/l in sample TP7 (4.5mbgl) at 5.7µg/l.

Tabulated soil leachate results are presented within **Appendix J**.

3.13 LEACHATE

3.13.1 Leachate Levels

Leachate levels were monitored in boreholes LW1 – LW6. However, in monitoring boreholes LW1, LW2, LW3, LW5 and LW6 the wells were dry. Results are presented in **Table 3.6**.

Table 3.6 Leachate Levels

Well ID	17/10/2018	08/11/2018	14/11/2018
LW1	-	-	-
LW2	-	-	-
LW3	-	-	-
LW4	110.62 mAOD	110.6mAOD	110.6mAOD
LW5	-	-	-
LW6	-	-	-

3.13.2 Leachate Parameters

Leachate results and parameters have been compared to guideline values within the following legislation and guidelines:

- European Communities Environmental Objectives (Groundwater) Regulations, 2010 (SI No. 9 of 2010) and (Amendment) Regulations 2015 (SI No. 366 of 2016);
- The EPA interim report "Towards Setting Guideline Values for the Protection of Groundwater in Ireland" (2003);

Tabulated leachate results are presented within **Appendix J**. Field measurements of temperature, electrical conductivity, dissolved oxygen, pH and redox for leachate samples were measured on site. The results are summarised in **Table 3.7**.

Table 3.7 Leachate Field Parameters

Well ID	Date	Temp (°C)	Electrical Conductivity (µS/cm)	Dissolved Oxygen RDO (mg/l)	pH	Redox (mV)
LW4	17/10/2018	11.80	516.4	3.09	6.74	-167.3
LW2	08/11/2018	11.40	-	1.18	6.63	1044.5
LW3	14/11/2018	12.30	486.0	-	6.21	-96.0

Location LW4 values were outside the Groundwater Regulations threshold value range for electrical conductivity with a range of 800-1875µS/cm when a value could be recorded. pH values were within the range for most of the samples with the exception of LW4 on 14/11/2018 that was outside the IGV range of 6.5-9.5 pH units. All locations were within the range of the temperature IGV (25°C).

3.13.3 Leachate Laboratory Results - Inorganics

Inorganic concentrations were all below the relevant groundwater guidelines with the exception in LW4 of the following:

- Iron which ranged from 11.38mg/l to 13.3mg/l and exceeded the guideline value of 0.2mg/l within LW4 samples on 17/10/2018, 09/11/2018 and 14/11/2018.
- Manganese which ranged from 3.440mg/l to 3.937mg/l and exceeded the guideline value of 0.05mg/l within LW4 samples on 17/10/2018, 09/11/2018 and 14/11/2018.
- Ammoniacal Nitrogen as N which ranged from 3.37mg/l to 4.33mg/l and exceeded the guideline values of 0.175mg/l within LW4 samples 17/10/2018, 09/11/2018 and 14/11/2018.

3.13.4 Leachate Laboratory Results – Microbial Indicators

- Total Coliforms values ranged from 4520MPN/100ml to 6550MPN/100ml and exceeded the guideline value of 0 MPN/100ml within LW4 samples 9/11/2018 and 14/11/2018, no result for 17/10/2018.
- Faecal Coliforms values ranged from 95cfu/100ml to 1400cfu/100ml and exceeded the guideline value of 0 cfu/100ml within LW4 samples 9/11/2018 and 14/11/2018, no result for 17/10/2018.
- E.coli values ranged from 3.1MPN/100ml to 77.1MPN/100ml and exceeded the guideline value of 0MPN/100ml within LW4 samples 9/11/2018 and 14/11/2018, no result for 17/10/2018.

3.13.5 Leachate Laboratory Results - Organics

Reported organic concentrations (volatiles or semi-volatiles) were all below laboratory detection limit with no exceedances of relevant groundwater guidelines. The only exception which exceeded the relevant groundwater guideline is benzene with a range of 5.4µg/l to 7.0µg/l, exceeding the guideline value of 0.75µg/l within all LW4 samples.

3.13.6 Leachate Laboratory Results - Pesticides

Reported pesticide concentrations were all below the laboratory detection limit. The average leachate quality for LW4 is compared in **Table 3.8** to the typical values for methanogenic leachate from large landfills with a relatively dry high waste input rate as presented in the EPA Landfill Manual (Table 7.2) EPA Landfill Manuals, Landfill Site Design 2000.

With the exception of manganese concentrations within LW4 (3.67mg/l) all leachate parameters were below the typical values for methanogenic leachate.

Table 3.8 Average Leachate values compared against typical Methanogenic Leachate

Parameter	Typical Methanogenic Leachate			Mean at LW4
	Min	Mean	Max	
pH-value	6.8	7.52	8.2	6.95
conductivity (µS/cm)	5,990	11,502	19,300	475.67
alkalinity	3,000	5,376	9,130	304.00
COD	622	2,307	8,000	24.67
BOD_5	97	374	1,770	15.33
TOC	184	733	2,270	0
ammoniacal-N	283	889	2,040	3.77
nitrate-N	0.2	0.86	2.1	-
nitrite-N	0.005	0.17	1.3	-
sulphate	2.5	67	322	4.27
phosphate	0.3	4.3	18.4	0
chloride	570	2,074	4,710	17.03
sodium	474	1,480	3,650	12.43
potassium	100	854	1,580	2.77
calcium	23	151	501	74.40
chromium	0.015	0.09	0.56	0.007
manganese	0.04	0.46	3.59	3.67
iron	1.6	27.4	160	12.43
nickel	0.015	0.17	0.6	0
copper	0.01	0.13	0.62	0
zinc	0.03	1.14	6.7	0.003
arsenic	0.0005	0.034	0.485	0.0024
cadmium	0.005	0.015	0.08	0
mercury	<0.00005	0.0002	0.0008	0
lead	0.02	0.2	1.9	0

* Grey shading indicates an exceedance

3.14 SURFACE WATER

Surface water results have been compared to guideline values within the following legislation and guidelines:

- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (SI No. 272 of 2009) and (Amendment) Regulations 2015 (SI No. 386 of 2015).

3.14.1 Surface Water Parameters

Field measurements of temperature, electrical conductivity, pH, dissolved oxidation reduction potential (ORP) for surface water samples taken at each of the sites are used as indicators of generic surface water properties (refer **Table 3.9**).

There are no guideline values for the surface water parameters with the exception of electrical conductivity of 1000 µS/cm and pH of 6.0-9.0. Electrical conductivity values were within the values for most of the samples with the exception of the Spring 2 sample which exceeded the (Surface Waters) Regulations, 2009 (SI No. 272 of 2009) and (Amendment) Regulations 2015 (SI No. 386 of 2015) Annual Average EQS of 1000µS/cm.

