Kildare County Council

Remediation of Legacy Landfill Site at Digby Bridge, Sallins, Co. Kildare,
Stage 1: Environmental Risk Assessment and Remediation Plan

Attachment D1-Tier 2 Report Tier 2 Report: Site Investigations and Testing

May 2020

CDM Smith

Document Control Sheet

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Project		Remediation of Legacy Landfill Site at Digby Bridge, Sallins, Co. Kildare Stage 1: Environmental Risk Assessment and Remediation Plan		
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Abbreviations

ACM	Asbestos Containing Material
BH	Borehole
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BS	British Standard
CoA	Certificate of Authorisation
CoC	Chain of Custody
COD	Chemical Oxygen demand
CoP	EPA Code of Practice in Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007
CSM	Conceptual Site Model
DO	Dissolved Oxygen
EM	Electromagnetic ground conductivity
ERT	Electrical Resistivity Tomography
EPA	Environmental Protection Agency
FID	Flame Ionisation Detector
Ha	Hectares
INAB	Irish National Accreditation Board
ISO/CEN	International Organization for Standardization/Comité European de Normalization
JAGDAG	Joint Agencies Groundwater Directive Advisory Group
LFG	Landfill Gas
Lk	Locally Important Karst Aquifer
m bgl	Metres below ground level
m OD	Metres above Ordnance Datum
MASW	Multi-Channel Analysis of Surface Waves
MTBE	Methyl tert-butyl ether
MW	Monitoring well
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PSD	Particle Size Distribution
SPR	Source Pathway Receptor
SVOC	Semi-Volatile Organic Compound
SW	Surface Water
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TON	Total Oxidised Nitrogen
TP	Trial Pit
TPH CWG	Total Petroleum Hydrocarbons Criteria Working Group
TSS	Total Suspended Solids
UKAS	United Kingdom Accreditation Service
UKTAG	UK Technical Advisory Group on the Water Framework Directive
VOC	Volatile Organic Compound
YSI	Yellow Springs Instrument (Water Quality Meter)

Section 1 Introduction

1.1 Project Background

Digby Bridge legacy landfill site is located south east of Digby Bridge, in the townland of Barrettstown, less than three kilometres from Sallins as shown in Figure 1.

A Tier 1 Risk Assessment of the site was completed in 2008 by Kildare County Council, in line with the Environmental Protection Agency (EPA) Code of Practice: Environmental Risk Assessment for Unregulated Waste Disposal Sites 2007 (CoP). A preliminary Conceptual Site Model (CSM) of the site was developed and the Source-Pathway-Receptor (SPR) linkages were evaluated. The Tier 1 categorized the site as being of 'High Risk (Class A)' due to the number of high risk SPR linkages. The site was entered on Kildare County Council's Waste Management Act Section 22 Register, a list of unregulated waste disposal sites.

Kildare County Council appointed CDM Smith Ireland Ltd (CDM Smith) in 2017 to prepare a Stage 1 Environmental Risk Assessment and Remediation Plan in accordance with the Environmental Protection Agency (EPA) Code of Practice and comprising of Tier 2 Site Investigation and Tier 3 Refinement of CSM and Quantitative Risk Assessment which will then inform the Remediation Plan. This will provide the basis for the Council's application for a Certificate of Authorisation (CoA) to the EPA as required under S.I. No. 524 of 2008 Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity), Regulations, 2008. It will also be required to inform Stage 2 of the Project: Remediation Works.

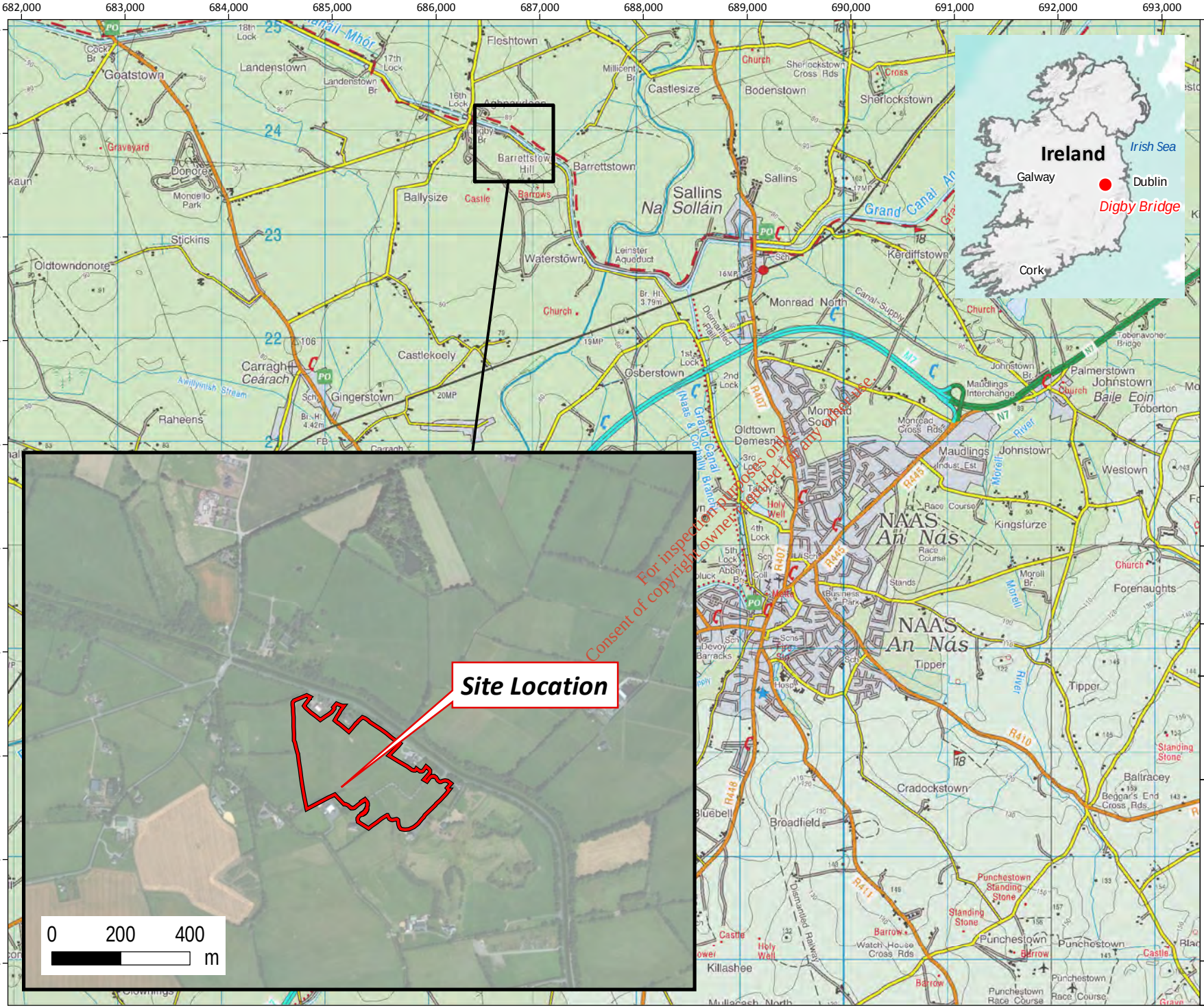
1.2 Purpose of this Report

In accordance with the objectives of the project, as set out in the Project Brief, three reports will be prepared as part of the project deliverables.

- Tier 2: Site Investigations and Testing (this report);
- Tier 3: Refinement of Conceptual Site Model and Quantitative Risk Assessment;
- Remediation Plan; and
- Appropriate Assessment Screening.

It is also stated that "*The consultant appointed to undertake the Project shall undertake such studies, analyses, assessments, investigations, monitoring and other works as necessary to meet the Project Objectives, in accordance with the EPA Code of Practice*."

An additional report (Doc. Ref. 117838/40/DG/10) has been prepared which reviews background information relevant to the project, including the Tier 1 Risk Assessment of the site completed in 2008 by Kildare County Council. The CSM and S-P-R linkages were updated where appropriate to inform the Tier 2 Site Investigation.



Source:

OSi Discovery Series 1:50,000
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Coordinates are in Irish Transverse Mercator

Consultant: CDM Smith

Client: Kildare County Council

Project Code: 117838

Project:

DIGBY BRIDGE

Drawing Title:

FIGURE 1: SITE LOCATION

Drawn By:	*Date:*
SM	24/05/2019

1.3 Format of this Report

The contents and format of this report follow the Reporting Requirements set out in Section 5.6 of the EPA Code of Practice and the requirements of the Project Brief.

Requirements of Project Brief	Section of this Report
Composition/characterisation of Waste	3.2.4 3.4
Area extent and depth of waste (vertical and horizontal extent of waste)	3.3.2
Presence of leachate and if necessary confirmation and quantification of migration to identified receptors	Tier 3 Report
Presence of Landfill gas and if necessary confirmation and quantification of migration to identified receptors	3.6 Tier 3 Report
Depth to water table	3.5
Presence of aquifer	3.5 Tier 3 Report
Geology of the area	Tier 1 Review 3.2
Impact of landfill on surface water and ground water through sampling both on and off site	3.5 Tier 3 Report
Presence of suitable capping material, if any on the site, in terms of depth/thickness and permeability	3.2.1 3.2.3 3.5.2
Quality of groundwater upgradient and downgradient of site	Tier 3 Report
The Conceptual Site Model. (Amendments to the initial Tier 1 CSM can be amended and refined in the Tier 3 stage based on information and results of the site investigation works)	Tier 3 Report
The SPR Linkages. All possible Source, Pathway, Receptor linkages should be explored, and conclusions reached at this stage of investigation	Tier 3 Report
Logs of all intrusive investigation including waste type, age of waste, level of waste decomposition, leachate generation, water level, ground level elevation or casing top elevation (mOD Malin Head) of trial pits/boreholes drilled or dug into the waste should be included in the report. Trial pits should, where possible, be excavated to the base of the waste and should be representative of the waste disposal area. The quantity of waste deposited on the site should be adequately determined using both the topographical and geophysical survey data or any other data and the methodology used for calculating the quantity of waste should be explained and justified in the report.	2.11 3.2 3.2.3 3.4 3.5 Appendix B1 & C1 Tier 3 Report
Site investigations shall comply with BS 10175:2001, Investigation of potentially contaminated sites. Subsoil investigation results to include all trial pit and borehole locations as per BS 5930: 1999. The EPA Landfill Manual: Landfill Monitoring, 2003 provides guidance on the design and implementation of a monitoring programme to accurately assess the impact of a landfill on the surrounding environment. It outlines minimum requirements for the location of monitoring points, the frequency of monitoring and the parameters to be analysed and the report should comply with the guidance given.	1.4
A topographical survey of the site and immediate surrounding area should be submitted with the report clearly identifying all relevant information and features, i.e. location of trial pits, boreholes, waste footprint, site topography, sampling locations, groundwater flow direction, structures.	2.11 Appendix E Figure 2,5 & 12 to 15

1.4 Standards

The principal standards used for this site investigation are as follows:

- EPA (2007) Code of Practice: Environmental Risk Assessment for Unregulated Waste Disposal Sites;
- EPA (2003) Landfill Manuals: Landfill Monitoring (2nd Edition);
- EPA (1999) Landfill Manuals: Site Investigations;
- Environment Agency (2004), CLR11, Model Procedures for the Management of Land Contamination Environment Agency;
- BS 5930:2015, Code of Practice for Ground Investigations;
- BS 10175:2011+A2:2017, Investigation of Potentially Contaminated Sites – Code of Practice
- BS 6068: 2009, Water Quality – Sampling. Part 11: Guidance on Sampling of Groundwaters;
- BS 8855 Soil analysis (all parts)
- BS 8576:2013, Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)

Section 2 Overview of Site Investigation

2.1 Summary

The site investigation involved intrusive and non-intrusive methods to assess the site. Table 1 shows key tasks with dates and responsible parties.

Table 1: Site Investigation Phase Summary

Task	Dates	Contractor	Section of Report	Appendix
Geophysical Survey	1-2 November 2017	APEX Geoservices Ltd	Section 2.2	A
Topographic Survey	22 November 2018	Focus Surveys	Section 2.11	E
Trial Pitting	8-12 October 2018	IGSL	Section 2.3, 2.4, 2.5	B
Soil Environmental Analysis	8-12 October 2018	ELS	Section 3.4	B
Soil Geotech Analysis	8-12 October 2018	IGSL	Section 3.5.2	B
Landfill Surface Emissions Survey	15-17 October 2018	CDM Smith	Section 2.12	-
Borehole Installation	15 October – 6 November 2018	IGSL	Section 2.5	C
Well Development	8 November 2018	CDM Smith	Section 2.5	-
Round 1: Leachate Sampling	30 November 2018	CDM Smith	Section 2.7, 2.8	D
Round 1: Groundwater & Surface Water Sampling	17 December 2018	CDM Smith	Section 2.7, 2.8	D
Round 1: Water Laboratory Analysis	30 November & 17 December 2018	Chemtest and Fitz Scientific	Tier 3	D
Round 2: Groundwater & Surface Water Sampling	7 May 2019 & 25 June 2019	CDM Smith	Section 2.7, 2.8	D
Round 2: Leachate Sampling	28 May 2019	CDM Smith	Section 2.7, 2.8	D
Round 2: Water Laboratory Analysis	7 May, 28 May & 25 June 2019	ALS	Tier 3	D
Offsite Well Survey	30 May & 25 June 2019	CDM Smith	Section 2.9	-
Round 1: Landfill Gas Analysis	4 March 2019	CDM Smith	Section 2.12	F
Round 2: Landfill Gas Analysis	25 June 2019	CDM Smith	Section 2.11	F
Household Gas Monitoring	15-17 October 2018, 25 June 2019	CDM Smith	Section 2.12	F

2.2 Geophysical Survey

The geophysical survey was carried out on 1-2 November 2017. The investigation consisted of reconnaissance electromagnetic (EM) ground conductivity mapping with a follow-up of seven lines of electrical resistivity tomography (ERT) and four lines of seismic refraction profiling with associated multi-channel analysis of surface waves (MASW), as shown on Drawing AGL17263_01

in the report of the geophysical investigation included in **Appendix A**. The findings of the survey are discussed in more detail in Section 3.2.3.

2.3 Trial Pits

It was initially envisaged that 30 trial pits would be excavated. In total, 26 trial pits were excavated with a 22-tonne excavator between 8 and 12 October 2018. They ranged from 2.0 to 4.8 m bgl (metres below ground level). The trial pit locations are shown in Figure 2.

A composite soil sample was collected from each trial pit (26 in total). Composite samples were collected from the waste body at regular intervals and where field observations indicated the possible presence of contamination/waste, e.g. as indicated by staining, discoloration or odour.

CDM Smith was on site for the duration of the investigation to observe the trial pit excavation, collect samples and log the encountered ground conditions. Trial pit descriptive logs are contained in **Appendix B1** and a photo log is included in **Appendix B2**.

Trial pit locations were surveyed using a total station to provide detailed coordinate and elevation data at each location. A photo ionisation detector (PID) was used during trial pitting to detect hazardous levels of volatile gases in the headspace of the excavation area.

