June 2018

Hydrogeological Risk Assessment
Walshestown Waste Management Facility

Walshestown Restoration Ltd

Waste Licence W0254-01

MALONE O'REGAN

QUALITY
ISO 9001:2008
NSAI Certified

Form ES - 04

MALONE O'REGAN ENVIRONMENTAL

Ground Floor- Unit 3
Bracken Business Park
Bracken Road, Sandyford
Dublin, D18 V4K6
Tel: + 353 1 5677655
Email: enviro@mores.ie

Title: Hydrogeological Risk Assessment, Walshestown Waste Management Facility

Job Number: E1172

Prepared By: Simon Firth **Signed:** ______

Checked By: Thomas Vainio-Mattila **Signed:** ______

Approved By: Thomas Vainio-Mattila **Signed:** ______

Revision Record

Issue No.	Date	Description	Remark	Prepared	Checked	Approved
1	13/06/18	Hydro RA	Final	SF	TVM	TVM

Executive Summary

Malone O'Regan Environmental (MOR) was retained by Walshestown Restoration Ltd. (the Client) to undertake a Hydrogeological Risk Assessment (HRA) for an inert waste landfill at the former worked out sand and gravel pit located at Walshestown, Blackhall, Tipperkevin, Bawnoge and Blackhall, Naas, County Kildare ('the Site'). The main objective of this HRA is to assess whether the disposal of waste with up to three times the WAC limit for inert waste (as defined in European Communities [EC] Council Decision 2003/33/EC) for specific substances would present an unacceptable risk to groundwater or surface water receptors. A further objective is to assess the risk from approximately 570,000 tonnes of material which has been imported to the site under Article 27 which is not within the engineered landfill cells. The specific substances considered are arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, tin, selenium, zinc, chloride, fluoride and sulphate.

The Site is licenced to accept 330,000 tonnes of waste per annum up to a total of 2,400,000 m3. The landfill is being constructed as a series of cells, each of which has a mineral liner on the base and sides which is at least 1m thick and has a permeability not exceeding 10^{-7} $m.s^{-1}$. Once each cell has been filled with waste it will be profiled and then capped with 1m thickness of soil and vegetated. The maximum proposed thickness of waste in each cell ranges from 8 to 18m. Each cell will take an average of around two years to fill, with final restoration of the Site being completed within about 15 years. The accumulation of significant quantities of leachate within the landfill is not anticipated and so leachate control measures are not proposed.

The Site is located to the immediate east of Punchestown racecourse and approximately 5km south east of Naas. The geology underlying the site comprises up to approximately 40m thickness of overburden deposits (glacial sands, gravels and till) underlain by siltstone bedrock of the Carrighill Formation. Groundwater monitoring indicates that groundwater is present in both the overburden and bedrock and that groundwater flow is towards the west/north-west.

A conceptual site model (CSM) of risk was developed which identified leaching of contaminants from the inert waste as the source, leakage of leachate through the mineral liner (landfilled waste only) and underlying unsaturated zone followed by dilution and migration in groundwater as the pathway and groundwater as the receptor. The risk to surface water was considered unlikely to be significant owing to the large distance to the nearest plausible surface water receptor (the River Liffey 8km north west of the Site).

A detailed quantitative risk assessment (DQRA) was conducted to further assess the risk to groundwater from the landfilled waste and Article 27 material. The probabilistic model LandSim was used for the assessment. LandSim had been used in previous HRAs conducted for the Site and is considered an appropriate tool for the DQRA. Probability distribution functions (PDFs) were defined for each input parameter based on site specific data (where possible) or literature values. The model was run for 20,000 years and was used to predict probability distributions of contaminant concentrations with time at a point of compliance.

The point of compliance and compliance values were chosen in accordance with EPA guidance (2011). The point of compliance was a hypothetical monitoring well immediately down-hydraulic gradient of the landfill. Minimum reporting values (MRVs) (where available) or practical limits of detection were used as the compliance values for hazardous substances (arsenic, cadmium, lead and mercury). EC Drinking Water Standards (where available) or Irish Groundwater Threshold Values were used as the compliance values for the remaining non-hazardous substances with the exception of barium, molybdenum, tin and selenium which had no suitable compliance values and were not modelled.

The source concentration for waste in the landfill cells was conservatively assumed to be three times the WAC limit (Co percolation test) for each modelled contaminant. The source concentration for the Article 27 material was conservatively assumed to be equal to the WAC limit (Co percolation test) for each modelled contaminant. The predicted maximum 95th percentile concentration of each contaminant at the compliance point was below (and in most cases well below) the compliance values. For this reason it has been concluded that the landfilling of waste with up to three times the inert WAC limits for the specific substances considered would not pose an unacceptable risk to groundwater (or surface water) receptors. Consideration should therefore be given to increasing the site specific WAC for these substances to three times the inert WAC limits as allowed in accordance with EC Council Decision 2003/33/EC. It is also concluded that the Article 27 material does not pose an unacceptable risk to groundwater (or surface water) receptors.

Hydrogeological Risk Assessment

Walshestown Waste Management Facility

Walshestown Restoration Ltd

Waste Licence W0254-01

Contents

DRAWINGS

TABLES

APPENDICES

Appendix A: Slug test analyses conducted by MOR

Appendix B: Golder Associates drawing showing proposed formation levels

Appendix C: LandSim Inputs

Appendix D: LandSim Outputs

1.0 INTRODUCTION

Malone O'Regan (MOR) was retained by Walshestown Restoration Ltd. (the Client) to undertake a Hydrogeological Risk Assessment (HRA) for a waste facility at the former worked out sand and gravel pit located at Walshestown, Blackhall, Tipperkevin, Bawnoge and Blackhall, Naas, County Kildare ('the Site') (Drawing 1).

WRL operates a waste recovery and disposal facility at the Site. This is an engineered facility with a base and side slope lining system and a surface water collection system. The facility is currently being engineered and developed to satisfy the requirements of Waste Licence Register Number W0254-01 issued by the Environmental Protection Agency (EPA or Agency) on the 23rd October 2013.

The Site is licenced to accept 330,000 tonnes of waste per annum. The license requirements include provision of a 1m thick mineral (clay) liner with permeability not exceeding $1x10^{-7}$ms on the base and sides of the landfill. The landfill is being constructed as a series of seven cells. Construction of the mineral liner for the first (Cell 1A) was completed end of 2016 and landfilling of this cell commenced in January 2017.