Table 3.9 Surface Water Field Parameters and Observations

Well ID	Date	Temp (°C)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (%SAT)	Redox (mV)	Observations
SW01	17/10/2018	10.0	124.6	7.27	10.91	111.6	Some red suspended solids
	31/10/2018	7.5	185.1	7.62	11.53	-44.0	-
SW02	17/10/2018	11.3	177.3	7.21	10.39	-86.1	Some black suspended solids
	31/10/2018	7.5	264.0	7.39	11.19	-20.6	-
SW03	31/10/2018	7.5	262.5	7.41	11.33	-19.7	-
Spring 1	17/10/2018	11.0	675.3	7.08	10.66	-104.8	-
SW Road	17/10/2018	11.9	5.334	7.29	9.47	-98.3	Some red/black suspended solids
Spring 2	31/10/2018	9.2	1130.0	7.10	10.32	-70.0	Orange precipitation within the area
Pipe Outflow	31/10/2018	10.3	-	7.93	10.62	-104.2	Brown/slightly orange staining directly around the pipe and where water dripped onto the rock blow. Close to the pipe leaching out of the rock was also observed as shown in **Plate 3.4**.

* Grey shading indicates an exceedance

3.14.2 Surface Water Laboratory Results - Inorganics

Reported inorganic concentrations were all below the relevant surface water guidelines with the exception of the following:

- Ammoniacal Nitrogen as N which ranged from <0.3mg/l to 125.51mg/l and exceeded the guideline value of 0.065mg/l within samples SW2 (25/10/2018 and 31/10/2018), SW3, Spring 2, Road Run Off and Pipe Outflow (as presented in **Table 3.10**).
- BOD (Settled) which ranged from <1mg/l to 30mg/l and exceeded the guideline value of 1.5mg/l within the Road Run Off and Pipe Outflow samples.
- Arsenic which ranged from <2.5µg/l to 86.4µg/l and exceeded the guideline value of 25µg/l within sample Spring 2.
- Nickel ranged from <2µg/l to 8µg/l and exceeded the guideline value of 4µg/l within Spring 2 and Pipe Outflow samples and within SW1 on 25/10/2018.

The full suite of results are shown in **Appendix J**.

Table 3.10 Surface Water Inorganic Parameters and Observations

Location	SW1		SW2		SW3	Spring 1	Spring 2	Road Run-Off	Pipe Outflow
Date	25/10/18	31/10/18	25/10/18	31/10/18	31/10/18	31/10/18	31/10/18	25/10/18	31/10/18
NH4	<0.03	<0.03	0.09	0.11	0.12	<0.03	2.94	125.51	109.94

* Exceedances shown in grey shading

3.14.3 Surface Water Laboratory Results – Organics

Reported organic concentrations (volatiles or semi-volatiles) were all below laboratory detection limit with no exceedances of relevant surface water guidelines. Tabulated surface water results are presented within **Appendix J**.

3.15 GROUNDWATER

3.15.1 Groundwater Flow Direction

Groundwater levels within the groundwater monitoring wells (GW1 and GW2) were measured on 2. No. occasions (09/11/2018 and 14/11/2018), the results are presented in **Table 3.11.** The values ranged from 109.79 mAOD to 105.78 mAOD and the groundwater contour map indicates that the groundwater flow is in west direction towards the River Dodder.

Table 3.11 Groundwater levels

Well ID	GW1		GW2	
Date	mbgl	mAOD	mbgl	mAOD
09/11/2018	7.31	109.77	5.67	105.87
14/11/2018	7.29	109.79	5.76	105.78

3.15.2 Groundwater Parameters

Groundwater results and parameters have been compared to guideline values within the following legislation and guidelines;

- European Communities Environmental Objectives (Groundwater) Regulations, 2010 (SI No. 9 of 2010);
- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (SI No. 272 of 2009) and (Amendment) Regulations 2015 (SI No. 386 of 2015);
- The EPA interim report “Towards Setting Guideline Values for the Protection of Groundwater in Ireland” (2003).

Groundwater samples were collected on 09/11/2018 and 14/11/2018. Tabulated groundwater results are presented within **Appendix J**. Field measurements of temperature, electrical conductivity, pH, dissolved oxygen and redox for groundwater samples were measured on site. The results are summarised in **Table 3.12**.

Temperature results ranged from 10.1°C to 12.0°C and were all below the guideline value of 25°C. Electrical conductivity values ranged from 685.0 µS/cm to 898.0 µS/cm and were all outside the guideline value range of 800-1875 µS/cm with the exception of GW2 (898.0 µS/cm) on 14/11/2018. pH values ranged from 6.18 to 7.14 all results were within the guideline value range of 6.5-9.5 with the exception of GW2 (6.18) on 14/11/2018.

There are no guidelines for Dissolved Oxygen or Redox, however a negative redox can indicate an anaerobic environment which was observed within GW1 (-108.9 on 08/11/2018) and GW2 (-105.0 and -26.0 on 08/11/2018 and 14/11/2018 respectively).

Table 3.12 Groundwater Field Parameters

Well ID	Date	Temp (°C)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/l)	Redox (mV)
GW01	09/11/2018	10.1	791.8	7.14	3.51	-108.9
	14/11/2018	11.4	685.0	6.59	-	80.0
GW021	09/11/2018	10.2	-	6.91	1.61	-105.0
	14/11/2018	12.0	898.0	6.18	-	-26.0

*Exceedance of guideline values indicated in grey.

3.15.3 Groundwater Laboratory Results – Inorganics

Inorganic concentrations were all below the relevant groundwater guidelines with the exception of the following:

- Arsenic values ranged from <20µg/l to 9.1µg/l and exceeded the guideline value of 7.5µg/l within samples from GW2 on 09/11/2018.
- Manganese values ranged from 7µg/l to 777µg/l and exceeds the guideline value of 50µg/l within samples from GW1 on 09/11/2018 and GW2 on 09/11/2018 and 14/11/2018.
- Chloride values ranged from 36.3mg/l to 61.10mg/l and exceeds the guideline value of 30mg/l within samples from GW1 and GW2 on 09/11/2018 and 14/11/2018.

3.15.4 Groundwater Laboratory Results – Microbial Indicators

Total Coliforms values ranged from 1046.2MPN/100ml to 31230MPN/100ml and exceeded the guideline value of 0MPN/100ml within all samples at all monitoring wells. Faecal Coliforms values ranged from <1cfu/100ml to 1600cfu/100ml and exceeded the guideline value of 0 cfu/100ml within GW1 on 09/11/2018 and GW2 on 09/11/2018 and 14/11/2018. E.coli values ranged from <1MPN/100ml to 14.6MPN/100ml and exceeded the guideline value of 0MPN/100ml within GW1 and GW2 on 09/11/2018.

3.15.5 Groundwater Laboratory Results - Organics

Reported organic concentrations (volatiles or semi-volatiles) were all below the laboratory detection limit.

3.15.6 Groundwater Laboratory Results - Pesticides

Reported pesticide concentrations were all below the laboratory detection limit.

3.16 LANDFILL GAS

Gas monitoring was carried out on 5 No. occasions (16/10/2018, 19/10/2018, 05/11/2018, 08/11/2018 and 14/11/2018). Atmospheric pressure during the monitoring events ranged from 1001 to 1027 mbar. Gas monitoring data is presented in **Appendix K**.

3.16.1 Gas Flow Rate

No measurable flow rate was recorded from any gas/leachate monitoring boreholes during the monitoring period except from LW2 (0.1l/h) and LW6 (0.1l/h) on 05/11/2018 and LW4 (0.1l/h) on 08/11/2018.