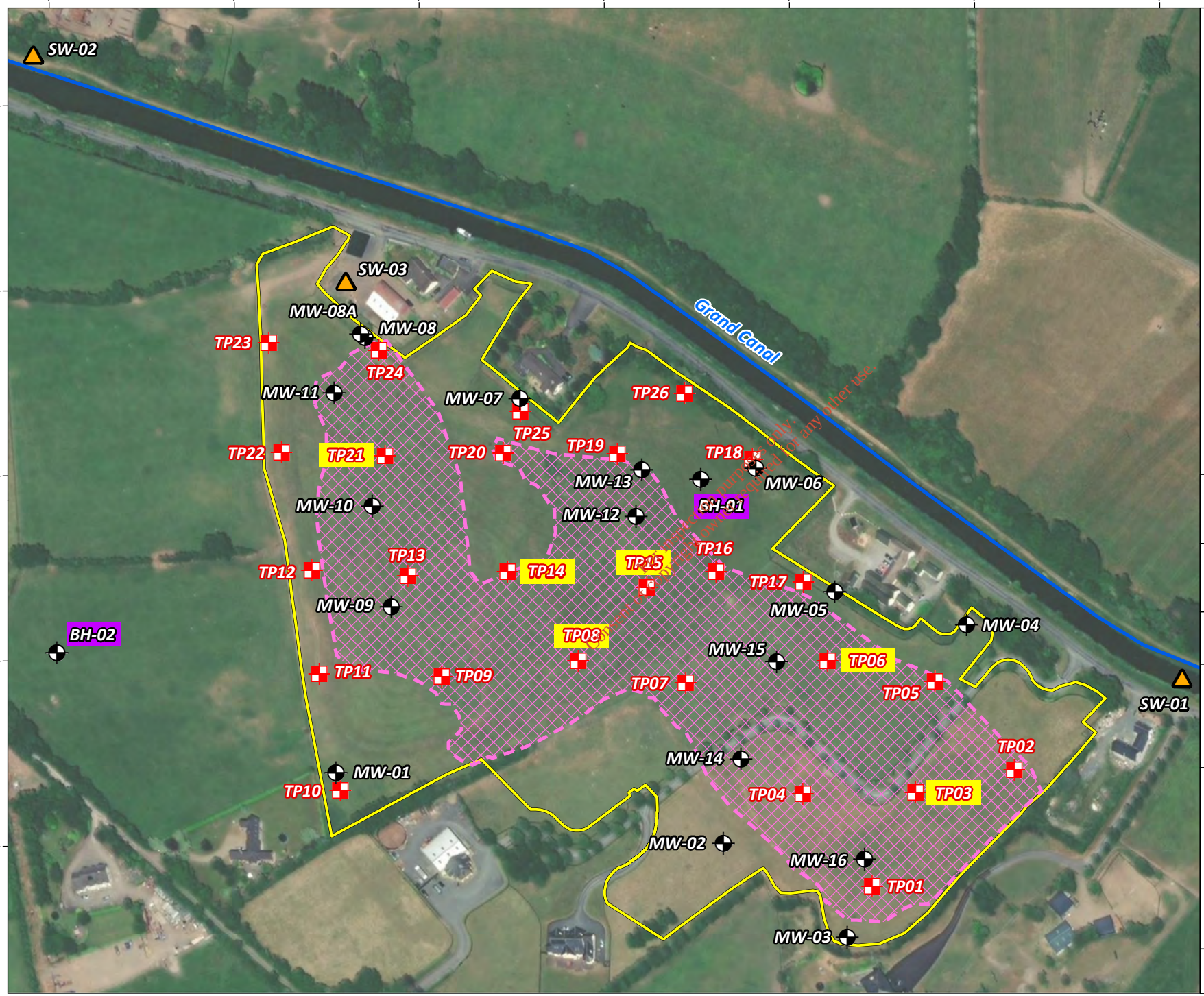
2.4 Subsoil and Waste Material Sampling

Representative soil samples were selected from six trial pits, shown in Figure 2. Soil samples were stored in laboratory supplied containers and cooler boxes in-line with best practice. Soil samples, along with chain of custody (CoC) documentation, were dispatched to Environmental Laboratory Services Limited (ELS) a UKAS certified laboratory. The laboratory methodologies were all ISO/CEN approved or equivalent. Original laboratory certificates and declaration of accreditation are presented in **Appendix B3**.

A total of six soil samples were scheduled for Rilta Suite analysis cognisant of current and historical land uses identified on site, the parameters for this suite include:

- Metals – arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc;
- Total Petroleum Hydrocarbons Criteria Working Group (TPH CWG);
- BTEX compounds - benzene, toluene, ethylbenzene and xylene;
- Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAHs); and
- Moisture content, Total Organic Carbon (TOC), Electric Conductivity, pH, Methyl tert-butyl ether (MTBE), Asbestos.

The soil analysis data was used to perform a waste assessment to permit classification of the waste as hazardous or non-hazardous. The leachate data was used to screen the samples against Waste Acceptance Criteria (WAC). The classification data is available in **Appendix B4** and results are discussed in Section 3.4.



0 50 100 m

N W E S

Legend

- Site Boundary
- Waste Body
- Boreholes
- Trial Pits
- Surface Water Locations

Note:

- Legacy Well
- Waste Sampled

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

Consultant: CDM Smith

Project Code: 117838

Project: DIGBY BRIDGE

Drawing Title:

FIGURE 2: SITE INVESTIGATION

Drawn By:	Date:
SM	08/05/2020

2.5 Samples for Particle Size Distribution (PSD) Testing

There were 10 samples taken in bulk bags from the capping material of the excavated trial pits and these were dispatched to IGSL Ltd., an Irish National Accreditation Board (INAB) accredited laboratory, see **Appendix B5**. The soils samples were submitted for particle size distribution (PSD) testing, the results of which are included in **Appendix B5** and discussed in Section 3.5.2.

2.6 Borehole Drilling and Monitoring Well Installation.

Boreholes were drilled between 15 October and 6 November 2018 by an air rotary Knebel drill rig (HY 79 83-C) using a casing advance technique referred to as symmetrix drilling. It was initially envisaged that 11 boreholes would be progressed on site. In total, 17 boreholes were drilled. 15 of the monitoring wells were installed with a single stand pipe. MW08 and MWO8A were independently installed while MW01 and MW07 were dual installations (MW01A and MW07A in addition), due to the proximity to residential properties a second shallow stand pipe was considered optimal for getting gas readings and assessing gas risk to the properties.

The monitoring well locations are shown in Figure 2. The borehole logs are presented in **Appendix C1** and a photo log is shown in **Appendix C2**. The response zones of the monitoring wells were designed depending on the target and purpose; a summary of which is presented in Table 2.

CDM Smith was on site for the duration of the investigation to observe the borehole drilling, log the encountered ground conditions and give directions on borehole installation. Monitoring well locations were surveyed with the elevation of the stand pipes using a total station to provide detailed coordinate and elevation data at each location. A PID was used during drilling to detect hazardous levels of volatile gases in the headspace of the drill area.

Table 2: Monitoring Well Response Zones

Well ID	Type of Well	Water Strike (m bgl)	Top of Response Zone (m bgl)	Base of Response Zone (m bgl)	Response zone
MW01	Groundwater MW	6.6	5	11	Gravels and Clays
MW01A	Gas Well	-	2	5	Silts and Gravels
MW02	Groundwater MW and Gas Well	-	1	14	Sands and Gravels
MW03	Groundwater MW and Gas Well	-	1	13.9	Sands and Gravels
MW04	Groundwater MW and Gas Well	-	1	7.9	Sands and Gravels
MW05	Groundwater MW and Gas Well	-	1	7.5	Sands and Gravels
MW06	Groundwater MW and Gas Well	8.6	1	7.1	Sands and Gravels
MW07	Groundwater MW	-	5	10	Sands and Gravels
MW07A	Gas Well	-	1.5	4	Sands and Gravels
MW08	Groundwater MW	-	10.5	15.2	Limestone

Well ID	Type of Well	Water Strike (m bgl)	Top of Response Zone (m bgl)	Base of Response Zone (m bgl)	Response zone
MW08A	Gas Well	-	2	5	Sands and Gravels
MW09	Leachate MW and Gas Well	-	1	6.8	Waste
MW10	Leachate MW and Gas Well	-	1	7.1	Waste
MW11	Leachate MW and Gas Well	-	0.3	2.7	Waste
MW12	Leachate MW and Gas Well	-	1	6.4	Waste
MW13	Leachate MW and Gas Well	-	1	2.3	Waste
MW14	Leachate MW and Gas Well	-	1	7.9	Waste
MW15	Leachate MW and Gas Well	-	1	6.5	Waste
MW16	Leachate MW and Gas Well	-	1	7.6	Waste
BH01*	Groundwater MW	-	1	7.5	Sands and Gravels
BH02*	Groundwater MW	-	1.5	10	Clays and Gravels

* BH01 is a historical monitoring well installed in 2006. BH02 is a historical monitoring well installed beside a newly built residence in May 2017; a requirement of the planning permission.

The monitoring and leachate wells were developed using Waterra tubing and surge bloc until the water from development was clear of suspended solids or cleared as much as practical. The water from development was stored on-site for disposal with a licensed waste facility.

2.7 Leachate, Groundwater and Surface Water Sampling

Two groundwater and surface water monitoring rounds were completed on five separate dates:

First Monitoring Round

- 30 November 2018;
- 17 December 2018;

Second Monitoring Round

- 7 May 2019;
- 28 May 2019; and
- 25 June 2019.

Prior to sampling, depth to groundwater/leachate was measured at each of the monitoring wells. The details are included in included in **Appendix D1**. The locations of the surface samples

(SW01 and SW02) from the canal and the location of the sample from the farmyard drainage ditch (SW03) are presented in Figure 2.

Sampling was carried out by CDM Smith. Samples were collected using Wattera tubing, with three well volumes purged before sampling. In the case where low volumes of water were measured in low recharge wells, a bailer was used to acquire samples. Bailers were also used to take grab samples from leachate wells.

The daily calibrated YSI multi-parameter probe was used to measure the field parameters (pH, redox potential, dissolved oxygen, temperature and conductivity) of the groundwater prior to sampling. The probe was not used on leachate wells in Round 1 due to the uncertainty of the chemical constituents and their potential to damage probes. The records of the field parameters and visual and olfactory observations are presented in **Appendix D2** and a summary is presented on Table 13. Purged groundwater from Round 1 was stored on-site in an IBC for appropriate disposal at a licensed facility. Purged groundwater from Round 2, excluding leachate, was disposed to ground due to the results reported in Round 1.

Over the two rounds, 25 total number of water samples, comprising 17 groundwater samples, 6 leachate samples and 4 surface water were taken. The samples were stored in the appropriate containers provided by the laboratory and transported in cooler boxes with ice packs to maintain appropriate temperatures. The cooler boxes were sealed and travelled under chain of custody documentation. The testing was carried out in UKAS accredited laboratory. All samples were scheduled for the following analysis based on recommended determinands in the EPA 2003 Landfill Monitoring Manual:

- Ammoniacal nitrogen, total alkalinity, ortho-phosphate;
- BOD, COD, dissolved oxygen, electrical conductivity, pH;
- Metals – cadmium, chromium, copper, lead, nickel, zinc, boron, iron, mercury, manganese, arsenic, calcium, magnesium, potassium and sodium;
- VOCs, SVOCs – PAHs, pesticides, herbicides, phenols and organotin compounds; benzene, toluene, ethylbenzene and xylene (BTEX);
- Chloride, sulphate, cyanide, fluoride;
- Total suspended solids, total organic carbon, total dissolved solids; and
- Total and faecal coliforms.

The results of the analysis of the groundwater, surface water and landfill leachate samples are presented in **Appendix D3** and **Appendix D4**, for the first and second monitoring rounds respectively. The schedules of accreditation for the laboratories are also provided here.

2.8 Samples Analysed

The numbers of samples analysed are summarised in Table 3.

Table 3: Laboratory Analysis Summary

Determinand	Number of Samples Analysed			
	Soil Samples	Groundwater	Leachate	Surface Waters
Metals	6	17	5	4
Polycyclic Aromatic Hydrocarbons (PAHs)	6	16	5	4
Total Petroleum Hydrocarbon Criteria Working Group (TPH CWG)	6	-	2	-
Polychlorinated Biphenyls (PCBs)	6	-	-	-
Total Organic Carbon (TOC)	6	16	-	-
Leachable Metals	6	-	-	-
Asbestos	6	-	-	-
Inorganic Ions	6	16	5	4
VOCs	-	16	6	4
Water Quality and Inorganics	-	16	5	4
Chemical Oxygen Demand (COD)	-	-	5	4
Biochemical Oxygen Demand (BOD)	-	-	5	4
Dissolved Oxygen (DO)	-	16	6	4
Total Suspended Solids (TSS)	6	-	-	4
Total Dissolved Solids (TDS)	-	16	-	-
Total Oxidised Nitrogen (TON)	-	16	5	4
Ammoniacal Nitrogen	-	16	5	4
Coliforms	-	16	-	-
Pesticides & Herbicides	-	15	5	4
Phenols	6	16	6	4
Organotin Compounds	-	16	5	4

Notes: BH02 sampled and submitted for analysis in monitoring Round 2. During monitoring Round 2, a groundwater sample was taken from offsite well BHF and was submitted for metals analysis.

2.9 Issues Encountered

Due to laboratory scheduling issues, for some samples taken during the second monitoring round, holding times were exceeded prior to analysis for the following analytes Polyaromatic Hydrocarbons, Total Petroleum Hydrocarbons, Pesticides, Organotins, Phenols, Chromium, Mercury, Ammoniacal Nitrogen, Sodium and Potassium.

The data was examined by CDM Smith and based on concentrations detected of determinands in the samples, overall the data has been deemed fit for purpose.