In accordance with the license conditions, waste deposited at the Site should meet the Waste Acceptance Criteria (WAC) for inert landfills given in EC Council Decision 2003/33/EC. Annex Section 2 of the EC Council Decision provides an option whereby Member States can, in certain circumstances, accept WAC limit values up to three times higher for specific parameters[1], subject to the following conditions:

- the competent authority (in this case, the Environmental Protection Agency [EPA]) gives a permit for specified wastes on a case-by-case basis for the recipient landfill, taking into account the characteristics of the landfill and its surroundings; and
- emissions (including leachate) from the landfill will present no additional risk to the environment according to a risk assessment.

The client wishes to apply to allow for the use of inert waste material with concentrations up to three times the inert WAC limit values for specific substances[1] in the restoration of the Site. The HRA presented herein is partly to support the application for this variation.

In order to meet EPA requirements, a secondary objective of the HRA is to assess the risk to the water environment from material that has been imported to the Site under Article 27 that is not contained within a landfilled cell.

1.1 Project Objective

The objectives of this HRA are as follows:

- to determine whether or not disposal of waste with concentrations of specific substances (namely arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, tin, selenium, zinc, chloride, fluoride and sulphate) of up to three times the WAC limit values for inert waste would lead to unacceptable risks to groundwater or surface water receptors via the leakage of leachate from the landfill; and,
- to assess the risk to the water environment from material that has been imported to the Site under Article 27 that is not contained within landfill cells.

[1] Namely arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, tin, selenium, zinc, chloride, fluoride and sulphate

1.2 Scope of Work

The following work has been conducted in order to meet the project objective:

- Review of existing relevant information. This included review of previous risk assessment reports for the Site, landfill construction details and groundwater monitoring data (see Section 1.3);
- Hydraulic conductivity testing. Falling/rising head tests were conducted in on-site groundwater monitoring wells BH7, BH8, BH9, BH10 and BH13 on the 18th and 23rd of October 2017. The test data were analysed to derive hydraulic conductivity estimates for the screened strata;
- Development of Conceptual Site Model (CSM) of risk. Information on the landfill design was used along with information on the Site geology, hydrogeology and hydrology to develop a CSM. This describes potential sources, pathways and receptors and identifies plausible source-pathway-receptor combinations that require further assessment;
- Detailed Quantitative Risk Assessment (DQRA). DQRA has been undertaken using the LandSim model. This has been used to estimate the concentrations of contaminants arising from the landfilled waste and Article 27 material at an applicable point of compliance in order to assess risk;
- Preparation of a detailed report.

1.3 Sources of Information

The following sources of information have been reviewed for this risk assessment:

- Waste Licence No. W0254-1, dated 23 October 2013;
- Golder Associates, 2008a. Summary Report on Ground Investigations at Walshestown Pit, Co. Kildare. Report 07 5071 50230 R01/V1, October 2008;
- Golder Associates, 2008b. Environmental Impact Statement for the Proposed Pit Restoration, Walshestown, Co. Kildare. December 2008;
- Golder Associates, 2008c. Waste License Application for the Proposed Pit Restoration, Walshestown, Co. Kildare. December 2008;
- Golder Associates, 2008d. Report on Conceptual Site Model and Water Impact Assessment for Walshestown Pit Restoration. Report 07 5071 50230 R02/V3, November 2008. This presents the LandSim modelling conducted by Golder Associates to assess the risk to groundwater from the proposed inert landfill. Golders Associates used the model results to propose waste acceptance criteria for the site;
- Golder Associates, 2011. Report on revised HRA. Report 09507150022.R02.A0, January 2012. Golder Associates revised the LandSim modelling to take account of the new groundwater threshold values brought in with the EC Environmental Objectives (Groundwater) Regulations 2010 (SI No. 9 of 2010);
- Borehole logs for monitoring wells BH1 to BH14;
- MOR groundwater monitoring data for the Site – groundwater levels and quality;

- MOR, 2016. Construction Quality Assurance (Phase 1 Development) Condition 3.5.5, Walshestown Waste Management Facility, Waste Licence W0254-01. December 2016; and,
- Geological Survey of Ireland (GSI) on-line mapping data.

In addition, the work has been conducted in accordance with the following guidance documents:

- EPA, 2011. Guidance on the Authorisation of Discharges to Groundwater. Version 1, December 2011; and,
- Defra and Environment Agency, 2016. Landfill developments: groundwater risk assessment for leachate. Available at https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate. First published 1 February 2016.

1.4 Disclaimer

The conclusions presented in this report are professional opinions based solely on the tasks outlined herein and the information made available to MOR. They are intended for the purpose outlined herein and for the indicated Site and project. The report is for the sole use of the Client. This report may not be relied upon by any other party without explicit agreement from MOR. Opinions and recommendations presented herein apply to the Site conditions existing at the time of the assessment. They cannot apply to changes at the Site of which MOR is not aware of and has not had the opportunity to evaluate. This report is intended for use in its entirety; no excerpt may be taken to be representative of this assessment. All work carried out in preparing this report has utilised and is based on MOR professional knowledge and understanding of the current relevant Irish and European Community standards, codes and legislation.

2.0 SITE LOCATION AND SETTING

2.1 Site Location and Surrounding Land Use

The Site is located to the immediate east of Punchestown racecourse and is approximately 5km south east of Naas. The Site covers a total area of approximately 70 Ha and is centred on Irish National Grid co-ordinate 292850 215500. The Site location is shown in Drawing 1.

The southern and central eastern parts of the Site have been restored to agricultural grazing land. The remainder of the Site is yet to be restored since the cessation of quarrying activities. An engineered landfill cell (Cell 1A) has been constructed in the north east corner of the Site. There are currently four large ponds at the Site: Ponds A1, A2 and A3 (which are interconnected) in the north east corner of the Site and Pond B in the central/south part of the Site (Drawing 2).

The Site is situated in an area of gently undulating topography. The topography over much of the Site has been modified by quarrying. As a result, ground levels range from approximately 168 metres above Ordnance Datum (mAOD) in the east of the Site to 140 mAOD in the area of the ponds in the northwest corner of the Site.

The Site is surrounded predominantly by agricultural land with the exception of the Punchestown racecourse to the immediate west of the Site, an EPA licenced waste facility adjacent to the east (Behans Land Restoration Ltd, Waste Licence Register number W0247-01) and a further (currently) inactive sand and gravel quarry to the south of the Site.

2.2 Hydrology

From a regional perspective, surface drainage is from southeast to northwest, although locally there is some variation because of topography. There are no major rivers in the immediate vicinity of the Site. The River Liffey is located approximately 6km to the south, which flows west to Newbridge and then northeast past Naas. A small stream flows northwest alongside the road at the entrance of the Site and joins the Morell River, which is a tributary of the River Liffey. A second small stream is located 300m south of the Site. These are understood to be perched on top of clayey Quaternary deposits and are not considered to be in hydraulic continuity with groundwater (Golder Associates, 2008b).