3.16.2 Methane Concentrations

Methane concentrations recorded within gas/leachate monitoring boreholes located within the waste body ranging from 0.0% v/v – 19.8% v/v (LW1), 1.0% v/v – 66.7% v/v (LW2), 30.9% v/v – 43.3% v/v (LW3), 47.2% v/v – 62.5% v/v (LW4), 0.0% v/v – 0.1% v/v (LW5) and 0.0% v/v – 12.7% v/v (LW6). Methane concentrations are presented in **Figure 3.7**.

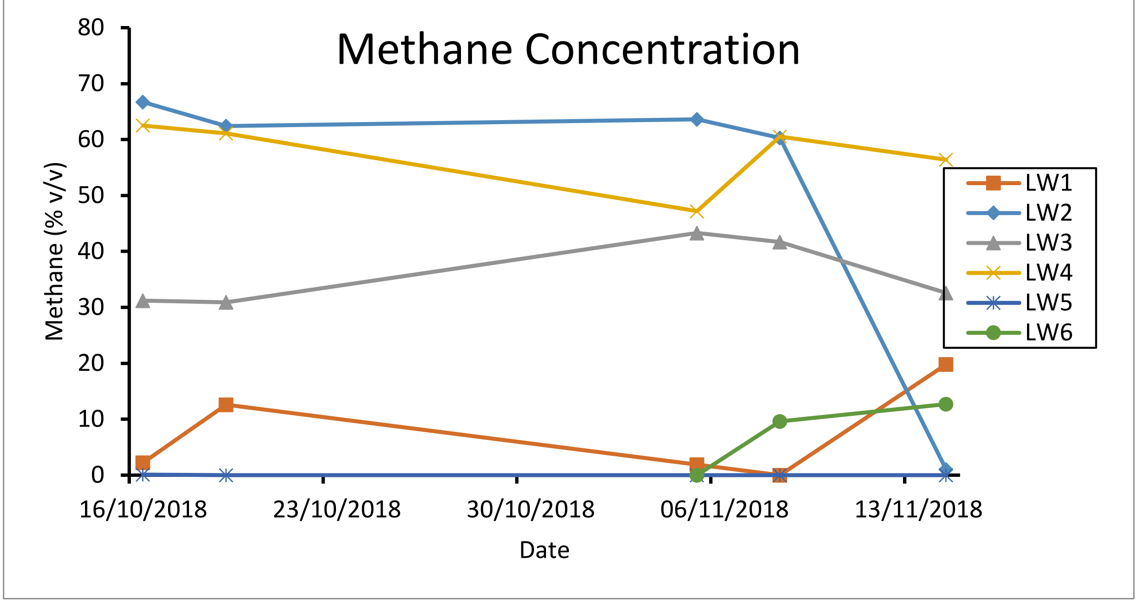

Figure 3.7 Methane Concentrations within the Waste Body

3.16.3 Carbon Dioxide

Carbon dioxide concentrations were recorded within all gas/leachate monitoring boreholes within the waste body ranging from 0.9% v/v – 25.1% v/v (LW1), 0.8% v/v – 34.0% v/v (LW2), 25.0% v/v – 29.2% v/v (LW3), 24.7% v/v – 31.2% v/v (LW4), 1.8% v/v – 7.5% v/v (LW5) and 12.1% v/v – 22.5% v/v (LW6) as shown in **Table 3.13** and **Figure 3.8**.

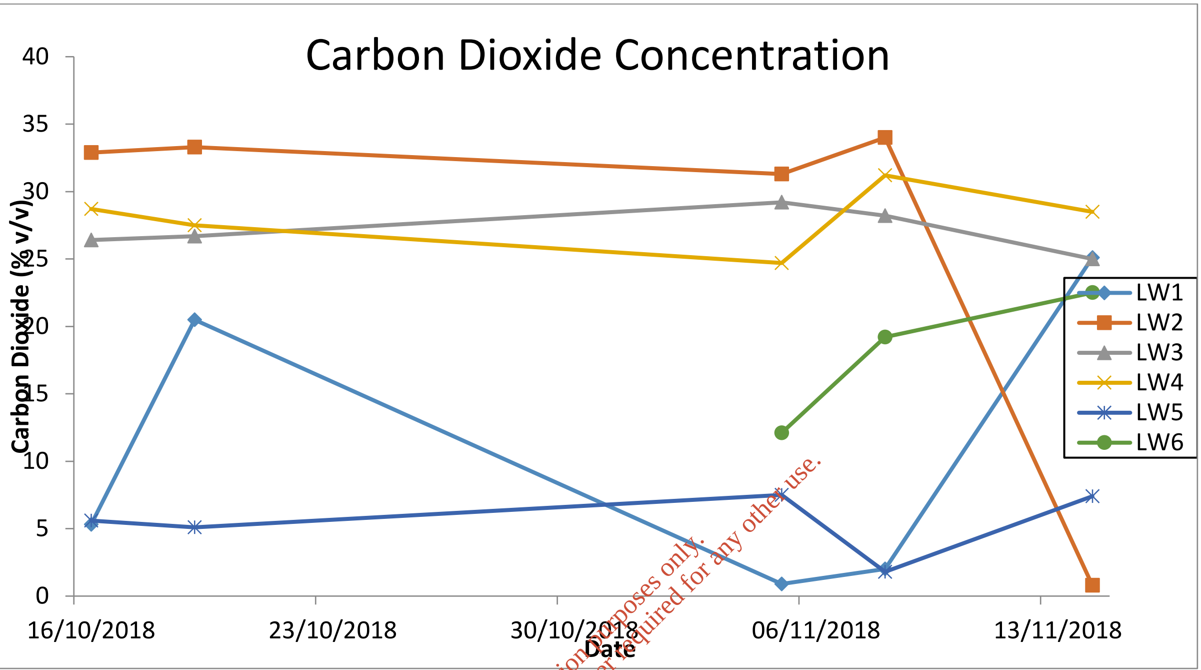

Figure 3.8 Carbon Dioxide concentration within the Waste Body

Table 3.13 Summary of Gas Monitoring Results

Well ID	Evidence of Contamination	No. of Monitoring Occasions	Range of Methane (%)	Range of Carbon Dioxide (%)	Steady Flow (l/hr)
LW1	Within waste	5	0.0 – 19.8	0.9 – 25.1	0
LW2	Within waste	5	1.0 – 66.7	0.8 – 34.0	0 - 0.1
LW3	Within waste	5	30.9 – 43.3	25.0 – 29.2	0
LW4	Within waste	5	47.2 – 62.5	24.7 – 31.1	0 - 0.1
LW5	Within waste	5	0.0 – 0.1	1.8 – 7.5	0
LW6	Within waste	3	0 – 12.7	12.1 – 22.5	0 - 0.1

* Methane gas detection shaded in grey

3.16.4 Hydrogen Sulphide and Carbon Monoxide

During all monitoring events, no measurable concentrations of hydrogen sulphide or carbon monoxide concentrations were detected with the exception of LW4, recording 25ppm and 26ppm of hydrogen sulphide on 08/11/2018 and 14/11/2018 respectively.