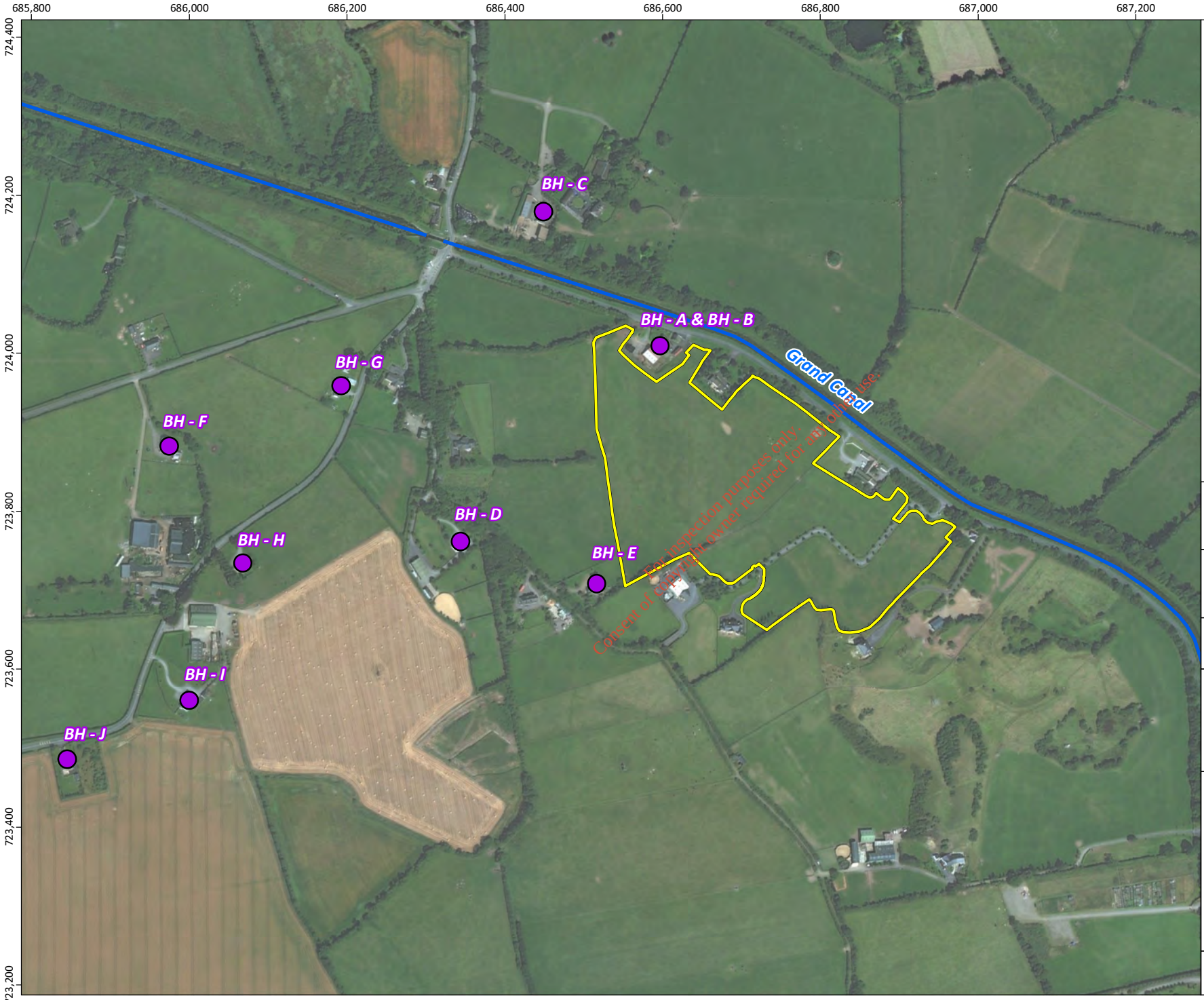
Insufficient sample was reported by the laboratory for PAH analysis of groundwater monitoring wells in round two. In addition, leachate wells were found to be dry or became dry when sampled during round two.

2.10 Offsite Well Survey

The presence of nearby offsite wells was investigated on 30 May and 25 June 2019. CDM Smith called to 21 properties querying the presence and the status of use for any private wells. Two well locations were known, and consent was received for groundwater gauging and a subsequent survey to take place, establishing the coordinates and elevation of groundwater. The details of the survey are shown in Table 4, the locations in Figure 3 and the measurements in **Appendix D1**.

Table 4: Offsite Well Details

Borehole	Location	Comment
BH A	65m north of site	No access to well head. Not in use
BH B	55m north of site	Precise location unknown. No access. Not in use
BH C	170m north of site	Precise location unknown. No access
BH D	215m west of site	Not in use
BH E	45m southwest of site	Location not precisely known, pump found. Not in use.
BH F	560m west of site	Used for drinking water
BH G	340m west of site	Precise location unknown. No access
BH H	475m west of site	Precise location unknown. No access at time
BH I	600m southwest of site	Precise location unknown. Not in use. No access
BH J	650m southwest of site	Precise location unknown. No access



0 100 200 m

N
W E
S

Legend

Site Boundary

Offsite Well Survey

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

Consultant: CDM Smith

Project Code: 117838

Project: DIGBY BRIDGE

Drawing Title: FIGURE 3: OFFSITE WELL SURVEY

Drawn By: SM

Date: 20/08/2019

2.11 Topographic Survey

A topographic survey of the land fill was carried out on 22 November 2018 and the data was used to generate a topographic map of the site, which is included in **Appendix E**. Table 5 presents the survey data of the site investigation locations, and offsite wells, which were surveyed into IRENET95 / Irish Transverse Mercator - EPSG:2157.

Table 5: Site Investigation Locations

ID	Easting	Northing	Elevation	Location Type
MW01	686555.044	723739.586	86.910	Monitoring Well
MW02	686764.453	723701.439	84.820	Monitoring Well
MW03	686831.276	723650.913	88.630	Monitoring Well
MW04	686895.673	723819.730	79.330	Monitoring Well
MW05	686824.731	723837.432	79.760	Monitoring Well
MW06	686781.980	723903.920	78.840	Monitoring Well
MW07	686654.511	723941.852	83.520	Monitoring Well
MW08	686570.852	723974.907	82.740	Monitoring Well
MW08A	686568.531	723976.633	82.620	Monitoring Well
MW09	686585.069	723829.343	86.960	Leachate Well
MW10	686574.743	723883.593	86.010	Leachate Well
MW11	686554.230	723944.802	84.690	Leachate Well
MW12	686717.384	723878.334	84.040	Leachate Well
MW13	686720.344	723903.431	83.570	Leachate Well
MW14	686773.878	723847.301	85.170	Leachate Well
MW15	686793.171	723799.745	83.830	Leachate Well
MW16	686840.684	723692.939	85.100	Leachate Well
BH01	686752.097	723897.926	81.990	Legacy Well
BHD	686324.693	723747.320	82.871	Offsite Well
BHF	685955.040	723870.722	87.272	Offsite Well
SW01	687015.000	723790.000	-	Surface Water
SW02	686392.000	724125.000	-	Surface Water
SW03	686545.000	724004.000	-	Surface Water
TP01	686844.699	723678.651	86.086	Trial Pit
TP02	686921.581	723741.405	83.316	Trial Pit
TP03	686868.275	723728.986	84.074	Trial Pit
TP04	686807.403	723728.362	84.973	Trial Pit
TP05	686878.612	723789.331	82.070	Trial Pit
TP06	686820.551	723800.066	82.535	Trial Pit
TP07	686743.950	723788.240	85.361	Trial Pit
TP08	686685.981	723800.201	86.487	Trial Pit
TP09	686612.170	723791.684	87.444	Trial Pit
TP10	686557.432	723730.134	86.538	Trial Pit
TP11	686546.149	723793.155	87.988	Trial Pit
TP12	686542.091	723848.913	87.279	Trial Pit
TP13	686594.134	723846.099	86.875	Trial Pit

ID	Easting	Northing	Elevation	Location Type
TP14	686647.714	723848.513	86.439	Trial Pit
TP15	686722.851	723839.724	84.420	Trial Pit
TP16	686760.298	723848.328	83.395	Trial Pit
TP17	686807.478	723842.898	80.607	Trial Pit
TP18	686780.177	723909.142	78.651	Trial Pit
TP19	686707.000	723912.000	84.450	Trial Pit
TP20	686645.361	723912.570	85.545	Trial Pit
TP21	686581.783	723911.021	85.888	Trial Pit
TP22	686525.670	723913.035	87.424	Trial Pit
TP23	686518.790	723971.954	84.662	Trial Pit
TP24	686578.287	723967.868	83.393	Trial Pit
TP25	686654.646	723934.974	84.492	Trial Pit
TP26	686743.313	723944.492	79.529	Trial Pit

A point was surveyed along the canal, from which the base of the canal was measured at 76.51 m OD and the level of water in the canal was measured 77.49 m OD.

2.12 Gas Monitoring

2.12.1 Landfill Gas Monitoring

Landfill surface emissions were measured between 15 and 17 October 2018 by CDM Smith, with the use of a supplier calibrated flame ionization detector (FID); see the calibration records of the device in **Appendix F2**. Readings were taken across the site, immediately above the land surface.

Landfill gas (LFG) analysis and gas flow rates from monitoring wells were obtained through direct measuring equipment, a GFM435 and GA5000. The GFM435 and GA5000 are universal LFG analysers, measuring five gases as standard: CH_4 CO_2, O_2, CO and H_2S. Atmospheric pressure, well flow and well pressure were also measured. Measurements were taken on 4 March and 25 June.

At each well, the gas tap and bung were visually inspected for possible gaps or leaks. The flow rate of each monitoring well was initially measured, followed by the gas analysis. New sample tubing was used at each well, thus removing the risk of residual organics present on reused tubing being drawn into subsequent sample pathways. The results of the LFG monitoring are presented in **Appendix F1**, and the results are discussed in Section 3.6.1.

Gas analysis was conducted in accordance with BS 8576. The analyser was pre-calibrated by the suppliers and the calibration certificates are presented in **Appendix F2**. The results of the monitoring are presented in Table 14 and a discussion can be found in Section 3.6.1.

2.12.2 Household Gas Survey

Residential properties were also surveyed using a supplier calibrated FID to measure explosive gases. All FID surveying was conducted between 15 and 17 October 2018 by CDM Smith. In coordination with local landowners and property owners, CDM Smith used the FID to measure fugitive landfill gas concentrations (e.g. CH_4) at all the residences adjacent to the landfill. Measuring points included sheds, garages, workshops, storm drains, manhole covers, pits,

sumps, trenches, cracks and drains in concrete retaining. The locations which were surveyed are shown on Figure 4. The highlighted houses in Figure 4 were entered with householder permission by a CDM Smith employee on 25 June 2019 to obtain readings with a landfill gas (LFG) analyser. Readings were taken from plugholes within the resident's home. The results of the survey are presented in Table 15 and Table 16, and a discussion can be found in Section 3.6.2.

0 50 100 m

N W E S

Legend

Site Boundary

External Gas Measurements

Internal Gas Measurements

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client:

Consultant: CDM Smith

Project Code: 117838

Project:

DIGBY BRIDGE

Drawing Title:

FIGURE 4: HOUSEHOLD GAS SURVEY

Drawn By:	Date:
SM	16/08/2019

Section 3 Results and Discussion

3.1 Surface Conditions Encountered

The site is managed for agricultural purposes; the land is cleared of scrub, covered with short grass and gently slopes from south to north as shown in Figure 5. The site is divided by fences delineating field boundaries. There are signs of settlement in places, this occurs within the extents of the waste body footprint on, the settlement may be related to the decomposition of landfill material over time. During high precipitation events several depressions pool with water, this was observed during site visits and monitoring rounds. Suspected consolidated ridges can also be identified on site, which may define the boundary ridges of the waste body. No liners were encountered at the sides or base of the waste mass during the ground investigation. The subsidence and ridges are defined by the waste body outline shown in Figure 2.

3.2 Subsurface Conditions Encountered

The ground conditions identified in the recent investigation are generally consistent with the desk study and the investigative borehole log (BH01) in relation to the residential development. The trial pit and borehole logs are presented in **Appendix B1** and **Appendix C1**. A summary of the ground conditions encountered is shown in Table 6 and cross sections have been generated on Figure 6 through Figure 11. Six subsurface layers were identified during intrusive works.

Table 6: Subsurface Stratum Encountered

Stratum	Description	Depth to Top of Unit (m bgl)	Range of Unit Thickness (m)
Topsoil	Topsoil capping	0	0.2 - 1.5
Made Ground	Infill material not on waste	0.2	0.2 - 4.9
Landfill Cover	Made ground over landfill	0	0.3 - 2.4
Landfill Waste	Waste material of landfill	0.4	1.6 - 7.5
Gravel Formation	Underlying in-situ gravel	0.2	0.2 - 16.5
Limestone	Bedrock	8.4	Not proven

3.2.1 Topsoil

A layer (0.2 to 1.5 m in thickness) of Topsoil type material was identified and has wide distribution across the site. The Topsoil is predominately silty sandy gravelly clay with rootlets and an occasional piece of plastic. Topsoil was found directly overlying landfill waste at several locations (TP01, TP08, TP20, MW11, and MW12 to MW16).

3.2.2 Made Ground / Fill (not waste material)

The site would have required extensive infilling and landscaping after landfilling. The Made Ground is described as the fill emplaced over natural ground, generally composed of a silty clayey gravelly sand fill. There were five locations where an occasional piece of plastic was observed (MW06, MW08, MW08A, TP11 and TP17). The Made Ground fill, not overlying the waste mass, was observed as deep as 4.6m bgl in MW08 and was only present in the following locations MW03, MW05, MW06, MW08, MW08A, TP11, and TP17. This may be due to the inclusion of the layer as part of the Topsoil or Gravel Formation when logging, where it may be difficult to distinguish.

0 50 100 m

N
W E
S

Legend

Site Boundary

Contours:

Interval 1 m

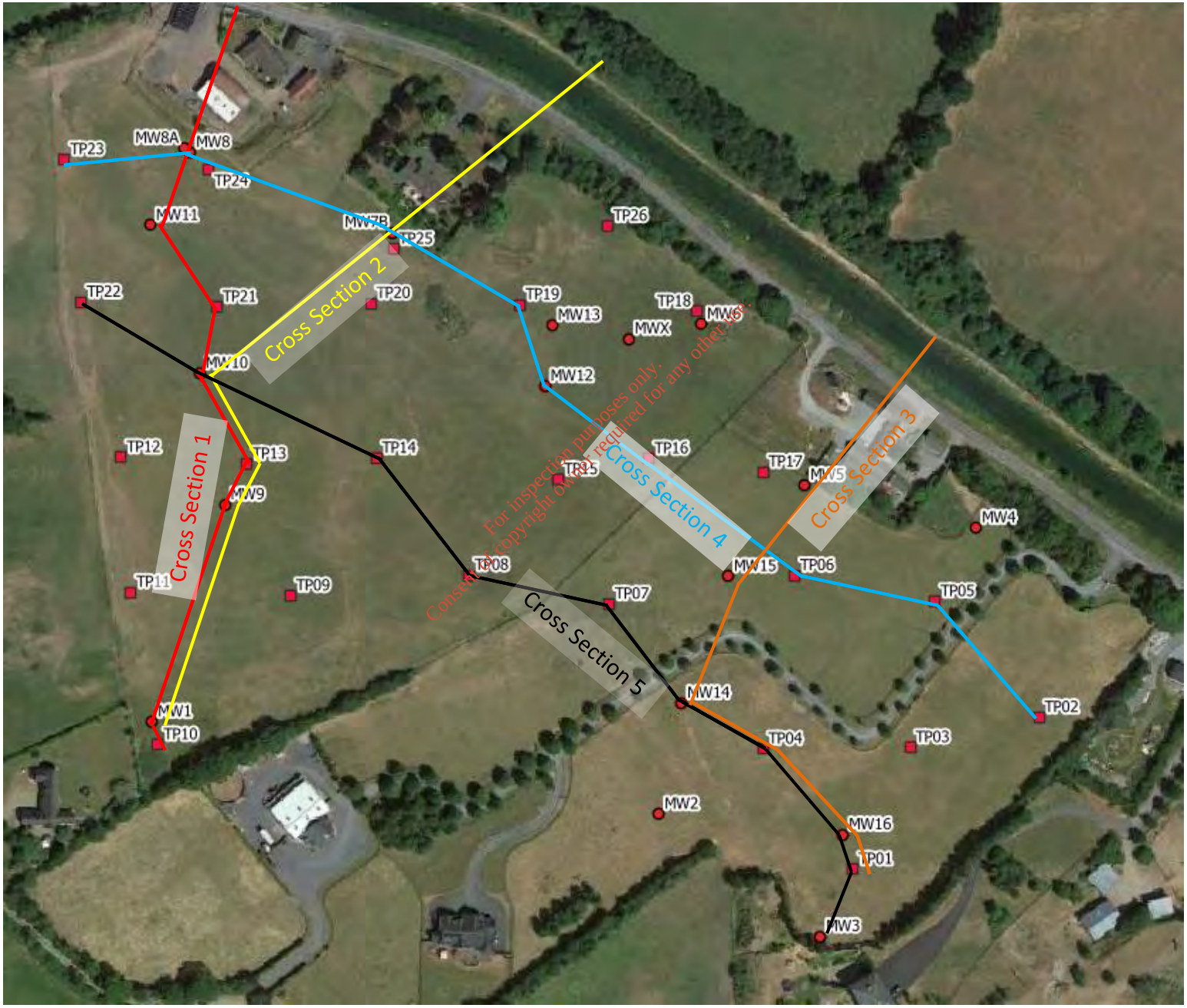
Interval 0.5 m

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

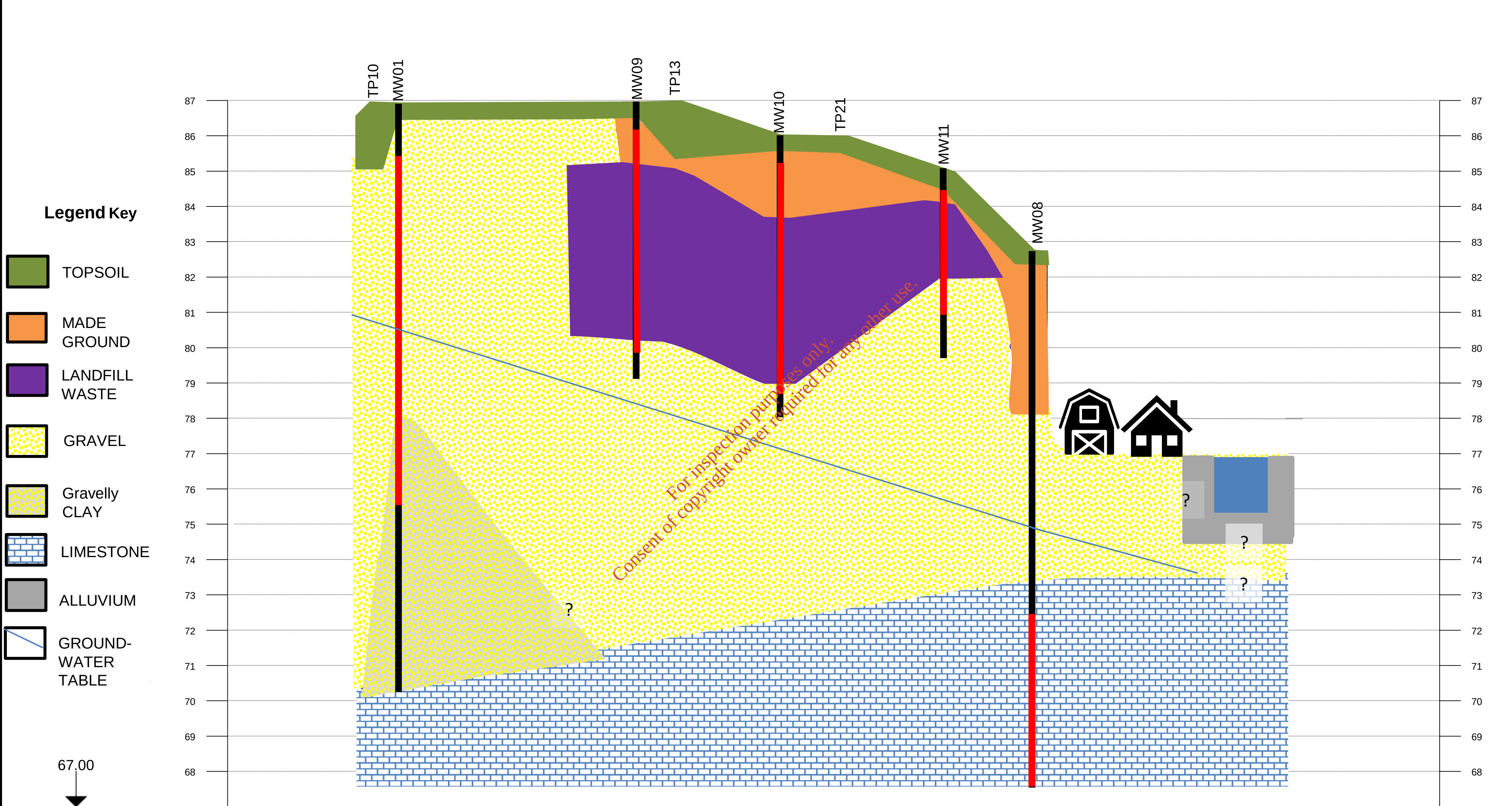
Client:	Kildare County Council
Consultant:	CDM Smith
Project Code:	117838
Project:	DIGBY BRIDGE
Drawing Title:	FIGURE 5: SITE TOPOGRAPHY
Drawn By:	SM
Date:	24/05/2019

Project ID: 117838	Title: Cross Section 1
Project Title: Digby Bridge	Vertical Scale:
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare	Horizontal Scale:
Client: Kildare County Council	Engineer: CDM Smith Ltd.



Project ID: 117838
Project Title: Digby Bridge
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare
Client: Kildare County Council

Title: Cross Section 1
Vertical Scale: 1:154
Horizontal Scale: 1:2150
Engineer: CDM Smith Ltd.

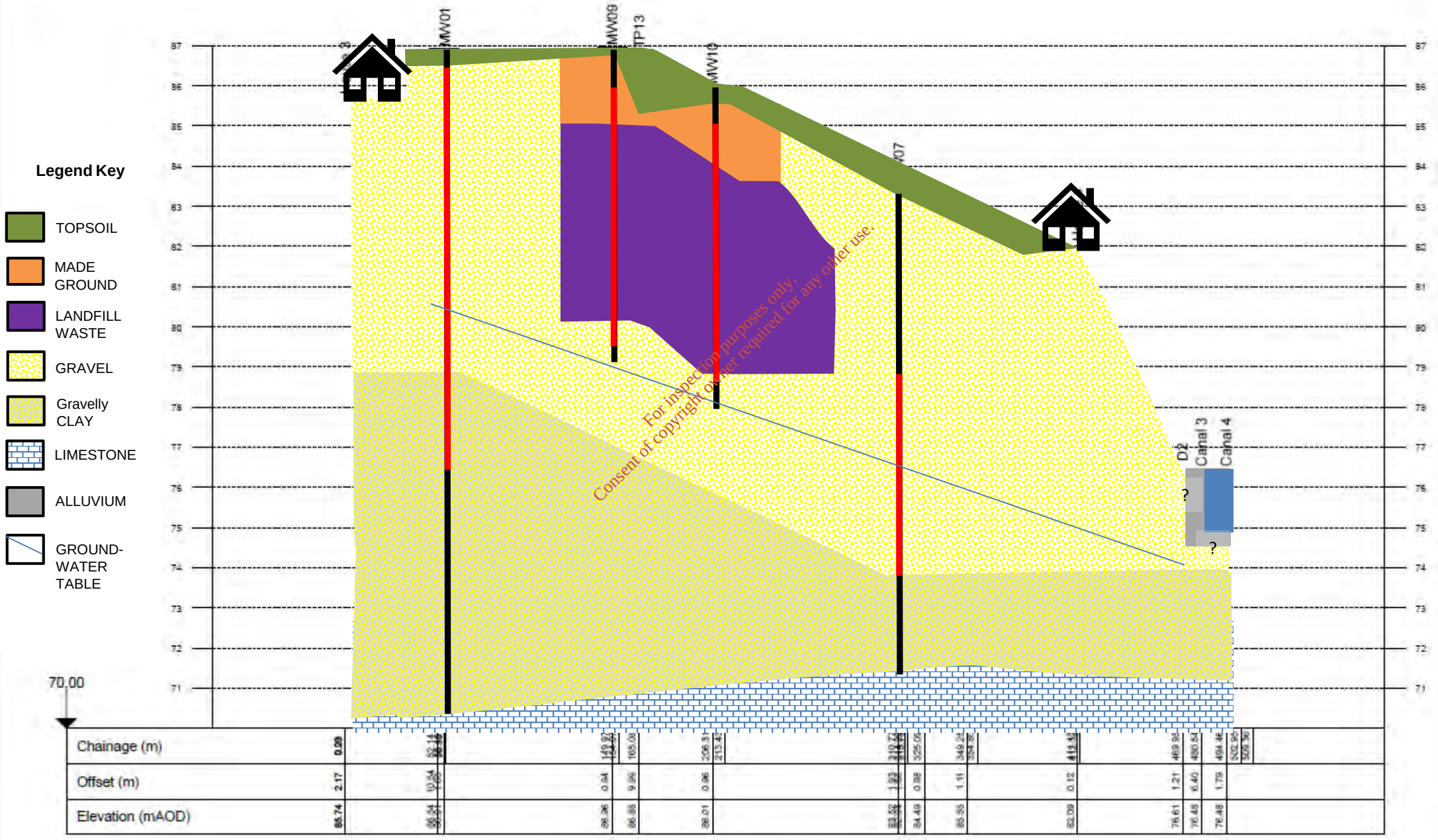


Chainage (m)	Offset (m)	Elevation (mAOD)
0.00		
4.00	1.04	86.54
13.61		
17.17	0.65	86.91
108.28	0.67	86.96
116.74		
123.25	8.91	86.88
164.39	0.52	86.01
176.46		
188.25	14.00	85.89
229.01	1.44	84.69
233.85		
261.78	11.47	83.39
264.26	1.41	82.64
270.60	1.63	82.74
274.90	2.36	77.20
290.74	3.79	77.20
314.19	7.76	77.20
338.20	0.10	76.99
356.95	0.91	76.99
367.61		
371.08		

Project ID: 117838
Project Title: Digby Bridge
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare
Client: Kildare County Council

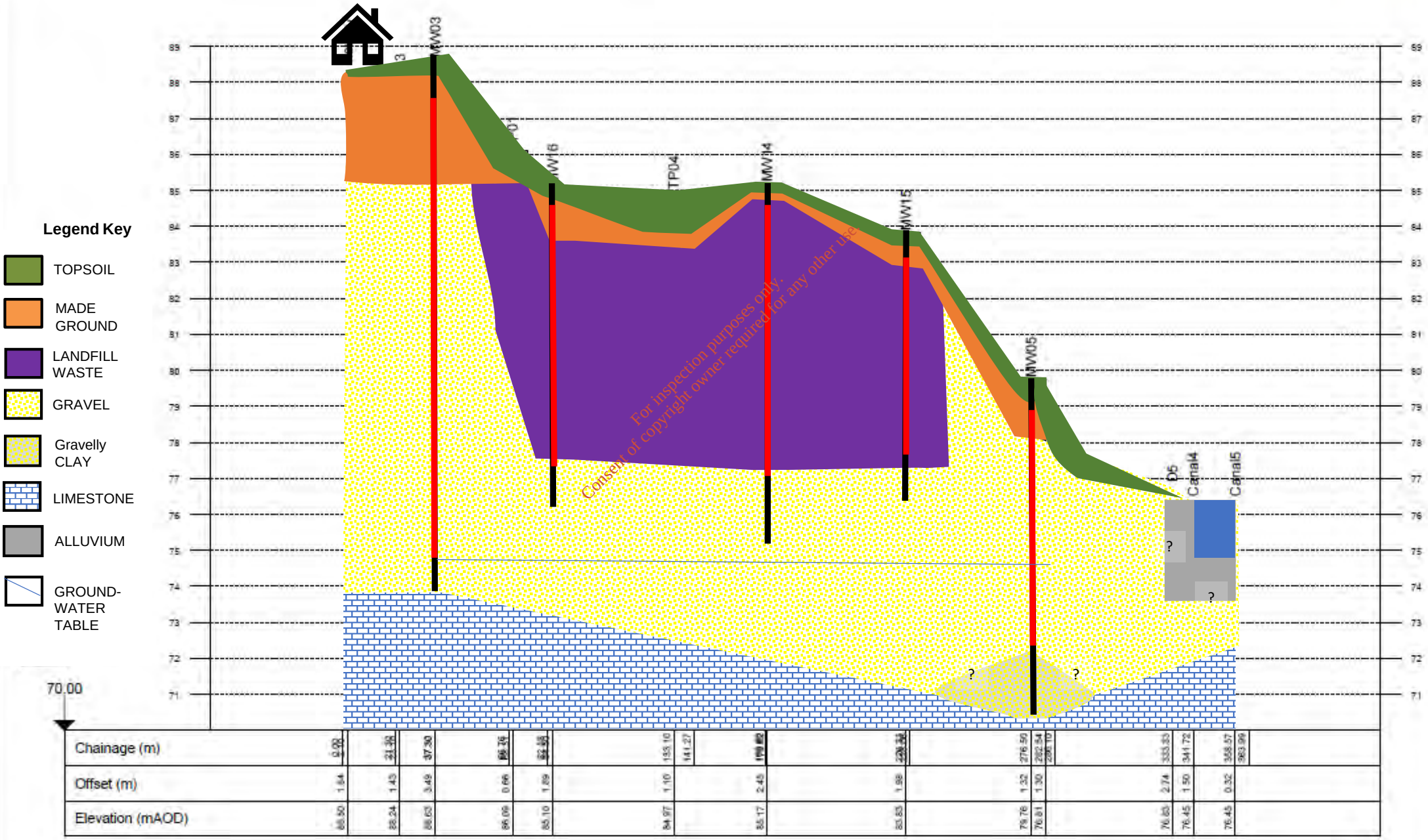
Title: Cross Section 2
Vertical Scale: 1:154
Horizontal Scale: 1:2150
Engineer : CDM Smith Ltd.