According to Golder Associates (2008b), average annual rainfall at Naas was 782 mm for the period 1961 to 1990.

2.3 Geology

The Geological Survey of Ireland (GSI) online mapper[2] indicates that the bedrock beneath the Site comprises the Silurian Carrighill Formation. This consists of calcareous greywacke, siltstone and shale and is shown to dip to the northwest at an angle of 42°. Lithological logs from boreholes drilled at the Site describe the bedrock as siltstone which is weathered in the uppermost few metres.

The GSI online mapper indicates that the bedrock at the Site is overlain by Quaternary overburden deposits. According to the online mapper the dominant sediment type in the uppermost 1m of these deposits at the Site is gravels. To the immediate west of the Site at the Punchestown racecourse the dominant Quaternary sediment type within the uppermost 1m is shown to be Till derived from limestones.

[2] http://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228

Borehole drilling at the Site has shown that the nature of the overburden deposits is highly variable (both vertically and horizontally) with descriptions ranging from relatively clean sands and gravels to gravelly silts and clays. The predominant sediment type appears to be sands and gravels, which are often described as clayey. Based on borehole logs the thickness of overburden deposits at the Site ranges from 15.1m (BH3) to 37.9m (BH5).

An interpreted geological cross-section at the Site is shown in Drawing 3.

2.4 Hydrogeology

The GSI online mapper indicates that the overburden deposits at the Site are part of the West Blessington Gravels aquifer. The bedrock is classified as a Poor aquifer which is generally unproductive. According to the GSI online mapper aquifer recharge within the vicinity of the Site is estimated to be 415 $mm.yr^{-1}$.

A number of groundwater monitoring wells have been installed at the Site, some of which are screened within the overburden deposits and some within the bedrock. The locations of the monitoring wells are shown in Drawing 2.

The majority of these wells have been monitored on a monthly basis since January 2017. Hydrographs of the monitored groundwater levels in the overburden and bedrock wells are shown in Drawing 4. These hydrographs show that there has been relatively little seasonal variation in groundwater levels, with the range in groundwater levels in each well typically being 1m or less.

Groundwater levels in the overburden range from approximately 151 mAOD in the east (BH4) to 135 mAOD in the west (BH14). Based on the monitoring data groundwater in the overburden appears to be flowing towards the northwest (Drawing 5) with a hydraulic gradient ranging from of approximately 0.016 (in the central area) to 0.030 (in the north east). Groundwater levels in the bedrock range from approximately 143 mAOD in the east (BH7) to 132 mAOD in the west (BH13). Based on the monitoring data groundwater in the bedrock appears to be flowing towards the west (Drawing 6) with a hydraulic gradient ranging from approximately 0.008 (in the west) to 0.027 (in the north east).

Groundwater levels in the overburden can be several metres higher than in the underlying bedrock indicating that there is not a good hydraulic connection between the two groundwater bearing units. This is likely due to the presence of relatively low permeability clayey sands and gravels (possibly Till) that overlie the bedrock across much of the Site (Drawing 3). The difference in groundwater levels means that there will be a vertical (downwards) component of groundwater flow from the overburden deposits into the bedrock. The exception is in the north east corner of the Site where groundwater levels are similar. As seen on the cross-section (Drawing 3) clean sands and gravels overlie the bedrock in this part of the Site.

The elevation of the surface watercourses nearest the Site are greater than the groundwater levels in the west of the Site and thus groundwater is most likely discharging to the River Liffey 8km to the northwest. Surface water level of the River Liffey at this location is approximately 70m, which is 62m below the groundwater levels in the bedrock in the west of the Site. Based on these levels, average hydraulic gradient in the bedrock between the Site and the River Liffey is estimated to be approximately 0.008 (62m/8000m), similar to that estimated for the bedrock in the west of the site.

A series of “slug” tests have been conducted in the monitoring wells at the Site in order to estimate hydraulic conductivity of the overburden and bedrock groundwater bearing units. Golder Associates conducted a number of slug tests in May 2008 and MOR conducted slug tests in October 2017. The same procedure was used on both occasions whereby the water level in the monitoring well was quickly increased by introducing a “slug” into the well and monitoring the recovery in water levels using a pressure transducer (“diver”). The slug was then removed (to quickly reduce water levels) and the recovery in water levels again monitored using the pressure transducer. Slug test analysis methods were then used to estimate hydraulic conductivity from the water level versus time data. The MOR analysis is presented in Appendix A. A summary of the hydraulic conductivity estimates derived is presented in Table 2-1 below:

Table 2-1 Hydraulic conductivity estimates from slug tests

Monitoring Well	Analyst	Geological Strata Tested	Analytical method	Hydraulic conductivity	
				m.s^{-1}	m.d^{-1}
BH1	Golder Assoc.	Running sand	General rising head	1.8E-4 – 9.6E-4	15.5 - 83
BH4	Golder Assoc.	Gravelly clay	General rising head	7.6E-5	6.6
BH5	Golder Assoc.	Clayey gravel, cobbles & weathered bedrock	General rising head	6.9E-7 - 1.2E-5	0.06 – 1.1
BH6	Golder Assoc.	Sand and gravelly clay	Simple rising head	1.0E-3	86
BH8	Golder Assoc.	Gravelly sand	Simple rising head	5.6E-6	0.5
	MOR		Bouwer-Rice	2.4E-6 – 5.0E-6	0.21 – 0.43
BH9	MOR	Clayey sandy gravels	Bouwer-Rice	4.0E-6 – 4.9E-6	0.34 – 0.42
BH3	Golder Assoc.	Siltstone bedrock	General rising head	3.8E-4	33
BH7	Golder Assoc.	Siltstone bedrock	General rising head	8.7E-6 – 5.0E-5	0.75 – 4.3
	MOR		Bouwer-Rice	9.2E-6 – 1.0E-5	0.8 – 0.88
BH10	MOR	Siltstone bedrock	Bouwer-Rice	3.6E-5 – 3.8E-5	3.1 – 3.3
BH13	MOR	Siltstone bedrock	Bouwer-Rice	1.4E-4 – 1.8E-4	12 – 16

The slug test analyses indicate that the hydraulic conductivity of the overburden deposits is highly variable, ranging from 0.06 to 86 m.d^{-1}, reflecting the variable nature of these deposits. The hydraulic conductivity of the bedrock ranges from 0.75 to 33 m.d^{-1}.