3.17 TIER II INTERPRETATION

3.17.1 Composition of Waste

Intrusive site investigations (trial pitting and borehole installations) identified the waste as black clay with varying amounts of decayed organic matter, ash, plastics, fabrics, wire, brick.

The majority of the biodegradable organic portion of the waste had degraded, however some fragments of paper had not degraded (a newspaper fragment was identified which was dated 1974). The waste was relatively dry as the organic fraction of the waste has decomposed and the lack of a basal liner allowed rain infiltration to pass directly through the waste before discharging to the River Dodder.

Lab analysis indicated the waste was hazardous and had several exceedances. Soil leachate analysis indicated exceedances.

3.17.2 Extent and Area of the Waste

The intrusive site investigation, in conjunction with the geophysical survey, identified that the waste extended across the entire site to edges of the site boundary with the exception of the southern boundary which was free from waste.

The waste was encountered at shallow depths (0.2m – 0.5m) with an overlying layer of slightly sandy silty clay which did not meet with the requirements of an engineering cap. The depth to waste varied across the site and could not be ascertained in one location (TP06 where depth to waste greater than 3.8m). Trial pit excavations indicated the waste had been deposited directly onto gravels or natural clays with no basal liner allowing for free drainage of any leachate.

3.17.3 Presence of Leachate

No significant volumes of leachate and seepages were encountered within the subsurface during the intrusive site investigations. All the leachate wells were dry with the exception of LW4.

Lab analysis from LW4 indicated exceedances of Iron, Manganese, Ammonia and microbial indicators. Organic contaminants were below the level of detection with the exception of a slight exceedance of Benzene, however the leachate was of low strength in comparison with typical leachate concentrations.

Sweet smells were noted while drilling LW4 which most likely originates from the anaerobic decomposition which releases volatile organic acids, esters, and thioesters.

The lack of a basal liner allows for free drainage of any leachate generated, to the underlying gravels or directly to the River Dodder, which accounted for the dry composition of the waste along with a very dry summer.

3.17.4 Presence of Landfill Gas

Landfill gas monitoring indicated that there was little or no measurable flow rate recorded indicating low surface emission rates. There is no evidence of vegetation die back.

Elevated concentrations of landfill gas (methane and carbon dioxide) were detected within the gas/leachate wells, the higher concentrations were detected within the middle of the site where the waste was thickest. Wells at the periphery of the site indicated lower concentrations of methane and carbon dioxide.

Based on the EPA Landfill Manual, Landfill Operational Practices, 1997, gas production is divided into four phases as shown in **Figure 3.9**. Phase I is aerobic with Phases II – IV anaerobic. Based on the low flow and the ratio of methane to carbon dioxide concentrations monitored within the wells it would suggest that gas production is in the later stages of degradation and in line with late stage Phase IV. The lack of an engineered cap has resulted in gas being able to migrate to the atmosphere.

Little or no flow indicates that the waste body is not actively producing landfill gas. This is due to the biodegradable component of the waste having been degraded. Therefore, there is not an active source of landfill gas.

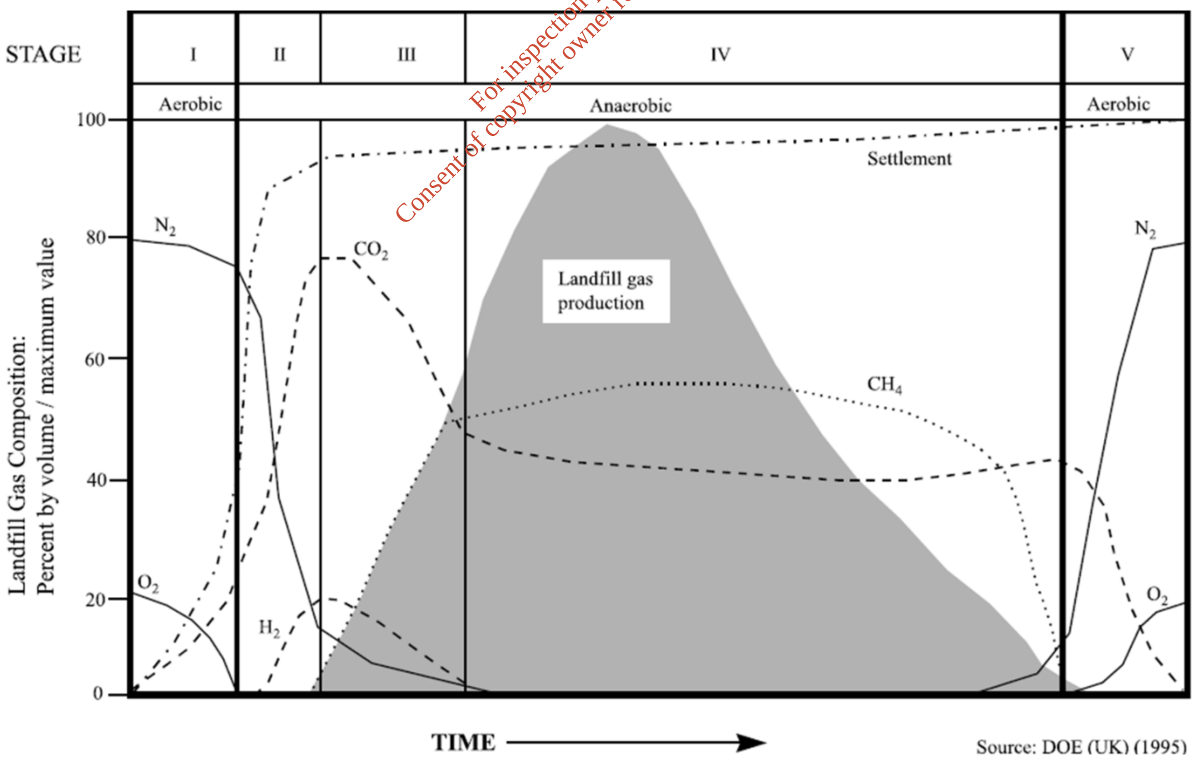

Figure 3.9 Development of Landfill Gas Progression (Source: EPA Landfill Manual, Landfill Operational Practices, 1997)

3.17.5 Depth to Water Table

The presence of waste across the majority of the site restricted groundwater well installation. Monitoring well MW2 was installed offsite immediately north of the site and represents an upgradient monitoring location. Depth to water was recorded at 105.8mAOD. Monitoring well MW1 was installed at the southern boundary of the site, depth to groundwater was 109.7mAOD, the groundwater flow direction follows the regional topology in a northern direction. Seepages noted along the banks of the River Dodder represent groundwater baseflow.

The leachate well, LW4, was installed within the waste and had a leachate level of 110.6mAOD, indicating potential connectivity of the groundwater with the waste body.

3.17.6 Presence of Aquifer

According to the EPA, the aquifer beneath the site is designated as a Poor Aquifer (PI). While the GSI indicates there are no designated gravel aquifers beneath the site, site investigations identified an intermittent gravel layer which was in contact with groundwater.