CDM Smith



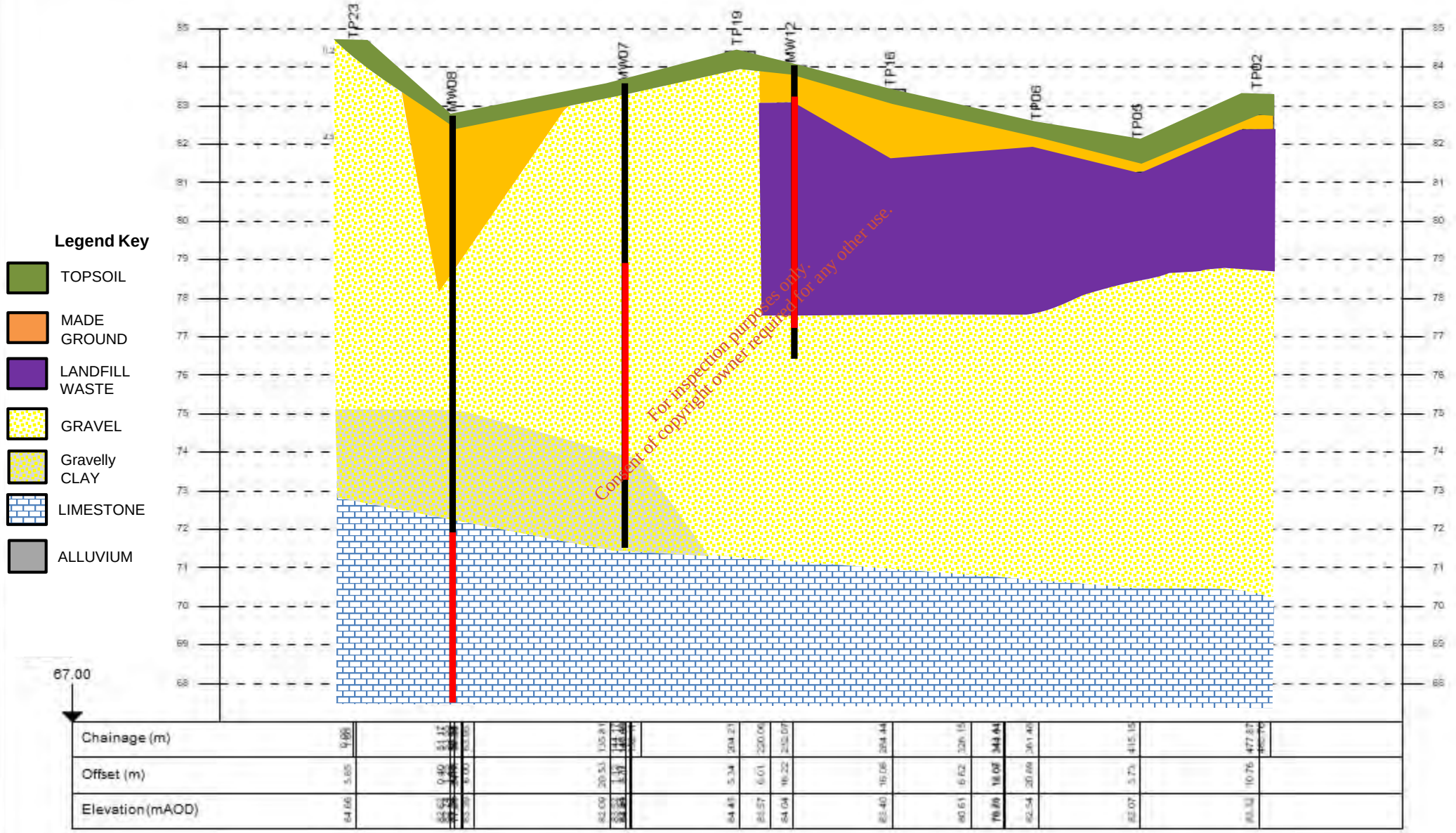
Project ID: 117838
Project Title: Digby Bridge
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare
Client: Kildare County Council

Title: Cross Section 3
Vertical Scale: 1:154
Horizontal Scale: 1:2150
Engineer: CDM Smith Ltd.



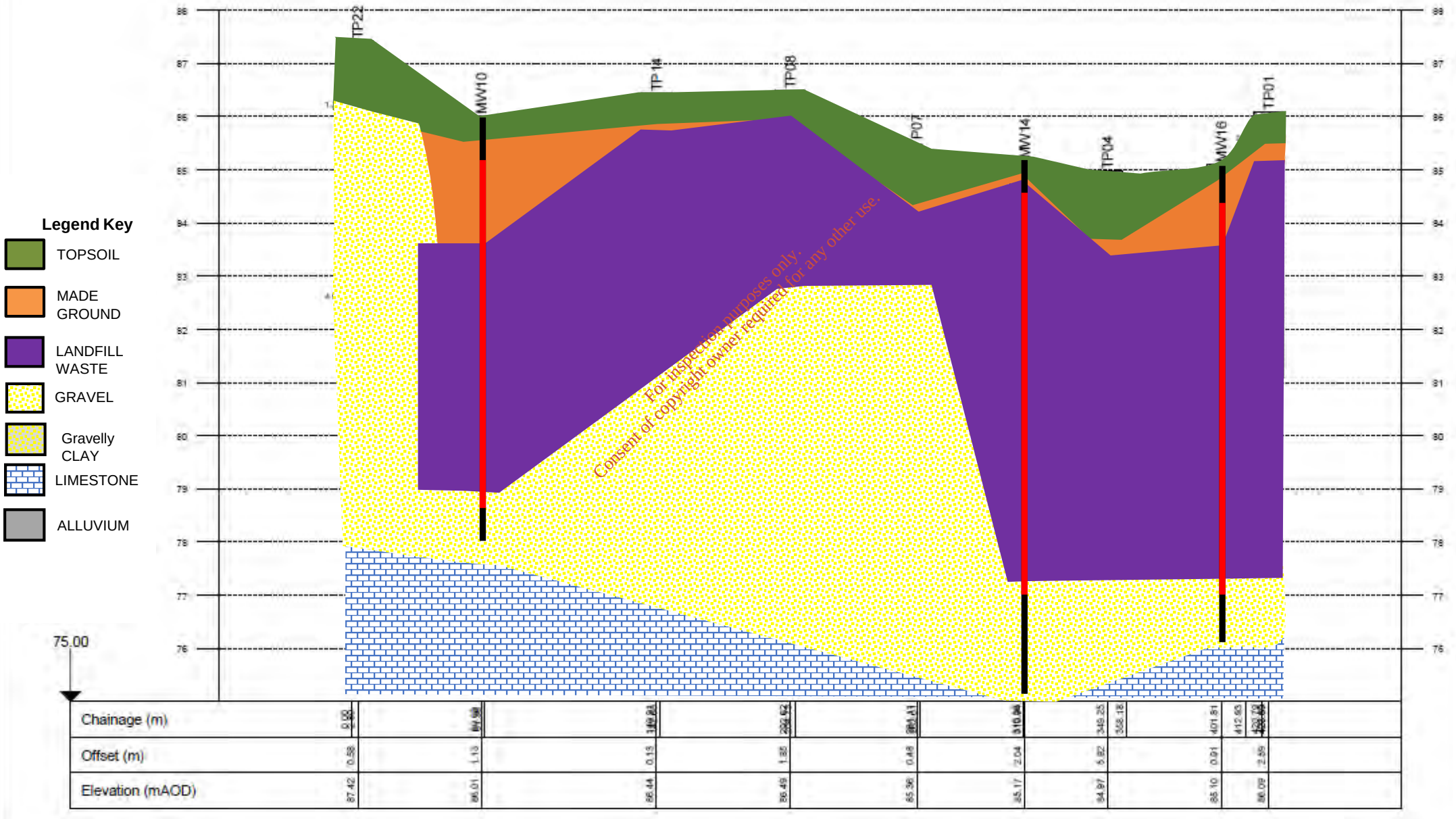
Project ID: 117838
Project Title: Digby Bridge
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare
Client: Kildare County Council

Title: Cross Section 4
Vertical Scale: 1:154
Horizontal Scale: 1:2150
Engineer: CDM Smith Ltd.



Project ID: 117838
Project Title: Digby Bridge
Location: Digby Bridge, Barrettstown, Sallins, Co. Kildare
Client: Kildare County Council

Title: Cross Section 5
Vertical Scale: 1:154
Horizontal Scale: 1:2150
Engineer: CDM Smith Ltd.



3.2.3 Landfill Cover (Made Ground/Fill over waste material)

The landfill cover is described as the made ground/fill overlying the waste body, it ranges in thickness between 0.3 to 2.4 m and is absent in places. The layer is predominantly composed of a clayey silty gravelly sand fill, which underlies the Topsoil.

A cross-section of the entire cover is presented in Figure 12. The clay Topsoil and gravelly sand Landfill Cover layers are projected over the site topography, the additional depth markers in plan-section indicate the depth to clay Topsoil.

3.2.4 Landfill Waste

Landfill waste was encountered in the following locations, MW09 to MW16, TP01 to TP09, TP12 to TP16, TP20, TP21 and TP24. The thickest section of waste mass encountered was in MW14, with a thickness of 7.5 m. However, an interbedded 0.5 m thick sand layer exists. Over 4.5 m of waste was also encountered in MW09, MW10, MW12, MW15 and MW16, these locations correlate with the historical gravel pits. The narrowest section of waste mass (0.7 m) was encountered in TP24.

The waste material was observed to be composed of a mixture of materials typical of municipal waste with strong putrid odours, these materials were as follows (amounts decreasing in order):

- Plastic;
- Decaying organic matter, timber, ash;
- Metal and wire;
- Glass and paper;
- Rope, cable rolls, concrete, insulation; and
- Fabric, tyres, video film, cotton, brick.

A car axel was found in TP11, however, there was no organic material or odour noted. Timber was observed in many areas and described as speckled (well distributed), which may indicate decay and degradation. Suspected fibre glass insulation was noted on the borehole log of MW15, intercepted from 2.4 to 6.5 m bgl in the waste body.

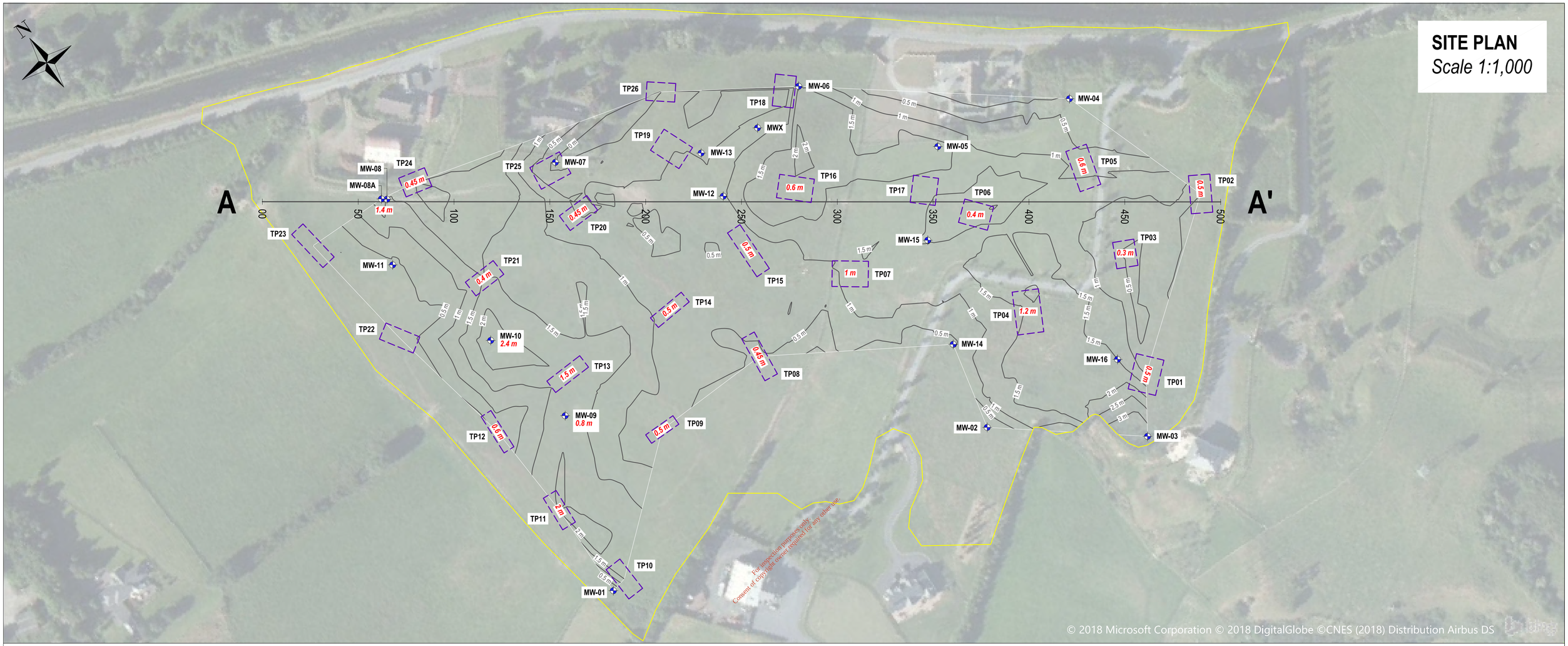
Boreholes drilled through the waste mass were not drilled to bedrock, to minimize the risk of creating a preferential pathway for leachate to travel from the waste mass into the bedrock aquifer.

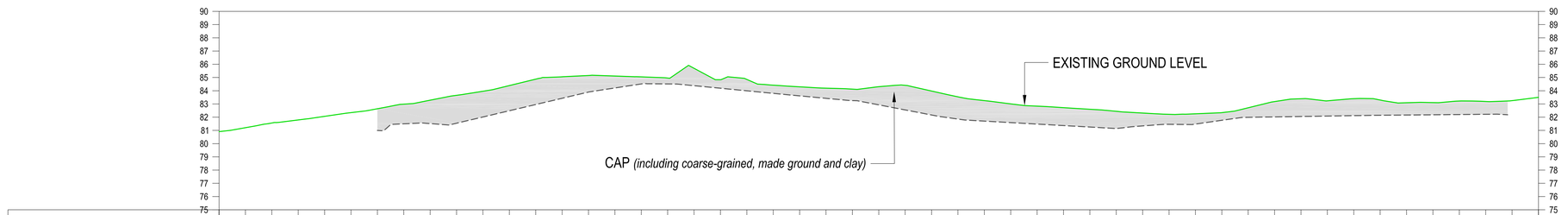
The geophysics results in **Appendix A** and the cross-section in Figure 10 show that the waste mass extends to the eastern boundary of the site. The driveway that runs along the eastern boundary is shown to be in the location of an infilled gravelled pit (Historic Map 25 inch, 1888-1913). To the east of this infill, a connected gravel pit appears to have remained open.