2.5 Groundwater Quality

MOR have been monitoring groundwater quality at the Site since April 2016. Groundwater samples have been analysed for a wide range of determinands including metals, volatile organic carbons (VOCs), semi-volatile organic carbons (SVOCs) and pesticides. VOCs have not been detected in groundwater with the exception of 0.9 µg.L^{-1} and 0.3 µg.L^{-1} vinyl chloride in BHA in November 2016 and January 2017, respectively. Vinyl chloride was not detected in this well when next sampled in July 2017. SVOCs and pesticides have not been detected in groundwater. The range in concentrations of metals and other key determinands are compared with groundwater standards in Table 2-2 below:

Table 2-2 Groundwater Quality Summary

Determinand	Units	Range in concentration	Groundwater Standard [1]
Dissolved Cadmium	ug.L^{-1}	<0.03 - <0.5	3.75
Total Dissolved Chromium	ug.L^{-1}	<0.2 – 1.8	37.5
Dissolved Copper	ug.L^{-1}	<3 - <7	1500
Dissolved Lead	ug.L^{-1}	<0.4 - <5	7.5
Dissolved Mercury	ug.L^{-1}	<0.5 - <1	0.75
Dissolved Nickel	ug.L^{-1}	<0.2 – 2	15
Dissolved Zinc	ug.L^{-1}	<1.5 – 3.7	75
Chloride	mg.L^{-1}	5.6 – 16.2	24 – 187.5
Fluoride	mg.L^{-1}	<0.3	-
Sulphate	mg.L^{-1}	4.3 – 49.6	187.5
Nitrate as NO_3	mg.L^{-1}	<0.2 – 15.9	37.5
Nitrite as NO_2	mg.L^{-1}	<0.02 – 0.05	0.375
Total Ammonia as N	mg.L^{-1}	<0.025 – 0.37	0.175 [2]

Notes: 1) Groundwater Regulations 2010 (S.I. No. 9 of 2010) as amended (S.I. No. 149 of 2012 and S.I. No. 366 of 2016)
2) Groundwater standard for ammonium (as N)

The table above indicates that all key deteminands recorded concentrations in groundwater consistently below their respective groundwater standards with the exception of total ammonia. Concentrations of total ammonia have been recorded above the groundwater standard for ammonium of 0.175 $mg.L^{-1}$ at two of the thirteen sampling locations, namely BH13 and BHA. In the case of BH13, a concentration of 0.25 $mg.L^{-1}$ was recorded in May 2017 but the concentrations in all subsequent monitoring rounds were below the groundwater standard. At BHA, the concentrations of total ammonia have exceeded the groundwater standard in eight of the eleven monitoring rounds and the average concentration in this well has been 0.22 $mg.L^{-1}$.

2.6 Landfill Design

The inert landfill is proposed to be constructed in phases as a series of cells (seven in total), each of which will have a mineral (clay) liner on the base and sides at least 1m thick with a permeability not exceeding 10^{-7} $m.s^{-1}$. Once each cell has been filled with waste it will be profiled and capped with a minimum of 1m thickness of subsoil/topsoil in order to meet the agreed restoration levels. Note that the proposed restoration profiling has been designed to encourage runoff to the Site storm water drainage system and thus to minimise infiltration and generation of leachate. As a result significant accumulation of leachate is not expected within the landfill and leachate control measures are not proposed.

The basal liner for Cell 1A has been constructed and the landfilling of inert waste has commenced in this cell. The Construction Quality Assurance (CQA) report for this cell (MOR, 2016) confirms that the clay liner is 1m thick and that the permeability is less than 10^{-7} $m.s^{-1}$.

The proposed arrangement of cells is shown in Drawing 7. The proposed cell areas, formation levels and anticipated maximum waste thicknesses are provided in Table 2-3 below.

Table 2-3 Proposed landfill cell dimensions

Cell	Surface Area (ha)	Proposed formation level (mAOD) [1]	Maximum anticipated waste thickness (m) [2]
1A	2.68	151	8
1B	2.52	151	8
2	8.0	143	12
3	8.0	143	10
4	5.8	147	10
5	8.5	147	18
6	4.5	151	15

Notes: 1) Formation level of Cell 1A from Drawing 113, CQA Phase 1 report (MOR, 2016). Formation level of Cell 1B assumed to be current ground level from Drawing 110, CQA Phase 1 report (MOR, 2016). Formation level of remaining cells from Golder Associates Drawing 8.14, December 2013 (see Appendix B)

2) Anticipated waste thickness calculated from difference between formation level and proposed restoration surface level (see Drawing 4) minus 1m allowance for liner and 1m allowance for capping soils

2.7 Article 27 Material

There are currently various stockpiles of inert waste material at the site that are not within the engineered landfill cells. This material has been imported to the site under Article 27 and is intended for use in construction of various elements of the landfill such as capping layers and screening bunds. The EPA now requires the potential risk from this material to be assessed. The areas of Article 27 material placed outside the landfill cells are shown in Drawing 8. The areas, ground levels and estimated average thickness of material in each area are provided in Table 2-4 below.

Table 2-4 Dimensions of stockpiles of Article 27 material at the site

Area	Surface Area (m^2)	Volume material imported to area (m^3) [1]	Estimated average thickness of material (m) [2]	Ground level (mAOD)
C1A	10440	32796	3.1	151
C2	12020	24439	2.0	141-155
B1	34820	189513	3.5 [3]	141-158
B2	7229			144-151
B3a	7361			143-153
B3b	2178			147-152
B4a	1053			147-152
B4b	1179			148-150
SP1	6561	24439	3.7	154-161
SP2	3921	4869	1.2	150-158
Process Area	4848	7356	1.5	158

Notes

1. *Volume estimated from total mass imported in tonnes divided by an assumed 2 tonnes.m^{-3}*
2. *Average thickness estimated from volume imported to each area (from Article 27 import records) divided by stockpile surface area (from Drawing 8).*
3. *Average thickness for B stockpiles calculated from total import volume to B areas divided by total surface area of B areas.*

3.0 CONCEPTUAL SITE MODEL

The development of the conceptual Site model (CSM) involves the identification of the potential sources, pathways and receptors and determining which combinations of these are plausible pollutant linkages. There must be at least one source, pathway and receptor in each linkage for there to be a risk. Plausible linkages have been assessed further using risk quantification (see Section 4).

3.1 Sources

This risk assessment considers the risk from the landfilled waste contained within the landfill cells and from the Article 27 material in its current location within various stockpiles across the site.

The source is the potentially contaminating components of the leachate, which may be generated from the leaching of the inert waste or Article 27 material by infiltrating rainfall. Given the objective of this risk assessment (see Section 1.1) the contaminants of potential concern (COPC) are considered to be arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, tin, selenium, zinc, chloride, fluoride and sulphate.