3.17.7 Geology of the Area

The site is located within a River Valley and there is variable local geology across the site. The waste body was overlain by a clay cap of approximately 0.5m. Site investigations indicate glaciofluvial gravels and sands underlying silty, sandy clay overlying gravel, which considerably varied in thickness across the site. The gravel layer was found to be intermittent across the site which can be partially attributed to the past quarrying activity on site.

Greywacke Sandstone bedrock outcrops located along river bank were noted, however bedrock was not encountered during groundwater installation.

3.17.8 Impact of Landfill on Surface Water and Groundwater through Sampling

Surface water samples were taken at several locations. Samples (SW1) taken from the River Dodder, directly upstream from the site indicate a slight exceedance of nickel, with no other exceedances observed. SW3 sampled from the River Dodder at the midpoint along the site boundary indicated an exceedance of Ammoniacal Nitrogen. Further down-stream and at the site boundary, samples (SW2) exceeded Ammoniacal Nitrogen and fluoranthene.

Springs sampled which represent groundwater indicated exceedances for arsenic. This represents the baseflow in contact with the waste. An arsenic exceedance was not observed at the down-stream sampling point (SW2).

It is considered that there is direct connectivity of leachate to the underlying gravel aquifer and the mixing of leachate with laterally flowing groundwater in the saturated aquifer dilutes the leachate concentrations. Notwithstanding this dilution, there are slight exceedances of the groundwater threshold value for arsenic at GW2. The arsenic mobilisation would be accelerated by the reducing condition generated from the decomposition of organics or from the groundwater from the bedrock from the oxidation of naturally occurring sulphides.

Small seepages/springs were noted that had emerged along the bank at the western perimeter as discreet seepages. These seepages then discharge directly to the River Dodder. The seepages are the point of emergence from the groundwater baseflow. Ochre staining was noted around the seepages.

The results indicate that the Bohernabreena landfill is currently having a minor impact on the River Dodder.

3.17.9 Revised Conceptual Site model

The Tier II Exploratory Site Investigation confirmed the assumptions of Tier I and does not change the risk scoring or CSM.

3.17.10 SPR Linkages

Based on the site specific information gathered during the site investigations, the SPR linkage scores were reviewed but there are no changes to the linkages presented for Tier 1.

4 TIER III REFINEMENT OF CSM AND QUANTITATIVE RISK ASSESSMENT

4.1 INTRODUCTION

The Environmental Risk Assessment was completed in a phased approach. RPS completed a Tier I: Preliminary Site Investigation which classified the site as a Low Risk (Class C) site. However, direct impact on the River Dodder has been observed from leachate discharging from the site into the river.

Subsequently the Tier II: Exploratory Site Investigation was completed and confirmed the presence of these risks. Therefore, the site required additional site investigations to investigate these risks further and confirm the risk assessment. The Tier II Main Site Investigation was completed in late 2018 to assess these risks and generate a more robust dataset which was used in this Tier III assessment to assess the overall risk of the site.

Following the completion of the Tier II Investigation and testing, a refined CSM was prepared for the site and is summarised in the cross sections provided in **Figure 4.1**. The refined CSM is based on the Tier 1 information (i.e. regional geological and hydrogeological data from the GSI) and results of the Tier II site investigation and associated environmental monitoring (i.e. dataset for trial pits, boreholes, geophysical survey, quality data and groundwater levels).

4.2 SCOPE OF WORK

For the purpose of this report RPS undertook the following scope of work:

- Review all the available desk based and site-specific information presented in the Tier I and Tier II reports;
- Reassess the Source-Pathway-Receptors (SPR) identified in Tier I and Tier II and assess if there are significant linkages present on the site specifically in relation to the presence of landfill gas and leachate;
- Refine the CSM;
- Final risk screening to classify the final risk of the site;
- Determine what level of QRA (if any) is required at the site; and
- Determine any remedial measure (if required).

4.3 REFINEMENT OF CONCEPTUAL SITE MODEL

A CSM was developed during the Tier I process and refined after the Tier II process. The potential for direct impact on the River Dodder had been observed from leachate discharging from the site into the river and the process concluded that the potential risk from leachate to the River Dodder needs to be investigated further. The CSM identified and classified the risk scoring of the SPR linkage shown in **Figure 4.1.**

Figure 4.1 Network Diagram for SPR 1 – Low Risk

Following the completion of the Tier II Main Site Investigation, the CSM was refined incorporating the desk based information on the geology and hydrogeology of the site and local area detailed within the Tier I assessment with the site-specific data obtained from the site investigations. The refinement of the CSM included updating the SPR linkages. A schematic diagram of the revised CSM is shown in **Figure 4.2**.

4.4 SOURCE

4.4.1 Waste

The source of the waste, its composition and lateral and vertical extent have been well defined though a series of site investigations including numerous site walkovers, trial pits, boreholes, geophysical surveys, soils and laboratory testing.

The waste (estimated at 151,200 tonnes deposited at the site) was found across the majority of the site, with the exception of the southern portion.

The waste was encountered at shallow depths (0.2m – 0.5m) with an overlying layer of slightly sandy silty clay which did not meet with the requirements of an engineering cap. The depth to waste varied across the site and could not be ascertained in one location (TP06 where depth to waste greater than 3.8m). Trial pit excavations indicated the waste had been deposited directly onto gravels or natural clays with no basal liner allowing for free drainage of any leachate.

The majority of the biodegradable organic portion of the waste had degraded, however some fragments of paper had not degraded (a newspaper fragment was identified which was dated 1974). The waste was relatively dry as the organic fraction of the waste has decomposed and the lack of a basal liner allowed rain infiltration to pass directly through the waste before discharging to the River Dodder.

4.4.2 Leachate

Intrusive site investigations indicated that the volume of leachate generated was generally low across the landfill area and within the waste body.

While the area was being built up, there would have been no cap, allowing infiltration of surface water into waste and percolation.

Lab analysis indicated exceedances of Iron, Manganese, Ammonia and microbial indicators within the leachate. Organic contaminants were below the level of detection with the exception of a slight exceedance of Benzene, however the leachate was of low strength in comparison with typical leachate concentrations.

The lack of a basal liner allows for free drainage of any leachate generated, to the underlying gravels or directly to the River Dodder, which accounted for the dry composition of the waste along with a very dry summer.

Similarly, the lack of an engineering cap over the waste body has resulted in rain infiltration through the waste which would expedite the degradation of waste but simultaneously generate leachate which is draining from the site to the Dodder. There is a thin layer of clay across the surface of the waste body that somewhat acts as a barrier for the ingress of water. While the layer is generally thin and not uniform across the site, it does provide a degree of protection against infiltration of rainwater across sections of the site.

4.4.3 Friarstown Landfill

It should be noted that the offsite leachate source from the adjacent Friarstown Landfill leachate holding tank has the potential to negatively impact on the River Dodder. Leachate overflow from this landfill is discharging directly to the river and has been observed to show exceedances for Ammoniacal Nitrogen and BOD.

4.4.4 Landfill Gas

Little or no measured landfill gas flow was detected at the site which indicates that the waste body is not actively producing landfill gas. This is due to the biodegradable component of the waste having already been degraded and hence there is insufficient pressure differential for the landfill gas to displace the balance gases (oxygen and nitrogen) within the waste body.