3.2.5 Gravel Formation

The Gravel Formation found during intrusive works describes the sediment package overlying the limestone bedrock. This material is predominately a sandy gravel but does contain clays and silts at depths. In addition, cobbles and boulders were found on rare occasions. As discussed in

SITE PLAN
Scale 1:1,000





CHAINAGE (m)	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500
EXISTING GROUND LEVEL (mOD)	80.91	81.20	81.56	81.79	82.06	82.34	82.64	82.99	83.28	83.65	83.96	84.39	84.87	85.05	85.15	85.11	85.05	84.96	85.70	84.83	84.85	84.42	84.30	84.19	84.12	84.30	84.40	83.98	83.54	83.25	83.01	82.84	82.72	82.60	82.44	82.31	82.22	82.26	82.34	82.71	83.18	83.40	83.24	83.40	83.30	83.09	83.10	83.22	83.19	83.25	83.50
CAP - BASE LEVEL (mOD)							81.00	81.50	81.52	81.54	82.02	82.49	82.96	83.43	83.90	84.21	84.51	84.51	84.38	84.19	83.99	83.80	83.61	83.43	83.25	82.83	82.55	82.17	81.86	81.70	81.59	81.48	81.37	81.25	81.14	81.34	81.46	81.48	81.76	81.99	82.02	82.05	82.08	82.12	82.14	82.16	82.18	82.20	82.22		
CAP THICKNESS (m)							1.64	1.48	1.77	2.11	1.95	1.90	1.92	1.62	1.25	0.90	0.53	0.44	1.31	0.65	0.86	0.62	0.68	0.77	0.87	1.37	1.86	1.81	1.68	1.55	1.42	1.36	1.35	1.34	1.30	0.97	0.75	0.78	0.58	0.72	1.16	1.34	1.15	1.28	1.15	0.93	0.92	1.02	0.97		

SECTION A-A'

Scale
H 1:1,000
V 1:200

Datum: 75 m

Client:

Kildare County Council
Comhairle Condae Chill Dara

Consultant:

15 Wentworth,
Eblana Villas
Dublin 2
D02 A611
Ireland

Tel: +353 1 232 1044
www.cdmsmith.com

Drawing Title:

FIGURE 12: LANDFILL COVER

Project Name:

DIGBY BRIDGE LANDFILL

Project Code:

117838

Legend

Landfill Boundary · *Borehole* · *Trial Pit*

Cap* thickness (shown as contours):

Interval 0.5 m · *0.5 m Clay cap thickness*

**Includes coarse-grained, made ground and clay*

Drawn:	Checked:	Approved:
OC	ML	CF

Date:	Scale:
JAN 2019	1:1,000 @ A1

Drawing Number:	Revision:
117838/01	**A**

the Tier 1 review, the gravel may have been quarried as far back as 1837, but at least 1942, and was later used as the county landfill. The Gravel Formation is encountered below the waste mass in locations MW09, MW10, MW11, MW12, MW13, MW14, MW15, MW16, TP05, TP07, TP08, TP11, TP16 and TP24.

Defined layers of gravelly clay are also present in the Gravel Formation, these tend to be found at the lower end of the formation. Table 7 presents the depths to the top and base of the layers, as well as unit thicknesses of the gravelly clay. The top of the layer ranges from 6.9 to 9.7 m bgl and the base of the layer ranges from 8.0 to 16.5 m bgl. The layer thickness ranges from 0.3 to 7.0 m.

Table 7: Gravelly Clay of the Gravel Formation Encountered Outside the Waste Body

Location	Depth to Top of Unit (m bgl)	Depth to base of Unit (m bgl)	Range of Unit Thickness (m)
MW01	8.0	8.5	0.5
MW01	9.5	16.5	7
MW05	7.7	8.0	0.3
MW06	6.9	8.6	1.7
MW07	9.7	12.0	2.3

The clayey gravel layer was absent at some locations, MW02, MW03, MW04 and MW08, sandy gravel directly overlies the limestone formation.

3.2.6 Rickardstown Formation (Bedrock)

The limestone bedrock of the Rickardstown Formation was encountered at depths between 8.3 and 14.8 m bgl, a summary of limestone intercept locations and depth are shown in Table 8. No evidence of voids was encountered during the site investigation, although MW08 was the only hole progressed significantly through the limestone bedrock.

Table 8: Depth to Limestone

ID	Depth to top of the Rickardstown Formation Bedrock (m bgl)
MW02	14.4
MW03	14.8
MW04	8.3
MW06	9.0
MW08	9.8

3.2.7 Visual and Olfactory Evidence of Contamination

There was a strong putrid smell from the landfill material, as would be expected with decaying organic material. There was a notable strong sweet and pungent odour observed in MW09. The landfill material also comprised metals, plastics and glass; see **Appendix B1** and **Appendix C1** for further details. No visual or olfactory evidence of contamination was noted in the Topsoil or Made Ground / Fill (over in-situ) during the investigation, except for a few occurrences of plastic highlighted in **Appendix B1** and **Appendix C1.**

There was no staining of the Gravel Formation observed below the waste mass. Additionally, there was no staining noted on the limestone bedrock. Asbestos containing material (ACM) was not observed during the intrusive investigation works. This does not preclude asbestos containing material from being present in the waste mass, as discussed in Section 3.4.2.

3.3 Waste Volume Assessment

3.3.1 Overview of Methodology

A geophysical investigation was undertaken by Apex Geophysics, commissioned as part of the Tier 2 assessment of the site. The geophysical survey was initially used to aid in selecting locations for the ground investigation. The data gathered was then used in conjunction with the intrusive investigation to determine the extent, thickness and volume of the waste body, to profile the site stratigraphy and to identify the presence of any anomalous features.

The geophysical investigation consisted of reconnaissance EM (electromagnetic) ground conductivity mapping with follow-up lines of Electrical Resistivity Tomography (ERT) (7 No.) and four lines of Seismic Refraction profiling with Multi-Channel Analysis of Surface Waves (MASW) as shown on Drawing AGL17263_01.

A review of the relevant information from the assessment is outlined below, while the full report is included as **Appendix A**.

3.3.2 Results of the Geophysical Assessment

Across the site MADE GROUND/TOPSOIL is c. 0.2 – 1.8m thick, with areas of little or no waste present close to the eastern, northern and south-western boundaries of the site.

The geophysical datasets in conjunction with trial pit and borehole logs are interpreted to define the type of waste - MADE GROUND/WASTE (mixed and organic) has been interpreted based on EM conductivity values of 30 - 148 mS/m and ERT resistivity values of 5 - 60 Ohm-m). Interpreted thickness of the waste ranges from 5.2 – 8.9m with an average of 7.8m.

The main waste body lies across central, southern and western parts of the site, covering approximately 4.7 Ha. The volume of waste is estimated as 366,600 m^3. Using a standard density of 1.4 tonnes/m^3 for municipal waste, the tonnage is estimated at 513,240 tonnes. However, based on inferred data from trial pit and borehole logs, the overall footprint of the waste may extend to approximately to 4.9 Ha.

Low model resistivity values (< 60 Ohm-m) beneath interpreted base of waste indicate possible leachate beneath base of waste. Depth to interpreted top of limestone bedrock varies from approximately 9.8 to 22.4m below ground level across the site.

3.3.3 Conclusion

The total waste tonnage at the site is estimated to be 513,240 tonnes, which is significantly higher than the original estimate of 100,000 tonnes, presumably because of the greater than expected thickness of waste across the site.

3.4 Waste Assessment and Classification

3.4.1 Overview of Methodology

Laboratory analysis was carried out on six representative subsoil samples from trial pits. The subsoil samples were taken from the waste body within the excavated soil heaps. Soil analysis and leachate analysis were preformed to permit waste classification and screen against the waste acceptance criteria (WAC), respectively. Subsoil samples were analysed for waste acceptance criteria (WAC) in accordance with 2003/33/EC.

3.4.2 Waste Classification

A waste assessment and classification were undertaken on the soil analytical data presented in **Appendix B3** in accordance with the *EPAs Waste Classification: List of Waste & Determining if Waste is Hazardous or Non-hazardous, 2015*, in accordance with 2014/955/EU. The laboratory data was processed using the hazWasteOnline^{tm} software. The results indicate that all samples are non-hazardous, however, asbestos was detected in one sample (TP6). If the waste were to be excavated for disposal, further screening would be carried out to assess if the asbestos renders the waste hazardous. The detection of asbestos in one trial pit presents a low risk while the material remains in-situ. The waste classification report is presented in **Appendix B4**.

3.4.3 Waste Acceptance Criteria

Table 9 contains the soil eluate (i.e. CEN leaching test 10:1 liquid to solid) and exceedances when compared to the Council Decision 2003/33/EC for waste acceptance criteria expressed as mg/kg for eluates and total pollutant concentration where applicable. Sulphate and total suspended solids exceeded the inert landfill waste acceptance criteria in five samples (TP03, TP06, TP08, TP14 and TP21,). Mineral oil was elevated above the inert landfill waste acceptance criteria in three samples (TP03, TP08, and TP14). Total Organic Carbon exceeded the inert landfill waste acceptance criteria (TP03, TP06, TP08, and TP14). All parameters were below the thresholds for stable non-reactive landfill waste acceptance criteria. The complete laboratory certificates of analysis are contained in **Appendix B3**.

Table 9 Summary of Soil Laboratory Analysis

Sample No	TP03	TP06	TP08	TP14	TP15	TP21	Landfill Waste Acceptance Criteria Limits [1]		
Solid Waste Analysis							Inert	Stable Non-reactive	Hazardous
Total Organic Carbon (%)	**4.5**	**3.8**	**3.8**	**4.0**	<1.0	2.4	**3**	5	6
BTEX (mg/kg)	1.4	0.24	0.75	2.8	0.27	0.37	6	-	-
PCBs (mg/kg)	0.034	0.59	0.012	0.1	0.007	0.011	1	-	-
Mineral Oil (mg/kg)	**804**	335	**883**	**810**	127	432	**500**	-	-
PAH (mg/kg)	8.1	1.8	3.6	15	1.8	2.3	100	-	-
Eluate Analysis							Limit values for compliance leaching test using BS EN 12457-2 at L/S 10 l/kg		
	mg/kg						mg/kg		
Antimony	0.03	0.027	0.027	0.026	0.016	0.026	0.06	0.7	5
Arsenic	0.024	0.0084	0.013	0.015	<0.0050	0.028	0.5	2	25
Barium	0.48	0.57	0.58	0.59	<0.20	0.77	20	100	300
Cadmium	<0.00040	0.00074	<0.00041	<0.00040	<0.00040	0.0029	0.04	1	5
Chromium	<0.0050	<0.0050	<0.0051	<0.0050	<0.0050	0.015	0.5	10	70
Copper	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	2	50	100
Mercury	0.00032	<0.00010	<0.00010	<0.00010	<0.00010	0.00017	0.01	0.2	2
Molybdenum	0.2	0.064	0.071	0.083	0.065	0.21	0.5	10	30
Nickel	0.076	0.046	0.057	0.14	0.017	0.13	0.4	10	40
Lead	<0.0050	0.026	0.015	<0.0050	<0.0050	0.023	0.5	10	50
Selenium	0.0068	0.005	0.0039	0.005	0.0053	0.0064	0.1	0.5	7
Zinc	<0.040	0.093	0.058	<0.040	<0.040	0.087	4	50	200
Chloride	75	38	77	430	11	42	800	15000	25000
Fluoride	1.5	2.3	2.2	1.3	3.2	1.3	10	150	500
Sulphate as SO4	**4200**	**2200**	**2400**	**7900**	560	**2600**	**1000**	20000	50000
Dissolved Organic Carbon	110	41	57	220	28	97	500	800	1000
Phenol	0.058	<0.0100	0.019	0.26	<0.010	0.035	1	-	-
Total Dissolved Solids	**7400**	**6100**	**5200**	**14000**	2200	**5400**	**4000**	60000	100000

[1]Relative to Council Decision 2003/33/EC guideline values for Inert, Stable/Non-Reactive and Hazardous Landfills

3.5 Site Hydrogeology

3.5.1 Groundwater Levels and Flow Direction

The ground investigation confirmed the main hydrogeological units underlying the site are the Gravel Formation and Rickardstown Formation. The groundwater flow direction in the Gravel Formation was determined using groundwater levels measured in monitoring wells with response zones in the Gravel Formation. The groundwater level measurements are presented on **Appendix D1** and were converted to groundwater elevations (m OD) using the surveyed top of casings of the monitoring wells as shown in Table 10.

Table 10: Groundwater and Leachate Elevations

Location	Response Zone	Elevations (m OD)		
		Monitoring Round 1 (i)	Monitoring Round 1 (ii)	Monitoring Round 2 (i)
		17/12/2018	04/03/2019	07/05/2019
MW01	Gravel	80.665	80.508	80.440
MW02	Gravel	74.838	75.225	75.560
MW03	Gravel	Dry	74.860	75.210
MW04	Gravel	74.624	74.871	75.140
MW05	Gravel	74.883	74.901	75.398
MW06	Gravel	75.304	75.237	75.411
MW07	Gravel	76.391	76.305	76.299
MW08	Limestone	75.602	75.498	75.349
MW09	Waste	80.611	80.504	80.705
MW10	Waste	79.344	- (1)	79.666
MW11	Waste	82.224	- (2)	82.030
MW12	Waste	Dry	Dry	77.660
MW13	Waste	82.177	82.216	82.087
MW14	Waste	77.998	77.922	77.805
MW15	Waste	Dry	78.761	77.617
MW16	Waste	Dry	78.102	77.793

[1] Measurement not possible due to flooding of headworks
[2] Rubber bung of well stuck, measurement not possible

The data from monitoring wells screened in the Gravel Formation was used to produce groundwater contour plots, these are presented on Figure 13, Figure 14 and Figure 15. The contours show that the groundwater flow direction is to the north east, which follows the Gravel Formation and topography, which turns to the south east towards the River Liffey. The Gravel Formation is most likely providing baseflow to the River Liffey. As such the River Liffey is a potential receptor to any potential contaminants in the groundwater of the Gravel Formation.

To complement the water level data from the onsite monitoring wells with a response zone in the Rickardstown Formation (Lk – locally important karstified aquifer), water levels were taken from domestic wells (which were surveyed) near the site. These were used to generate a groundwater contour map shown on Figure 16, which shows the groundwater gradient in the Rickardstown Formation (Lk) moving north east.