It is assumed that the initial concentrations of these constituents are either:

- Up to the WAC limit for inert waste for the material placed under Article 27 in areas outside the landfill cells; or
- Up to three times the WAC for the inert waste placed inside the landfill cells.

The concentrations in leachate are expected to reduce with time as contaminant mass is leached from the landfilled waste.

As discussed in Section 2.6, the landfill will be constructed as a series of seven cells where a total of up to 2,400,000 m^3 inert waste will be landfilled over a duration of approximately 15 years. The material imported to the Site under Article 27 is currently stockpiled and is intended for uses such as landfill liner, capping and construction of screening bunds.

3.2 Pathways

Possible pathways linking the potential sources to the identified receptors are:

- Migration of leachate through the landfill basal layer. Leachate will migrate downwards by gravity drainage through the low permeability engineered layer at the base of the landfill. Although the basal layer is relatively low permeability it will not prevent leakage through it, but will lengthen the time taken for any contamination in the pore water to reach the underlying groundwater. This will increase the natural attenuation processes such as dispersion to occur[3], thus reducing contaminant concentrations within the infiltrating pore water. It is noted that this pathway is not valid for the Article 27 material placed outside cells as no basal layer is present beneath these areas;
- Migration of contaminants through the unsaturated zone in the overburden. Contaminants can migrate through the unsaturated zone of the overburden to the water table either directly from the base of the material (Article 27 areas) placed outside the landfill cells or from the bottom of the basal layer under the landfill cells. The presence of clay rich layers within the overburden will help to

[3] Note that degradation is unlikely to be a significant attenuation process for the COPC considered

attenuate contaminants and will further reduce the concentrations of contaminants in the infiltrating pore water;

- Dilution at the water table. Pore water at the base of the unsaturated zone will mix with groundwater and will result in a further decrease in contaminant concentrations; and,
- Dissolved phase migration in groundwater. Groundwater in the overburden and bedrock flows to the west/north-west and likely ultimately discharges to the River Liffey located 8km to the northwest (principally via flow through the bedrock). Retardation, dispersion and dilution of contaminants in groundwater will reduce contaminant concentrations further[3].

3.3 Receptors

For the purposes of this risk assessment the receptors considered are groundwater and surface water. These are discussed further below:

- Groundwater. Groundwater is present within both the overburden deposits and the underlying siltstone bedrock. According to the GSI online mapper the overburden deposits at the Site are part of the West Blessington Gravels groundwater body, whereas the bedrock is classified as a Poor aquifer that is generally unproductive. However, slug testing at the Site has shown that the bedrock is relatively permeable and therefore likely has a greater potential as a water resource than indicated on the GSI online mapper. Both groundwater bearing units are therefore considered as potential resources for water supply and are considered sensitive receptors.
- Surface water. There are a number of small watercourses within the vicinity of the site but these are not considered to be in hydraulic continuity with groundwater. Groundwater is interpreted to discharge to the River Liffey 8km northwest of the site and therefore this is considered the nearest plausible surface water receptor of contamination arising from the landfill leachate.

3.4 Plausible Pollutant Linkages

The following pollutant linkages are considered plausibly significant, i.e. potentially capable of causing an unacceptable risk:

- Risk to groundwater from the Article 27 material from the vertical migration of leachate through the underlying unsaturated zone within the overburden deposits followed by dilution and migration within groundwater.
- Risk to groundwater from the landfilled waste from the vertical migration of leachate through the basal liner of the landfill and underlying unsaturated zone within the overburden deposits followed by dilution and migration within groundwater.

The risk to surface water is considered to be significantly less than that to groundwater due to the large distance to the nearest surface water receptor and dilution within the surface water body. Thus, provided it can be demonstrated that the risks to groundwater are acceptable it can be assumed that the risks to surface water will also be acceptable.

4.0 DETAILED QUANTITATIVE RISK ASSESSMENT

DQRA has been undertaken to further assess the risk to groundwater from the landfilled waste and the Article 27 material placed outside the landfill cells. This section describes the DQRA work undertaken.

4.1 Model Selection

As with the previous HRAs conducted by Golder Associates (2008a, 2012), the LandSim model (v2.5.17) has been used to conduct the DQRA. LandSim is a probabilistic model developed by Golder Associates on behalf of the Environment Agency (England and Wales) that has been designed specifically for assessing the risk to groundwater from the leakage of leachate from landfills. The model is able to account for various engineered elements of the landfill including the basal liner, leachate control systems (if present) and the presence of any capping and can account for long-term degradation and failure of these elements (where relevant). The model simulates migration and attenuation of contaminants in pore water through the basal liner and underlying unsaturated zone as well as dilution, migration and associated attenuation within groundwater. The outputs of the model include estimates of the rate of leakage of leachate through the basal liner, the concentrations of contaminants at the base of the unsaturated zone and in groundwater at a point of compliance down-hydraulic gradient of the landfill and how these change with time. LandSim is able to simulate the various elements and processes described in the CSM and is therefore considered a suitable modelling tool for the purposes of this DQRA.

LandSim has been run probabilistically to allow a better understanding of the effect that uncertainty in the model inputs has on uncertainty in the model outputs. A probability density function (PDF) has been selected for each input parameter. The PDF represents the range and distribution of possible values for that parameter. LandSim then uses Montecarlo analysis to run the model with a single set of input values chosen randomly from the PDFs. It does this many times (in this case 1001) selecting a different set of input values each time such that the distribution of values for each input parameter conform to the PDF. LandSim is then able to produce a probability distribution of outputs values (e.g. concentrations at compliance points). These can be used to estimate the probability of the target value at the compliance point being exceeded. For example if the 95th percentile concentration at the compliance point is less than the target value then this means that there is less than a 5% probability of the target value being exceeded.

4.2 Modelled Contaminants

As discussed in Section 1.1, the objective of this risk assessment is to assess the risk to groundwater (and surface water) from:

- Material placed under Article 27 in areas outside the landfill cells which is assumed to have specific constituents, which are up to the WAC limit for inert waste
- Waste material placed within landfill cells which has specific constituents which are up to three times the WAC limit for inert waste.

The specific constituents are arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, tin, selenium, zinc, chloride, fluoride and sulphate. These constituents have been modelled with the exception of barium, molybdenum and tin which do not have Irish groundwater threshold values or EC drinking water standards.