4.5 PATHWAY

The vertical pathway for leachate generation is driven by direct rainfall percolating through the waste body. The rate of rainfall infiltration is somewhat limited due the sections of made ground on the surface of the waste body at certain areas around the site. But the direct pathway for rainwater entering the waste body and leaching through to the underlying groundwater remains at the site.

Site investigations indicate that the groundwater flow across the site is in a westerly direction towards the River Dodder in line with the local topography. It is considered that there is direct connectivity of leachate to the underlying gravel aquifer and the mixing of leachate with laterally flowing groundwater in the saturated aquifer dilutes the leachate concentrations. As such, groundwater is intercepting the waste body and carrying contaminants directly to the River Dodder.

Site investigations have shown that the local geology across the site is very variable. There is an intermittent clay layer at the base on the waste body. This underlying clay later has acted as a barrier to further downward vertical migration of leachate. However, it is noted that there are areas underling the site were the gravel is in contact with the waste body.

There are a number of observed discreet direct discharges in the form of seepages from the groundwater to the river. These groundwater breakouts were identified along the western boundary of the site along the bank to the River Dodder.

Landfill gas is not actively being produced, however any gas migration would be through lateral and vertical pathways within pore spaces through the waste body and the overlying clays. However, the recorded flow rates at the gas monitoring wells demonstrate that there is no pressure from the landfill gas and as such little risk of migration. Also, as the subsurface is mainly low permeability clay this presents resistance/barrier to the migration of any gases.

4.6 RECEPTOR

The closest and highest risk receptor is the River Dodder which bounds the site to the west. The Dodder flows northeastwards and discharges to the South Dublin Bay SAC (000210) and South Dublin Bay and River Tolka SPA (004024) approximately 12.4km north east and downstream of the site. Surface water samples taken from the Dodder along the site boundary indicated an exceedance of Ammoniacal Nitrogen possibly from the waste body.

There is also an observed localised impact on tufa and water quality of the springs identified on the area on the western boundary of the site.

According to the EPA, the aquifer beneath the site is designated as a Poor Aquifer (PI). While the GSI indicates there are no designated gravel aquifers beneath the site, site investigations identified an intermittent gravel layer which was in contact with groundwater. This underlying gravel aquifer is directly impacted by vertical migration of leachate from the waste body.

4.7 REFINEMENT OF RISK SCREENING AND CLASSIFICATION

A Tier III Refinement of Risk Screening has been conducted for the site based on the information collected as part of the Tier II Site Investigations.

The risk screening has been further developed based on the findings of the additional site investigation and testing and the subsequent refinement of the CSM. The revised site risk model is based on the subdivisions of SPR linkages as set out in the initial CSM and is presented in **Table 4.1**.

Table 4.1 Tier III Revised Risk Model

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
Controlled Waters									
S1	Leachate	P1	Vertical to groundwater then horizontally through SW drainage channels into the river	R1	Surface Water Body	Likely	Medium	Moderate risk	Known evidence of leachate migrating directly to the River Dodder through groundwater
				R2	Surface Water Protected Area	Likely	Low	Low risk	South Dublin Bay SAC (000210) and South Dublin Bay and River Tolka SPA (004024) approximately 12.4km north east from the site. Potential hydrogeological link.
		P2	Vertical & Horizontal through Groundwater	R3	Private Wells	Unlikely	Medium	Low risk	There are no residential properties or private wells down gradient of the site.
				R4	Ground Water Dependent Terrestrial Ecosystems	Unlikely	Medium	Moderate risk	Tufa Deposits were observed along the River Dodder within the vicinity of the site which are sensitive to leachate generation.
				R5	Aquifer	Unlikely	Medium	Low risk	The underlying bedrock is poorly productive
				R6	Public Supply Well	None	Minor	No risk	There are no public water supply wells in the area.
				R1	Surface Water Body	Unlikely	Medium	Moderate risk	The River Dodder as noted above is observed to be subject to leachate impact from the waste body
		P3	SW Drainage	R1	Surface Water Body	Likely	Medium	Moderate risk	Observations of leachate migrating to the River Dodder supported by SW monitoring.
				R2	Surface Water Protected Area	Likely	Low	Low risk	

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
Human Health									
S2	Waste	P4	Direct dermal contact Ingestion dust and soil Inhalation of dust	R7	Current Site Users	Unlikely	Low	Low risk	Site is currently used as pasture from grazing, no soil is exposed.
S3	ACM	P4	Direct dermal contact Ingestion dust and soil Inhalation of dust	R7	Current Site Users	Unlikely	Low	Low risk	Site is currently used as pasture from grazing, no soil is exposed.
S4	Landfill Gas	P5	Lateral Migration Subsoil Inhalation and/ or explosion	R7	Current Site Users	Unlikely	Low	Low risk	Potential for ingress to existing buildings and structures.
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
				R9	Vegetation Stresses/Ecology	None	None	No risk	
S4	Landfill Gas	P6	Lateral Migration Groundwater	R7	Current Site Users	Unlikely	Low	Low risk	Potential for ingress to existing buildings and structures.
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
S4	Landfill Gas	P7	Vertical Migration Subsoil	R7	Current Site Users	Unlikely	Low	Low risk	The lack of an engineered cap will enable vertical migration of gas and atmospheric dispersion and dilution at surface.
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
				R9	Vegetation Stresses/Ecology	None	None	No risk	
S4	Landfill Gas	P8	Existing & Proposed Services Routes	R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	No offsite gas monitoring known to have been completed.

4.8 REVISED SCREENING ASSESSMENT

A Tier III Risk Screening and Classification has been completed for the site in accordance with the requirements as set out in the CoP using the available information sources. This updated assessment is shown in **Table 4.2** and confirms the findings of the Tier 1 screening. The associated risk classification is shown in **Table 4.3** and again, this confirms the Tier 1 determination that the site can be classified a Low Risk Site (Class C).

Table 4.2 Tier III Revised Screening Assessment

Source Assessment	Score Matrix	Site Score	Rational/Comments
Leachate	1a	2	>1 ≤5 ha Pre 1977 Site (Site is 2.2ha and closed in 1974)
Gas	1b	0.75	>1 ≤5 ha Pre 1977 Site (Site is 2.2ha and closed in 1974)
Leachate Migration Pathway Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Vertical Pathway (Aquifer Vulnerability)	2a	3	Extreme Vulnerability
Horizontal Pathway (Groundwater Flow Regime)	2b	1	LI poorly productive bedrock
Surface Water Pathway	2c	2	Direct linkage to the Dodder River
Gas Migration Pathway Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Assuming lateral migration (assuming receptor within 250m of source)	2d	3	Made ground
Vertical migration (assuming receptor located above source)	2e	0	No receptors located above waste body
Receptor Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Residential dwellings with potential for private water supply	3a	3	Domestic dwellings located within 50m of waste body
Protected Areas	3b	3	Glensamole Valley SAC (001209) 12m south east of waste body
Aquifer	3c	1	Poor Aquifer
Public Water Supplies	3d	0	No public water supplies within 1km of waste body
Surface Water Bodies	3e	3	Dodder within 50m of site boundary
Buildings and enclosed spaces used by humans or livestock	3f	5	Within 50m of site boundary