0 50 100 m

N W E S

Legend

Site Boundary

Wells

Contours:

Interval 1 m

Interval 0.2 m

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

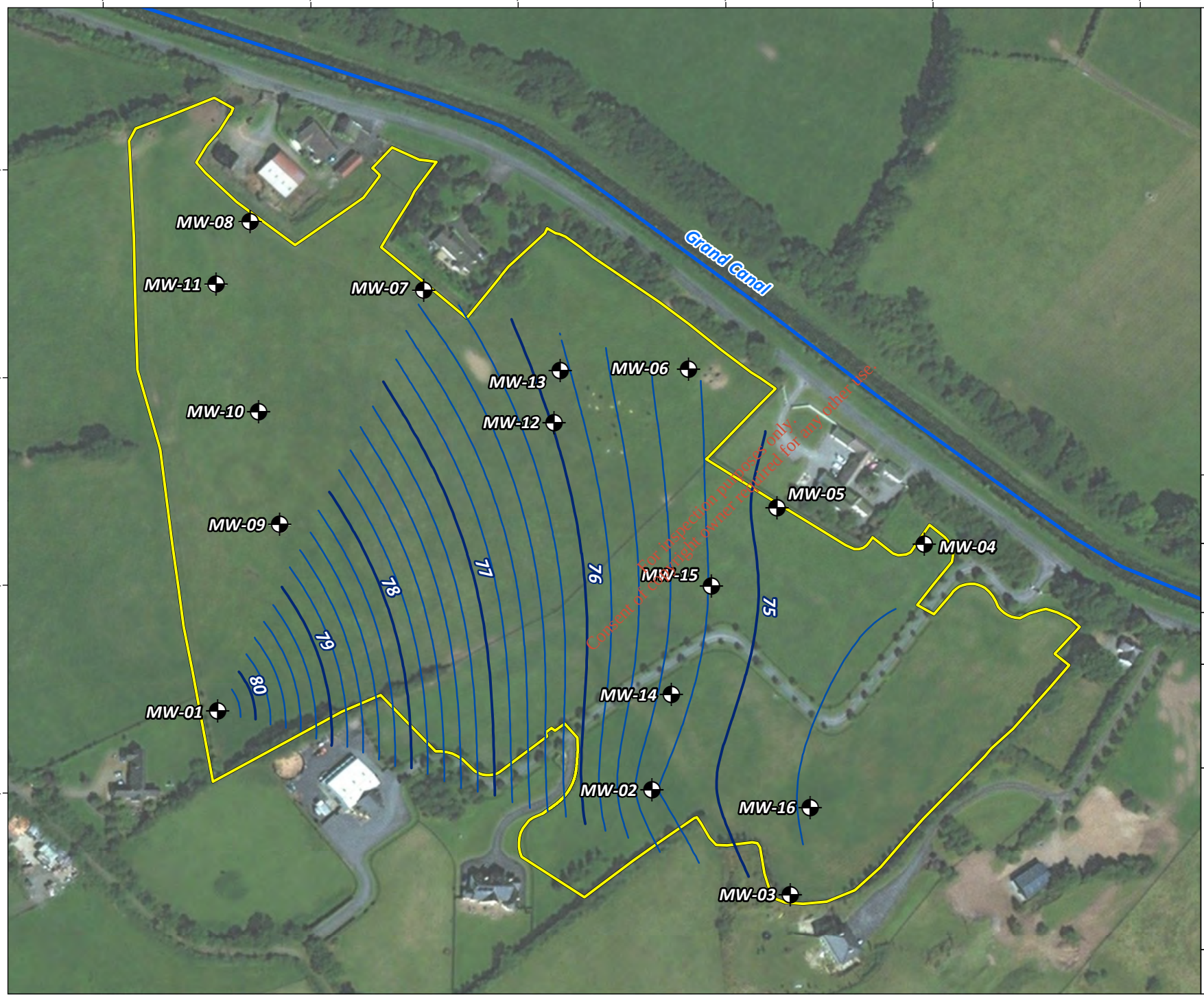
Consultant: CDM Smith

Project Code: 117838

Project: DIGBY BRIDGE

Drawing Title: FIGURE 13: GROUNDWATER CONTOUR - GRAVEL (DECEMBER 2018)

Drawn By:	Date:
SM	16/08/2019



0 50 100 m

N W E S

Legend

Site Boundary

Wells

Contours:

Interval 1 m

Interval 0.2 m

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

Consultant: CDM Smith

Project Code: 117838

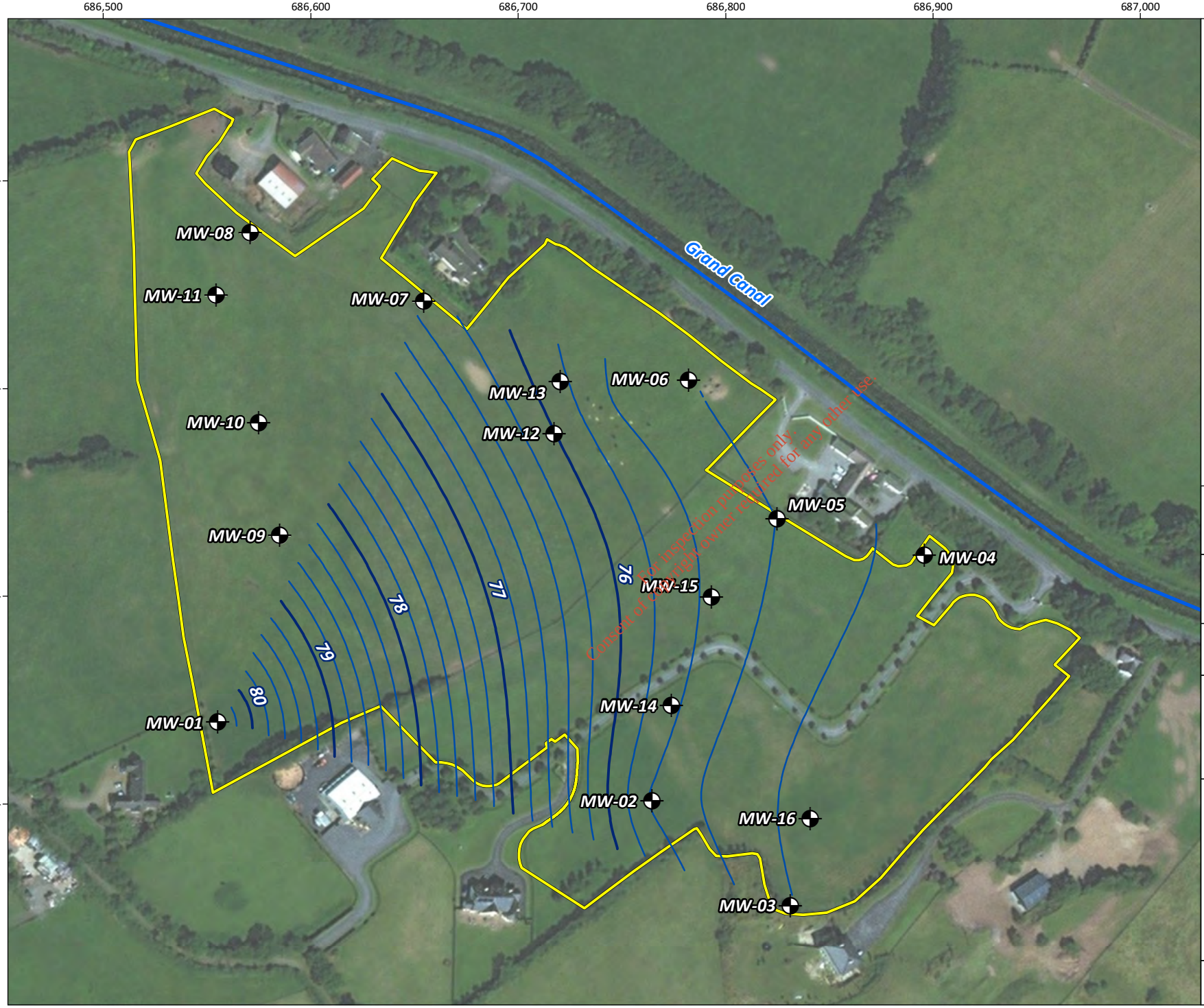
Project:

DIGBY BRIDGE

Drawing Title:

FIGURE 14: GROUNDWATER CONTOUR - GRAVEL (MARCH 2019)

Drawn By:	Date:
SM	16/08/2019



0 50 100 m

N W E S

Legend

Site Boundary

Wells

Contours:

Interval 1 m

Interval 0.2 m

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

Consultant: CDM Smith

Project Code: 117838

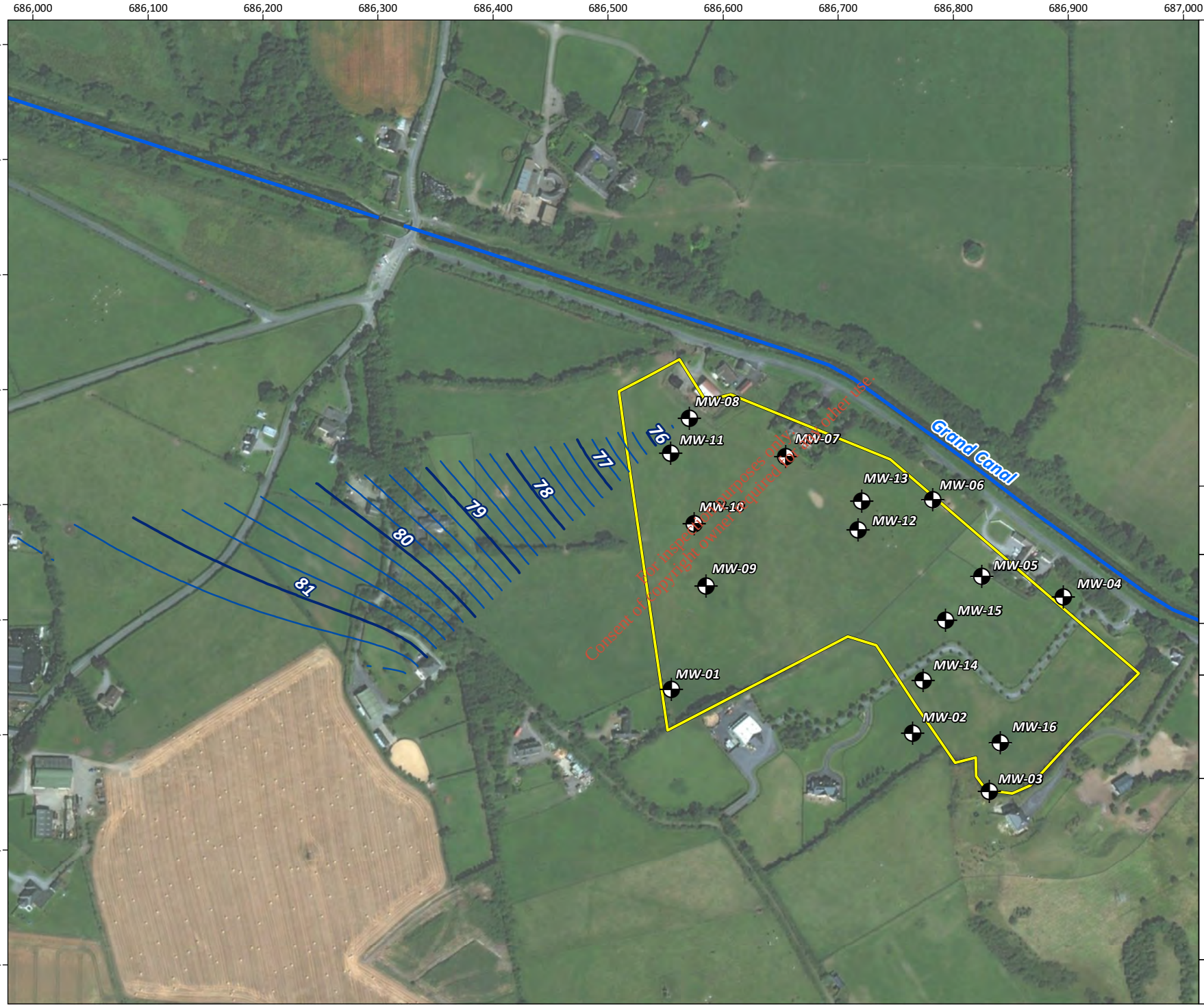
Project:

DIGBY BRIDGE

Drawing Title:

FIGURE 15: GROUNDWATER CONTOUR - GRAVEL (MAY 2019)

Drawn By:	Date:
SM	16/08/2019



0 50 100 m

N W E S

Legend

Site Boundary

Wells

Contours:

Interval 1 m

Interval 0.2 m

Source:
- ESRI World Imagery. © ESRI (Vivid-UK imagery courtesy of Digital Globe, acquired on 13/08/2015)

Coordinates are in Irish Transverse Mercator

Client: Kildare County Council

Consultant: CDM Smith

Project Code: 117838

Project: DIGBY BRIDGE

Drawing Title: FIGURE 16: GROUNDWATER CONTOUR - LIMESTONE (JUNE 2019)

Drawn By:	Date:
SM	14/08/2019

Groundwater levels were plotted on the cross-sections shown on Figure 6 through Figure 11, which shows the base of the canal above the groundwater water table in the Gravel Formation. Table 11 presents a summary of the levels observed at the canal and in the closest monitoring wells.

Table 11: Canal Levels

Location	Response Zone	Elevation (m OD) on 04/03/2019
MW04	Gravel	74.87
MW05	Gravel	74.90
MW06	Gravel	75.24
MW07	Gravel	76.31
MW08	Limestone	75.80
Canal Water Level	NA	77.49
Base of Canal	NA	76.51

The groundwater monitoring wells nearest the canal are MW04, MW05, MW06, MW07 and MW08. The water level in the canal was surveyed at 77.49 m OD and the base of the canal was measured at 76.51 m OD. The canal is above the groundwater table, and as such is not gaining water from the aquifer, but it may be losing water to the aquifer depending on the lining of the canal and its hydraulic integrity. As such there is no risk to canal water quality from contaminated groundwater in the Gravel Formation. This does not rule out the potential of surface water from the site impacting the quality of water in the canal.

The cross sections shown in Figure 6 through Figure 11 indicate that there is direct contact between the Gravel Formation and Rickardstown Formation (Lk). The contour plots on Figure 13 through Figure 16 show that the site groundwater levels in the Gravel Formation are similar to that of the groundwater levels in the Rickardstown Formation (Lk). As such, there is a potential pathway for contaminants between the Gravel Formation and Rickardstown Formation (Lk). Leachate levels have been measured above the groundwater levels on site during all site-wide gauging events. Leachate levels in waste body monitoring wells not dry at the time of measuring are generally higher than that of the Gravel Formation, as shown on Table 10. MW01 has groundwater levels above that of some leachate monitoring wells but that is due to MW01 being an upgradient monitoring well.

The waste mass is composed of highly variable materials at different stages of decay. The waste material has been deposited during landfilling of the site and compacted as such that flow and leachate levels in the waste mass will be highly variable. There will be layers and sections which are relatively impermeable, and conversely there will be layers that may be permeable and may behave as a preferential flow path.

During two sampling rounds, leachates were observed in some of the monitoring wells. The sampling was timed to coincide with rainfall events. The sampled wells were observed to go dry quickly after the rainfall events. This suggests that leachates are generated in pulses following wet weather events. Not all leachate wells dried up. Two wells-maintained leachate levels which were well above the groundwater table. As such, they represent perched levels within the waste

mass. The infiltration drains through the waste mass, into the Gravel Formation and the Groundwater in the Gravel Formation.

3.5.2 Landfill Cap Permeability

The Topsoil landfill cap is predominately sandy gravely clay with variable thickness. In places it overlies the Landfill Cover (fill over waste material) or is directly over the Landfill Waste material. PSD samples were taken of the landfill topsoil cap, these samples can be used to estimate hydraulic conductivity. Equations for estimating hydraulic conductivity from grain size commonly use two metrics from a grain size distribution plot: D_{10}, the grain diameter for which 10% of the sample is finer (90% is coarser), and D_{60}, the grain diameter for which 60% of the sample is finer (40% is coarser). AQTESOLV[1] provide a calculator which estimates hydraulic conductivity using D_{10} and D_{60}, based on equations by Hazen, Kozeny-Carmen, Beyer and Wang et al. The D_{10} and D_{60} for 10 No. of samples of the Topsoil covering the landfill is taken from PSD data presented in **Appendix B5**, this is summarised on Table 12.