As discussed below, in the risk assessment it is important to distinguish between hazardous and non-hazardous substances. Hazardous substances, in the Water Framework Directive context, are substances or groups of substances that are toxic, persistent and liable to bio-accumulate, as well as other substances or groups of substances which give rise to an equivalent level of concern. Non-hazardous substances are pollutants that are not considered hazardous but that present an existing or potential risk of pollution. Where a substance is determined to be hazardous, its entry to groundwater should be prevented. Where a substance is determined to be non-hazardous, its entry to groundwater should be limited so that it does not cause a groundwater body to be at poor status, or result in a statistically and environmentally significant upward trend in the concentration of the substance (EPA, 2011).

EPA has defined which substances are considered hazardous and non-hazardous in its document entitled "The Classification of Hazardous and Non-Hazardous Substances in Groundwater" (EPA, 2010). In this document arsenic, cadmium and mercury are defined as hazardous substances and chromium, copper, nickel and zinc are defined as non-hazardous substances. Chloride and sulphate have not been determined but are assumed to be non-hazardous for the purposes of this risk assessment. Lead and selenium are not listed in the document but it is noted that Joint Agencies Groundwater Directive Advisory Group (JAGDAG, 2017) have recently recommended lead to be considered as a hazardous substance and selenium as non-hazardous and therefore these have been considered as such for this risk assessment.

4.3 Compliance Points and Compliance Values

LandSim has been used to estimate the concentrations of contaminants at a point of compliance for comparison with the appropriate receptor based compliance values. The compliance points and compliance values for hazardous and non-hazardous substances have been chosen in accordance with EPA guidance on the Authorisation of Discharges to Groundwater (EPA, 2011) as shown in Table 4-1 below:

Table 4-1 Compliance Points and Compliance Values Requirements from EPA, 2011

Substance Type	Substances	Compliance Point	Compliance Value
Hazardous substances	Arsenic, cadmium, lead & mercury	Groundwater at the down-gradient margin of the source	Minimum reporting values
Non-hazardous substances	Chromium total, copper, nickel, selenium, zinc, chloride, fluoride, sulphate	Groundwater, with default location down-gradient of source, at or close to site or property boundary	Groundwater quality standard (mostly defined by EC drinking water standards)

A hypothetical monitoring well located immediately down-hydraulic gradient of the landfill has been chosen as the compliance point for both hazardous and non-hazardous substances. Minimum reporting values (MRVs, where available in EPA, 2011) have been used as the compliance values for hazardous substances. Where these are not available practical limits of detection (LOD) have been used as the compliance value. For non-hazardous substances the EC Drinking Water Regulations (2014) have been used as the compliance values. Note that zinc does not have an EC drinking water standard and therefore the Irish groundwater threshold value of 75 $\mu g.L^{-1}$ has been used as the compliance value for this substance.

The compliance values used for the assessment are shown in Table 4-2 below:

Table 4-2 Compliance Values Chosen for the DQRA

Substance	Classification	Compliance value ($\mu g.L^{-1}$)	Units	Compliance value type
Arsenic	Hazardous	1	$\mu g.L^{-1}$	LOD
Cadmium	Hazardous	0.1	$\mu g.L^{-1}$	MRV
Total Chromium	Non-hazardous	50	$\mu g.L^{-1}$	DW Regs
Copper	Non-hazardous	2000	$\mu g.L^{-1}$	DW Regs
Lead	Hazardous	1	$\mu g.L^{-1}$	LOD
Mercury	Hazardous	0.01	$\mu g.L^{-1}$	MRV
Nickel	Non-hazardous	20	$\mu g.L^{-1}$	DW Regs
Selenium	Non-hazardous	10	$\mu g.L^{-1}$	DW Regs
Zinc	Non-hazardous	75	$\mu g.L^{-1}$	Groundwater Threshold
Chloride	Non-hazardous	250	$mg.L^{-1}$	DW Regs
Fluoride	Non-hazardous	0.8	$mg.L^{-1}$	DW Regs
Sulphate	Non-hazardous	250	$mg.L^{-1}$	DW Regs

4.4 Model Inputs

This section describes the model inputs values chosen for the LandSim modelling and gives justification for those values. LandSim print-outs of the model inputs are provided in Appendix C.

4.4.1 Waste Areas, Landfill Phases and Area / Cell Geometry

As discussed in Section 2.6, the landfill is being constructed in phases as a series of seven cells, the proposed layout of which is shown in Drawing 7. In addition, Article 27 material has been stockpiled in several areas across the site as shown in Drawing 8.

LandSim allows multiple phases to be modelled at the same time and can account for the approximate spatial inter-relation of these phases with respect to groundwater flow direction. However, LandSim only allows one off-site compliance point to be modelled at a time. In order to allow the risk from all seven cells and all areas of Article 27 material to be characterised five separate model runs have been conducted:

- Run 1: Models the risk from cells 1A, 1B, 2 & 6;
- Run 2: Models the risk from cells 3, 4 & 5;
- Run 3: Models the risk from Article 27 material areas C1A, C2, B1, B2 and processing area;
- Run 4: Models the risk from areas B3a, SP1 and SP2; and
- Run 5: Models the risk from areas B3b, B4a and b

The spatial inter-relation of the areas / cells in relation to groundwater flow direction and the location of the hypothetical monitoring well are shown for each model run in Drawing 9. One area / cell has been assumed per phase. Note that LandSim assumes each phase is rectangular and therefore the phases have been set up to approximate the actual area / cell dimensions as far as possible.

Each landfill cell is assumed to take two years from start to end of filling. Cells are assumed to be filled in number order with landfilling of Cell 1A commencing in Year 1 and completion of filling of Cell 6 in Year 14. It is assumed that all Article 27 areas were filled at the same time before landfilling in the cells commenced and that these stockpiles remain in place for a period of two years before re-use elsewhere on-site.

The modelled dimensions of each cell and each Article 27 area together with year offset (i.e. number of years after infilling of first cell commences) are shown in Tables 4-3 and 4-4, respectively. The landfill cell top area has been based on the surface areas for each cell shown in Table 2-3. The area of each Article 27 material stockpile is based on the surface area of each stockpile shown in Table 2-4.

The cell base area of Cell 1A is approximately 70% of the top surface area and this ratio has been applied to all cells. Thus, the length and width of the base of each cell has been determined such that the cell base area equals 70% of the cell top area. In the absence of site data it has been assumed that the top and base areas for the Article 27 material are the same.

A triangular PDF has been chosen for the final waste thickness for each landfill cell. The minimum, maximum and median thicknesses of waste have been calculated by comparison of the proposed restoration levels minus the formation base levels minus 2m to account for the liner and capping materials. The formation base level of Cell 1A has been taken from the as-built drawings (MOR, 2016). For the remaining cells the formation level has been taken from Golder Associates Drawing No. 8.14 entitled “Cell layout and formation levels of liner”, dated December 2011 (Appendix B).