Table 4.3 Revised Risk Classification and Prioritisation

SPR No.	Equation	SPR Linkage Score	% Score	Risk Classification
Leachate migration through combined surface water and groundwater pathways				
SPR1 Surface Water Body	1a X (2a+2b+2c) X 3e 2 X (3+1+2) X 3	36	12%	Low
SPR 2 Protected Area (SWDTE)	1a X (2a+2b+2c) X 3b 2 X (3+1+2) X 3	36	12%	Low
Leachate migration through groundwater pathway				
SPR 3 Human Presence (Private well)	1a X (2a+2b) X 3a 2 X (3+1) X 3	24	10%	Low
SPR 4 Protected Area (GWPTE)	1a X (2a+2b) X 3b 2 X (3+1) X 3	24	10%	Low
SPR 5 Aquifer Category	1a X (2a+2b) X 3c 2 X (3+1) X 1	8	2%	Low
SPR 6 Public Supply (well)	1a X (2a+2b) X 3d 2 X (2+1) X 0	0	0%	Low
SPR 7 Surface Water Body	1a X (2a+2b) X 3e 2 X (2+1) X 3	24	10%	Low
Leachate migration through surface water pathways only				
SPR 8 Surface Water Body	1a X 2c X 3e 2 X 2 X 3	12	20%	Low
SPR 9 Protected Area (SWDTE)	1a X 2c X 3b 2 X 2 X 3	12	20%	Low
Landfill gas migration pathways				
SPR 10 Lateral Migration to Human Presence	1b X 2d X 3f 0.75 X 3 X 5	11.25	8%	Low
SPR 11 Vertical Migration to Human Presence	1b X 2e X 3f 0.75 X 0 X 5	0	0%	Low

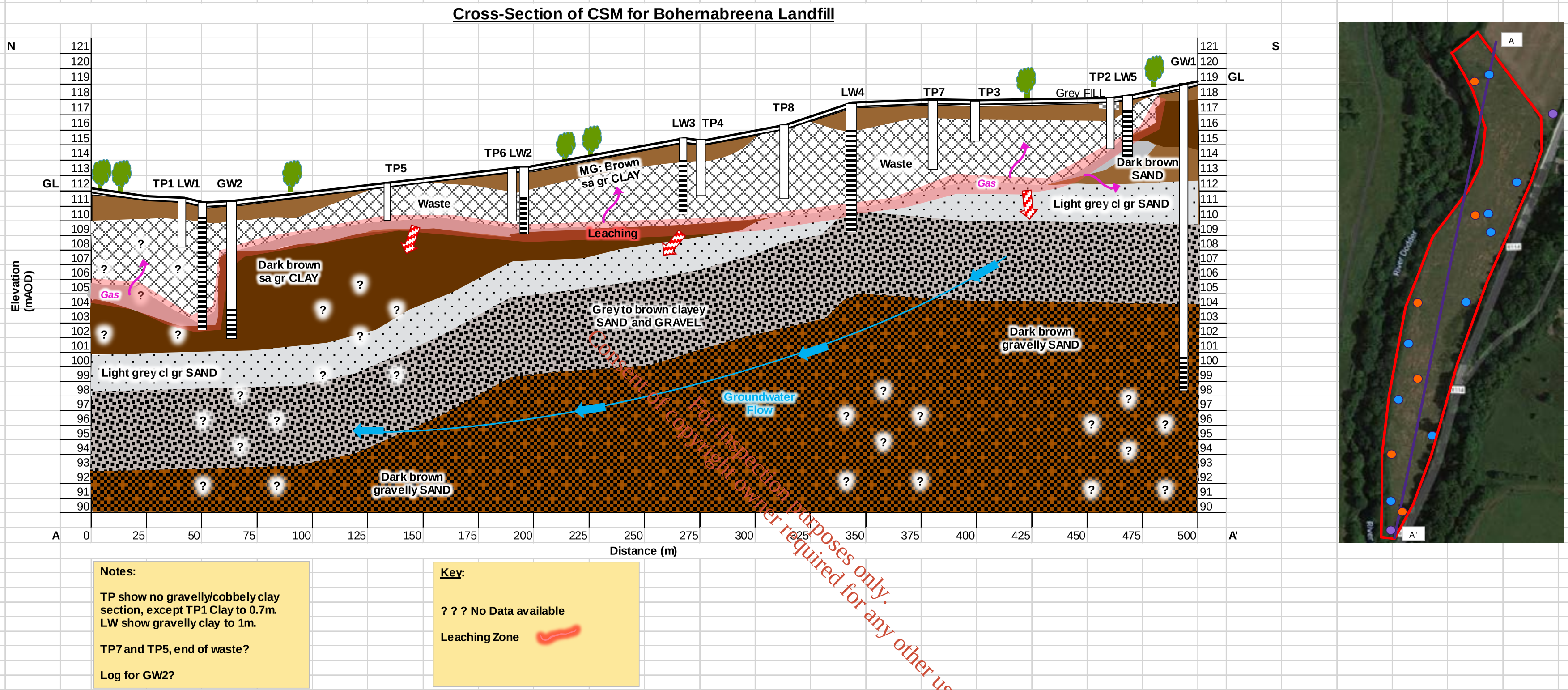

Figure 4.2 Conceptual Site Model

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The following conclusions have been derived from this assessment of Bohernabreena landfill:

- The waste was located across the entire site and at shallow depths, with the exception of the southern boundary which was free from waste. The waste was mixed municipal with the putrescible waste having decayed over time.
- The waste was hazardous with elevated levels of metals and Ammoniacal Nitrogen.
- The waste was relatively dry, due to the lack of a basal membrane allowing free drainage to the underlying gravels and direct discharge to the River Dodder.
- The lack of an engineered cap allows infiltration of rainwater and surface water, however the site investigation was completed during a very dry period which also accounts of the lack of leachate.
- Leachate was only found in one leachate well with some exceedance of values but generally well diluted. This is as a result of the groundwater being in contact with the waste body.
- Elevated levels of concentrations of methane and carbon dioxide (the principal landfill gases) were observed across the site, with the highest concentrations localised to within the centre of the landfill waste body. Gas flow rates are used to predict surface emissions and can refer to either the volume of gas being emitted from a monitoring well per unit time or the rate of movement of gas through permeable strata. Given the age of the landfill, the composition and the levels of landfill gas with no measurable flow, it would be considered that the landfill is within Phase IV, anaerobic. The risk from landfill gas is considered low.
- Based on the EPA methodology the Environmental Risk Assessment methodology the site is Low Risk, which is described by the EPA as "*not considered to pose a significant risk to environmental or human health*".
- While the EPA CoP indicates the site is low risk there is evidence of the site having a direct impact on the River Dodder.
- The groundwater baseflow is contact with the waste body therefore groundwater beneath the site appears to be directly impacted which is flowing into the River Dodder.
- A leachate tank overflow pipe from the Friarstown landfill which is adjacent to the Bohernabreena landfill is having a negative impact on the river, as Ammoniacal Nitrogen levels far exceed the statutory limit.
- An additional unconfirmed landfill immediately north of the site may also have a cumulative effect on the River Dodder.
- It is recommended that remediation options are considered.
- Any future development on the site will require an updated Environmental Risk Assessment in relation to the proposed development.