Table 12: D10 and D60 values with estimated Hydraulic Conductivity of Capping Material

Sample	Depth (m)	D10	D60	Hydraulic Conductivity (m/s)
TP03	0.1	0.001	1.1	$8.07x10^{-9}$
TP05	0.3	0.002	0.3	$3.23x10^{-8}$
TP06	0.1	0.002	0.6	$3.23x10^{-8}$
TP08	0.1	0.005	2	$2.02x10^{-7}$
TP09	0.2	0.002	2	$3.23x10^{-8}$
TP10	1.0	0.005	0.3	$2.02x10^{-7}$
TP11	0.8	0.002	0.6	$3.23x10^{-8}$
TP12	0.3	0.005	1.18	$2.02x10^{-7}$
TP15	0.1	0.002	0.425	$3.23x10^{-8}$
TP03	0.2	0.002	0.425	$3.23x10^{-8}$
			Average:	$8.08x10^{-8}$

The values of hydraulic conductivity presented in Table 12 range between $8.07x10^{-9}$ and $2.02x10^{7}$ which is in the range of a low permeability till. The effectiveness of the Topsoil cap as a hydraulic barrier to precipitation infiltrating into the underlying layers can be considered limited. A combination of the following highlights the ability of precipitation to infiltrate the landfill cover and enter the waste mass to generate landfill leachate:

- Topsoil cap is very thin, 0.3m in places;
- Effects of differential settlement in opening fractures and fissures;
- The action of roots from vegetation planted on the landfill; and
- The underlying granular material which would not impede infiltration.

[1] AQTESOLV (2019) *Representative Values of Hydraulic Properties*< http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm>

There are no records of the construction of the landfill cover and cap, however, anecdotal evidence from a landowner suggests that approximately 60cm was designed for the landfill cap.

3.5.3 Field Observations and Field Parameters

Groundwater field parameters measurements are presented in **Appendix D2**. The range of values observed for the groundwater field parameters are provided on Table 13.

Table 13: Field Water Quality Parameters

Monitoring Event	Parameter	Units	Minimum	Maximum	Mean
Round 1 (1)	pH	pH units	6.37	6.90	6.61
	Temperature	°C	10.7	11.8	11.3
	Electrical Conductivity	µS/cm	650	1635	1084
	Redox Potential	mV	169.0	289.0	228.0
	Dissolved Oxygen	mg/L	0.19	3.09	0.97
Round 2 (2)	pH	pH units	6.49	6.99	6.71
	Temperature	°C	10.4	11.3	10.7
	Electrical Conductivity	µS/cm	616	2382	1138
	Redox Potential	mV	294.7	437.6	365.1
	Dissolved Oxygen	mg/L	0.22	3.08	1.30

[1]Leachate wells not included as chemical constituents were not known – potential to damage probes of water quality meter
[2]Leachate wells not included as sampled wells did not have sufficient sample water for measurement.

There were no unusual odours observed from monitoring wells (MW01 to MW08). Pungent odours were noted from some leachate samples obtained. Sour or H_2S odours were recorded at the headworks of the following monitoring wells, MW09, MW13, MW14, MW15 and MW16. No field evidence of non-aqueous phase liquids (NAPLs) were detected during the purging and sampling of the groundwater or leachate wells.

The pH of the groundwater is slightly acidic, ranging from 6.37 to 6.99, the most acidic being MW02. The redox potential measured ranged between 169.0 and 437.6, the lowest measured was in MW08. The Dissolved Oxygen ranged between 0.19 and 3.09 with the lowest observed in MW08. The field parameters indicate that aerobic conditions prevail in the aquifer.

3.5.4 Groundwater, Surface Water and Leachate Quality

Groundwater, leachate and surface water sampling monitoring was undertaken on 30 November, 17 December 2018, 8 and 28 May 2019, as well as 25 June; noted in Section 2.7. The laboratory reports are presented in **Appendix D3** and **Appendix D4**. The groundwater, leachate and surface water quality data has been collated and is included on **Appendix D2**.

Regulation 7 of the Groundwater Regulations further states that "*Point source discharges and diffuse sources liable to cause groundwater pollution shall be controlled so as to prevent or limit the input of pollutants into groundwater*".

This 'prevent or limit' objective is the core groundwater quality objective addressed by this guidance. In principle, 'prevent or limit' measures are the first line of defence in restricting inputs of pollutants to groundwater and thereby avoiding or reducing pollution. The 'prevent' objective relates to hazardous substances, whereby all necessary and reasonable measures

should be taken to avoid the entry of such substances into groundwater and to avoid any significant increase in concentration in groundwater, even at a local scale. The 'limit' objective relates to non-hazardous substances, whereby all necessary measures should be taken to limit inputs into groundwater to ensure that such inputs do not cause deterioration in status of groundwater bodies, nor significant and sustained upward trends in groundwater concentrations.

The EPA[2] published a list of hazardous substances and non- hazardous substances in 2010. The list has been further updated by Joint Agencies Groundwater Directive Advisory Group (JAGDAG), the January 2019 list is available from the UK Technical Advisory Group on the Water Framework Directive (UKTAG) website[3]

The risks to groundwater and surface waters will be evaluated with in the Tier 3 Refinement of CSM and Quantitative Risk Assessment as per the requirements of the EPA Code of Practice.

3.6 Ground Gas

3.6.1 Results of Landfill Gas Monitoring

The landfill surface emissions survey was conducted between 15 and 17 October 2018. The FID did not detect any gases, measuring zero for the duration of the survey.

Landfill gas monitoring was undertaken on 4 March and 25 June 2019. The results are presented in **Appendix F2** with a summary of the landfill gas monitoring results presented in Table 14. The results were screened against criteria provided in the EPA 2003 Landfill Monitoring Manual, 2nd Edition.

The EPA 2003 Landfill Monitoring Manual guidance recommends that monitoring can be discontinued when the following criteria are met:

- The maximum concentration of methane is less than 1% by volume (21% LEL) at all monitoring points over a 24-month period;
- The maximum concentration of carbon dioxide is less than 1.5% at all monitoring points over a 24-month period; and
- Measurements must be carried out on at least four separate occasions, including two occasions when atmospheric pressure was falling and was below 1,000 mbar.

The trigger levels for emissions of methane and carbon dioxide are 1% v/v and 1.5% v/v respectively in boreholes outside the waste body. The trigger levels also apply to measurements in any service duct or manhole on, at or immediately adjacent to the landfill. Elevated readings are shown on Figure 17.

[2] EPA (2010) Classification of Hazardous and Non-hazardous Substances in Groundwater
[3] UKTAG (2019) JAGDAG, https://www.wfduk.org/sites/default/files/Confirmed_Haz-NonHaz_January2019.pdf 19.05.2019

Table 14: Landfill Gas Summary Results and Screening against EPA Trigger Values

Well ID	Flow Rate (l/h)		Methane (% v/v)		Carbon Dioxide (% v/v)		No. of Exceedances of EPA 2013 Screening Values		Maximum Concentration of Trace gasses (ppm)	
	Min	Max	Min	Max	Min	Max	CH_4	CO_2	H_2S	CO
Monitoring Locations Outside the Waste Mass										
MW01A	0.0	0.0	0.0	0.0	4.2	5.9	0	2	1	1
MW02	-1.7	0.0	0.0	0.0	6.8	7.2	0	2	0	2
MW03	0.0	0.0	0.0	0.8	0.1	11.3	0	1	0	1
MW04	-0.6	0.0	0.0	0.0	0.0	0.4	0	0	0	1
MW05	0.0	0.0	0.0	0.0	9.2	11.9	0	2	0	2
MW06	0.0	0.0	0.0	0.0	0.0	6.0	0	1	0	1
MW07A	0.0	0.0	0.0	0.0	6.1	8.0	0	2	0	1
MW08A	-0.8	0.0	7.9	8.0	15.4	13.0	2	2	1	2
Monitoring Locations Inside the Waste Mass										
MW09	-0.4	0.0	52.0	56.2	4.2	13.0	2	2	2	4
MW10	0.0	0.0	7.6	7.6	6.0	6.0	1	1	0	1
MW11	0.0	0.0	1.2	8.5	1.1	8.9	2	2	0	2
MW12	-0.1	0.0	44.6	47.8	29.2	31.3	2	2	0	3
MW13	-0.3	0.0	36.0	56.5	26.1	28.0	2	2	0	3
MW14	-0.1	0.0	51.4	66.5	22.3	35.1	2	2	10	7
MW15	-0.8	0.0	0.0	10.3	0.1	4.7	1	1	0	1
MW16	0.0	0.0	0.2	40.6	0.2	5.5	1	1	0	1
Total no. of Exceedances over two monitoring rounds							**15**	**25**		

During the first round of LFG monitoring on 4 March 2019, atmospheric pressure rose from 991.4 hPa at 11:30 to 993.6 hPa at 14:00. Within the analysis window for the second round of monitoring on 26 June 2019, atmospheric pressure reduced from 1031 hPa at 13:00 to 1030.8 hPa at 16:00. The annual average of atmospheric pressure in Ireland falls within 1010 and 1020 hPa. A summary description of the results is listed below:

- Trigger level exceedances of CO_2 outside the waste body were detected in all monitoring wells except for MW04, ranging from 4.2 to 15.4% v/v;
- Exceeding concentrations of CO_2 inside the landfill were detected in all leachate wells, ranging from 4.2 to 35.1% v/v;
- A trigger level exceedance of CH_4 outside the waste body was detected in monitoring well MW08A, between 7.9 and 8.0% v/v in each round. An elevated concentration of CH_4 was detected in MW03, at 0.8% v/v; and
- Exceeding concentrations of CH_4 inside the landfill were detected in all leachate wells, ranging from 1.2 to 66.5% v/v.

3.6.2 Results of Household Gas Survey

The external gas property survey was conducted between 16 and 18 October 2018 at the locations shown on Figure 4, the results are shown in Table 15. The FID did not detect any gases, measuring zero for the duration of the survey.

The internal household gas survey took place on 25 June 2019 at the locations shown on Figure 4. The results are shown in Table 16. Stable methane concentrations were below the limit of detection (0.1% v/v) and carbon dioxide levels were at normal atmospheric concentrations. No trigger values were exceeded at the offsite properties.

Table 15: Results of External Household Gas Survey

Location	Date	Hydrocarbon Concentration (ppm)
FID01	15/10/2018	0.0
FID02	15/10/2018	0.0
FID03	15/10/2018	0.0
FID04	15/10/2018	0.0
FID05	15/10/2018	0.0
FID06	15/10/2018	0.0
FID07	15/10/2018	0.0
FID08	15/10/2018	0.0
FID09	15/10/2018	0.0
FID10	15/10/2018	0.0
FID11	17/10/2018	0.0
FID12	17/10/2018	0.0
FID13	17/10/2018	0.0
FID14	17/10/2018	0.0
FID15	17/10/2018	0.0
FID16	17/10/2018	0.0
FID17	17/10/2018	0.0
FID18	17/10/2018	0.0

Table 16: Results of Internal Household Gas Survey

Location	Date	Atmospheric Pressure (mb)	CH_4 % (v/v)	CO_2 % (v/v)	O_2 % (v/v)	H_2S ppm	CO ppm
House 1 Kitchen	25/06/2019	1015	0.0	0.1	20.5	0	1
House 1 Bathroom	25/06/2019	1015	0.0	0.1	20.8	0	1
House 2 Kitchen	25/06/2019	1017	0.0	0.1	21.7	0	1
House 3 Kitchen	25/06/2019	1017	0.0	0.2	21.5	0	7

Section 4 Conclusions and Recommendations

4.1 Hydrogeology

Following the Tier 2 Site Investigation, a Tier 3 assessment for controlled waters (surface and groundwater) should be undertaken whereby Generic Quantitative Risk Assessment (GQRA) and Detailed Quantitative Risk Assessment (DQRA) will be completed to assess risk to groundwater and surface water (controlled waters) from the Digby Bridge Legacy Landfill Site. The CSM and S-P-R linkages will be refined and revised using the data and information collected during the Tier 2 investigation.

A 'Remedial Target Criteria' (RTC) for soil or groundwater contamination will be developed and additional processes such as dilution and attenuation will be considered as progressive levels, which may affect contaminant concentrations along the pathway from the source to the receptor are included in the assessment allowing for derivation of less stringent RTC's. Remediation measures may be required (for example, remediation of the existing cap to minimise leachate generation), or long-term monitoring depending on the outcome of the Tier 3 Refinement of CSM and Quantitative Risk Assessment.

4.2 Landfill Gas

The landfill monitoring has identified high concentrations of landfill gas in the waste mass and concentrations of landfill gas above EPA 2003 trigger values in monitoring wells both inside and outside the waste body. Based on the EPA 2003 Landfill Monitoring Manual guidance discussed in Section 3.6.1, Kildare County Council should undertake regular gas monitoring of the Digby Bridge site to assess the trend in ground gas concentrations.

There are several houses and buildings adjacent to and within 250 metres of the site. The offsite gas property survey did not detect any landfill gas concentrations above EPA 2003 trigger values. The site investigation shows the subsurface to be predominantly composed of sands and gravels which could act as horizontal pathway for landfill gas. The Made Ground (over in-situ) is predominantly gravelly sand material which gas can pass through both horizontally and vertically. The Topsoil is predominately gravelly clay, but its narrow thickness, rootlets and noted subsidence has most likely resulted in many fractures (vertical pathways) for the gas to vent to the atmosphere.

Landfill gas poses various risks to human health and property including:

- Flammability and explosion;
- Asphyxiation; and
- Potential impacts due to many minor constituents present at low concentrations.

The S-P-R linkage is presented in Table 17.

Table 17: S-P-R Linkage – Landfill Gas

Source	Pathway	Receptors	Discussion
Landfill gas generated by the waste mass - high concentrations present	Vertically through the gravelly sand capping material	Human (onsite)	Very low likelihood, high dilution with the atmosphere makes it unlikely that gases would be at concentrations harmful to humans
		Building (onsite)	Very low likelihood, no buildings directly over the landfill
		Buried services (onsite)	Very low likelihood, no services or manholes in the landfill
	Horizontally through the gravel and sand formation	Human (offsite)	Possible risk, asphyxiation caused by landfill gas migrating. Possible risk or injury if dwelling or farmhouse has a fire or explosion
		Building (offsite)	Possible risk, dwelling or farmhouse has a fire or explosion caused by landfill gas migrating
		Buried services (offsite)	Possible risk, dwelling or farmhouse has a fire or explosion caused by landfill gas migrating into service duct

The monitoring results indicate that a possible risk may exist to offsite receptors. These results give context to exceedances in specific climatic conditions but to establish overall risk and to complete the Tier 3 Refinement of CSM and Quantitative Risk Assessment, the true nature of the landfill gas within the waste body needs to be understood further.

We recommend that an additional investigation is undertaken using time-limited withdrawal of landfill gas while measuring temperature, flow and the concentration of CH_4, CO_2, CO and O_2 at different horizons in monitoring wells. This investigation should aim to:

- Determine gas composition;
- Determine organic carbon discharge via the gas path;
- Verify first aerobic degradation in areas of the landfill;
- Verify gas production and gas potential; and
- Determine the presence of possible leaks in vertical gas wells.

A parallel time-limited extraction test could also be conducted to assess gas quality present in the vicinity of gas monitoring wells and measure the underlying pressure in wells nearby. All gas data would be used in a Tier 3 Refinement of CSM and Quantitative Risk Assessment of landfill gas potentially migrating offsite through the subsurface to impact offsite receptors.

Overall, this will allow the exact nature of the gas system within the waste mass to be assessed more comprehensively, providing more conclusive data on gas composition, as well as its present and potential production in the future. The results of this additional investigation would assist in determining the actual risk to receptors both on and off site and allow a much more robust Tier 3 Risk Assessment to be completed.