For the Article 27 material single values have been used for the estimated waste thickness in each area. These have been estimated by dividing the total waste volume in each stockpile divided by the stockpile surface area (see Table 2-4).

Table 4-3 Modelled cell dimensions

Cell	Year off-set	Width at base (m)	Length at base (m)	Base Area (Ha)	Top Area (Ha)	Final waste thickness (m)*
1A	0	140	134	1.88	2.68	Triangular (1,5,8)
1B	2	160	110	1.76	2.52	Triangular (1,5,8)
2	4	220	254	5.6	8.0	Triangular (1,7,12)
3	6	156	360	5.6	8.0	Triangular (1,6,10)
4	8	217	187	4.06	5.8	Triangular (1,7,10)
5	10	225	264	5.95	8.5	Triangular (6,11,18)
6	12	160	197	3.15	4.5	Triangular (3,10,15)

* - Values in brackets represent minimum, most likely and maximum values of the triangular distribution

Table 4-4 Modelled Article 27 Area dimensions

Cell	Year off-set	Width at base (m)	Length at base (m)	Base Area (Ha)	Top Area (Ha)	Thickness (m)
C1A	0	80	131	1.04	1.04	Single (3.1)
C2	0	65	185	1.20	1.20	Single (2.0)
B1	0	348	100	3.48	3.48	Single (3.5)
B2	0	120	60	0.72	0.72	Single (3.5)
B3a	0	147	50	0.74	0.74	Single (3.5)
B3b	0	36	61	0.22	0.22	Single (3.5)
B4a & b	0	20	112	0.22	0.22	Single (3.5)
SP1	0	82	80	0.66	0.66	Single (3.7)
SP2	0	75	52	0.39	0.39	Single (1.2)
Process Area	0	70	70	0.49	0.49	Single (1.5)

Note: Areas B4a and B4b are modelled as one area.

The PDF chosen for the waste porosity, waste dry density and field capacity and justification for these are shown in Table 4-5. Note that these values have been applied to all cells and the Article 27 material.

Table 4-5 Modelled waste properties

Property	Type of PDF	Min.	Max.	Justification
Waste porosity (fraction)	Uniform	0.37	0.55	Range calculated using Environment Agency Remedial Targets Methodology porosity calculator with bulk densities of 1.25 to 1.75 kg.L^{-1}
Waste dry density (kg.L^{-1})	Uniform	1.25	1.75	Reasonable range for waste deposits (and as used by Golder Associates 2008d & 2012)
Field capacity (fraction)	Uniform	0.1	0.35	Based on typical range for unconsolidated deposits (from Fetter, 1994)

4.4.2 Leachate Inventory

The initial leachate concentrations of the modelled contaminants for Runs 1 and 2 (waste placed in landfill cells) are taken to be single values equal to three times the C_0 (percolation test) values from the WAC limits for inert waste as given in EC Council Decision 2003/33/EC. This makes the highly conservative assumption that the leachate within the landfill is all equal to three times the WAC limits. The initial leachate concentrations of the modelled contaminants for Runs 3, 4 and 5 (Article 27 material placed outside landfill cells) are taken to be single values equal to the WAC limits for inert waste The WAC limits and modelled values are shown in Table 4-6 below.

Table 4-6 Initial leachate concentrations modelled

Substance	Initial leachate concentration modelled for Runs 1 and 2 (mg.L^{-1})	Initial leachate concentration modelled for Runs 3, 4 and 5 (i.e. C_0 - WAC limit for inert waste) (mg.L^{-1})
Arsenic	0.18	0.06
Cadmium	0.06	0.02
Total Chromium	0.3	0.1
Copper	1.8	0.6
Lead	0.45	0.15
Mercury	0.006	0.002
Nickel	0.36	0.12
Selenium	0.12	0.04
Zinc	3.6	1.2
Chloride	1380	460
Fluoride	7.5	2.5
Sulphate	4500	1500

The declining source term has been used in LandSim to model the expected decline in leachate source concentrations with time. The default Kappa value constants within LandSim v2.5 have been used to model the rate at which the leachate concentrations decline.

4.4.3 Infiltration

Each area / cell is assumed to be left open for two years prior to capping or re-use elsewhere on-site. During this time infiltration is conservatively assumed to be equal to average annual rainfall. A normal distribution has been assumed with the mean value equal to the mean annual rainfall measured at Naas (782 mm, Section 2.2) and a standard deviation of 10% of this value to allow for uncertainty.

For the landfill cells, once filling has been completed the cell is assumed to be profiled, capped and vegetated to limit infiltration. A value of half the estimated aquifer recharge rate of 415 mm.yr^{-1} (i.e. 207.5 mm.yr^{-1}) has been assumed as the best estimate to take account of surface drainage from the profiled cap. Again, a normal distribution has been assumed using a value of 207.5 mm.yr^{-1} as the mean and 10% of this value as the standard deviation.

For the Article 27 material, after a period of two years the material is assumed to be used elsewhere on-site and is then assumed to be profiled and vegetated which will limit infiltration. The PDF for the capped landfill cells described above has been assumed for the Article 27 material once re-used.

Table 4-7 Modelled infiltration

Property	Type of PDF	Mean	Standard Deviation
Infiltration to open waste (mm.yr^{-1})	Normal	782	72.8
Cap design infiltration ((mm.yr^{-1})	Normal	207.5	20.75

4.4.4 Drainage System

As discussed in Section 2.6 there is not expected to be significant accumulation of leachate in the landfill cells. A fixed leachate head of 1m has therefore been assumed as a reasonable estimate for the purposes of the modelling landfill cells. Leachate breakout is not expected and so has been set at a level above the fixed leachate head (2m).

For the Article 27 areas, there are no drainage systems and no engineered barrier systems therefore no head of leachate is assumed (single value of 0).

4.4.5 Engineered Barrier

For the landfill cells, a single clay engineered barrier system (EBS) has been selected to simulate the mineral liner on the base and sides of each cell. The liner thickness has been modelled with a single value of 1m. Triangular distribution PDFs have been used for moisture content, hydraulic conductivity and pathway density. Minimum, most likely and maximum values for these PDFs have been based on the minimum, average and maximum values from the CQA testing of the liner in Cell 1A (MOR, 2016). It is assumed that these values will be a reasonable approximation for the other cells. Longitudinal dispersivity is assumed to be 10% of pathway length (i.e. 0.1m). The property values used for the mineral liner are shown in Table 4-8 below:

Table 4-8 Modelled properties of engineered barrier

Parameter	PDF type	Min	Most likely	Max
Design thickness of mineral liner (m)	Single	-	1	1
Moisture content (fraction)	Triangular	0.082	0.13	0.16
Hydraulic conductivity ($m.s^{-1}$)	Triangular	1.92E-10	5.87E-10	2.12E-09
Longitudinal dispersivity (m)	Single	-	0.1	-
Pathway density ($kg.L^{-1}$)	Triangular	1.67	1.89	2.13

Sorption to clay minerals within the clay liner is assumed to retard the metals as they travel through the clay liner. The sorption coefficients (K_d values) have been modelled as log triangular PDFs using the minimum, median and maximum values from USEPA (2005). Chloride, fluoride and sulphate are assumed not to be sorbed and so K_d values of 0 have been used for these substances. The modelled K_d values are shown in Table 4-9 below.