5.2 REMEDIATION OPTIONS

A remediation strategy examines ways of breaking SPR linkages and thereby ensuring a contaminated site no longer poses a risk of environmental pollution. Based on the risk screening and the final CSM of the site the pollutant linkages resulting from the landfill are all low risk. However, there is a direct impact from leachate and groundwater beneath the site on the River Dodder. Based on this pollutant linkage the following options are most suitable for the site in the current condition:

1. Waste Removal;
2. Leachate Treatment; and
3. Engineered Low Permeability Landfill Cap.

5.2.1 Waste Removal

Complete removal of the waste mass would remove the contamination source hence sever all pollutant linkages. However, there would be significant issues associated with this approach.

Excavation - The quantity of waste present across the site is estimated to be 151,200 tonnes. Excavation and replacement of the waste would lead to the removal of the source of environmental pollution and thereby eliminate the potential for future environmental liabilities. However, the practicalities of excavating this volume of waste, lying directly adjacent to a steep densely-wooded river valley would be extremely difficult and could result in significant impacts on the River Dodder considering the short pathway to the river. Excavating aged waste can cause the release of noxious odours and gases, the potential to attract pests (birds, flies, rodents), and the generation of dust and other nuisances including wind-blown litter. In addition, any excavated waste would need to be replaced with clean soil material in order to reinstate the areas. Significant traffic movements would be required in order to excavate/ replace the required volume of material from/ to the site with the potential to significantly impact on local communities over several years.

Disposal - The disposal of 151,200 tonnes of waste would present major difficulties particularly given the current waste management challenges in Ireland with regard to suitably licenced facilities and their remaining landfill capacity. It is likely that the excavated waste would have to be hauled considerable distances for landfill, pre-treatment or to be exported. The EPA reported residual waste capacity in Irish landfills to be “critically low” in ‘Ireland’s Environment 2016 - An Assessment’ (EPA, November 2016).

Cost - The cost of excavating 151,200 tonnes of waste and disposal would be considerable. On top of this the costs of excavation, haulage and environmental management of the sites during the excavation and replacement with clean material would run into further multi-millions.

5.2.2 Leachate Treatment

Site constraints including the steep bank along the River Dodder mean it is not feasible to construct a barrier at this interface. Consideration of the slope stability at the site would likely rule out any potential engineered solution to collect and treat the leachate discharges. Furthermore, given the low volumes of leachate expected, the cost benefit of such a solution would be prohibitive.

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5.2.3 Engineering Low Permeability Landfill Cap

The capping of a landfill with a low permeability barrier is an accepted method for reducing leachate generation on landfill sites. The capping system will comprise engineering and restoration layers. The main objectives of the capping system are to:

- Minimise infiltration of water; and
- Promote surface drainage and maximise run off.

The capping system would reduce the infiltration of rainwater through the waste and reduce the volume of leachate entering the underlying aquifer and the River Dodder.

5.3 RECOMMENDATIONS

5.3.1 Installation of a Landfill Cap

It is recommended that SDCC install a cap on the waste body with a low permeability barrier. The cap should be designed and constructed in line with the EPA Landfill Manuals – Landfill Site Design. The capping system should consist of at a minimum the following:

- Top soil (150 – 300mm) and subsoil of at least 1m total thickness;
- Drainage layer of 0.5m thickness having a minimum hydraulic conductivity of $1x10^{-4}$m/s
- Compacted mineral layer of a minimum 0.6m thickness having a hydraulic conductivity of less than or equal to $1x10^{-9}$m/s or a geosynthetic material (e.g. GCL) or similar that provides equivalent protection; and
- A gas collection layer of natural material (minimum 0.3m) or a geosynthetic layer. This layer may be unnecessary given the gas generating potential of the waste body.

An engineered low permeability capping solution allied with controlled water and ecological monitoring would represent the preferred strategy for managing the risks associated with the site, assuming a net betterment approach be acceptable to the regulator.

5.3.2 Friarstown Outlet Pipe

The Friarstown Landfill leachate tank overflow pipe which is discharging to the River Dodder urgently requires redirecting to the foul drainage network to control the impact of this discharge.

Samples for the overflow pipe indicated that this discharge is adversely impacting the River Dodder. Based on historic maps, there appears to be pipes upgradient from the site which flow into the SAC. Theses pipes were not identified during this risk assessment. This is in breach of the Water Framework Directive.

It is recommended an Environmental Risk Assessment is completed on the Friarstown Landfill in order to fully assess the impact on the River Dodder.

5.3.3 Aftercare Monitoring

To support the capping, the following environmental monitoring is proposed at the site:

- Surface water monitoring at the locations shown in **Figure 3.3** should be undertaken monthly during the capping works and quarterly thereafter for a period of five years.
- Groundwater monitoring at the locations shown in **Figure 3.2** should be undertaken annually for a period of five years.
- While landfill gas is considered a low risk on the site, this was based on monitoring within a limited time frame. It is recommended to take a conservative approach and carry out additional gas monitoring in accordance with industry best practice (EPA Landfill Manual) over a longer period to fully assess seasonal trends.

5.4 FUTURE DEVELOPMENTS AT THE SITE

Any future development or construction works proposed at the site require a revised environmental risk assessment to be completed prior to the commencement of any works. The current risk assessment is based on the site in its current use and condition. A revised risk assessment should take into account additional receptors and contaminant pathways.

5.4.1 Landfill Gas

While the current risk posed by landfill gas is low, this is based on the site it its current state. Any future developments will require a landfill gas quantitative risk assessment as outlined BS8485 2015:+A1:2019 *code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*. The purpose of the risk assessment based approach is to determine the appropriate mitigation measures to appropriately deal with the risk posed by the gas.

5.4.2 Waste Classification and Disposal

If it is proposed to develop the site and contaminated soil/ waste is to be excavated, the proper classification, handling, transport and disposal of the waste must be undertaken.

All waste must be classified in accordance with the guidance document "Waste Classification, List of Waste & Determining if Waste is Hazardous or Non-hazardous" (EPA, 2015).

Transport of the waste from the site must be carried out by a permitted waste haulier registered with the National Waste Collection Permit Office (https://www.nwcpo.ie/). The haulier must be registered for the transport of the specific waste material identified through the waste classification process.

Disposal of the waste must be to an appropriate facility holding a valid waste authorisation. If the waste material is to be disposed of to landfill, waste acceptance criteria (WAC) testing must be undertaken, i.e. "*Establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex to Directive 1999/31/EC (2003/33/EC)*". This document establishes criteria and procedures for the testing of waste to ensure it is disposed of to landfills designed to accept it, i.e. inert, non-hazardous and hazardous landfills throughout Europe. If the waste is to be disposed of outside of Ireland, a transfrontier shipment (TFS) process must be undertaken (http://www.dublincity.ie/main-menu-services-water-waste-and-environment-waste-and-recycling/national-tfs-office).