Table 4-9 Modelled sorption coefficients

Substance	PDF type	Units	Min	Most likely	Max
Arsenic	Log Triangular	$L.kg^{-1}$	2	2512	19953
Cadmium	Log Triangular	$L.kg^{-1}$	1.26	794	100000
Total Chromium	Log Triangular	$L.kg^{-1}$	10	7943	50120
Copper	Log Triangular	$L.kg^{-1}$	1.26	501	3981
Lead	Log Triangular	$L.kg^{-1}$	5	15489	100000
Mercury	Log Triangular	$L.kg^{-1}$	158	6310	630957
Nickel	Log Triangular	$L.kg^{-1}$	10	1259	6310
Selenium	Log Triangular	$L.kg^{-1}$	0.5	10	251
Zinc	Log Triangular	$L.kg^{-1}$	0.1	1259	100000
Chloride	Single	$L.kg^{-1}$	-	0	-
Fluoride	Single	$L.kg^{-1}$	-	0	-
Sulphate	Single	$L.kg^{-1}$	-	0	-

The Article 27 material has been modelled with no engineered barrier.

4.4.6 Unsaturated Pathway

Uniform PDFs have been assumed for the unsaturated pathway parameters based on the estimated properties of the overburden materials. The range in values used along with justification for these values are given in Table 4-10 below.

Table 4-10 Modelled properties of the unsaturated zone

Parameter	PDF type	Min	Most likely	Max	Justification
Pathway length (m)	Uniform				
- C1A		5.4	-	6.4	Estimated distance from base of liner on base of landfill/ base of Article 27 material to groundwater table
- C2		0.1	-	12	
- B1		0.1	-	16.5	
- B2		5.5	-	11.5	
- B3a		4.5	-	13.5	
- B3b		2.5	-	10.5	
- B4a & b		2.5	-	10.5	
- SP1		9.3	-	15.3	
- SP2		7.8	-	14.8	
- Process Area		12.5	-	13.5	
- Cell 1A		10	-	13	
- Cell 1B		13	-	14.5	
- Cell 2		5	-	7	
- Cell 3		4	-	8	
- Cell 4		1	-	8	
- Cell 5		2	-	8	
- Cell 6		7	-	13	
Longitudinal dispersivity (m)	Uniform				
- C1A		0.54		0.64	10% of pathway length
- C2		0.01	-	1.2	
- B1		0.01	-	1.65	
- B2		0.55	-	1.15	
- B3a		0.45	-	1.35	
- B3b		0.25	-	1.05	
- B4a & b		0.25	-	1.05	
- SP1		0.93	-	1.53	
- SP2		0.78	-	1.48	
- Process Area		1.25	-	1.35	
- Cell 1A		1.0	-	1.3	
- Cell 1B		1.3	-	1.45	
- Cell 2		0.5	-	0.7	
- Cell 3		0.4	-	0.8	
- Cell 4		0.1	-	0.8	
- Cell 5		0.2	-	0.8	
- Cell 6		0.7	-	1.3	
Moisture content (fraction)	Uniform	0.1	-	0.2	Range in values of field capacity for sand from Fetter (1984)
Hydraulic conductivity ($m.s^{-1}$)	Triangular	6.9E-7	4.7E-5	1E-03	Estimated from slug test analyses of overburden deposits. Most likely = geomean of mid-point estimates for each well.
Pathway density ($kg.L^{-1}$)	Uniform	1.15	-	2.1	Range of values given for glacial deposits in ConSim help files (Golder Associates, 2003)

As with the mineral liner, retardation of metals is assumed to occur within the unsaturated zone. The modelled sorption coefficients used are the same as those used for the mineral liner as shown in Table 4-9.

4.4.7 Aquifer Properties

The aquifer pathway lengths and widths for each area / cell are shown in Table 4-11. Note that the pathway length is determined by LandSim according to the distance to the compliance point. Width has been estimated as the width of the cell perpendicular to groundwater flow direction.

Table 4-11 Modelled aquifer pathway length and width

Area / Cell	Length (m)*	Width (m)
Area C1A	Uniform (434.75, 565.25)	80
Area C2	Uniform (77.5, 262.5)	65
Area B1	Uniform (265,365)	348
Area B2	Uniform (9.9, 70.1)	120
Area B3a	Uniform (15.5, 65.5)	147
Area B3b	Uniform (9.75, 70.25)	36
Area B4a & b	Uniform (74.2, 185.8)	20
Area SP1	Uniform (300.5, 380.5)	82
Area SP2	Uniform (244.36, 296.64)	75
Process Area	Uniform (485.685, 555.315)	70
Cell 1A	Uniform (427, 573)	190
Cell 1B	Uniform (305, 425)	220
Cell 2	Uniform (4, 296)	190
Cell 3	Uniform (0.5, 219.5)	440
Cell 4	Uniform (222, 478)	220
Cell 5	Uniform (0.5,219.5)	290
Cell 6	Uniform (432, 688)	220

* - Values in brackets represent minimum and maximum values of the uniform distribution

The other aquifer parameter values along with justification for these are shown in Table 4-12. Note that the properties of the aquifer pathway have been based on those of the overburden as this is the uppermost groundwater bearing unit.

Table 4-12 Modelled aquifer properties

Parameter	PDF type	Min	Most likely	Max	Justification
Mixing zone thickness	Uniform	15	-	17	Estimated saturated thickness of overburden deposits
Hydraulic conductivity ($m.s^{-1}$)	Triangular	6.9E-7	4.7E-5	1E-03	Estimated from slug test analyses of overburden deposits. Most likely = geomean of mid-point estimates for each well.
Regional gradient (-)	Uniform	0.016	-	0.030	Range in estimated hydraulic gradients in the overburden deposits
Pathway porosity (fraction)	Uniform	0.2	-	0.3	Reasonable range in values for effective porosity of sands and gravels
Longitudinal dispersivity (m) - Run 1 - Run 2 - Run 3 - Run 4 - Run 5	Uniform	 0.4 0.05 0.99 1.55 0.975	 - - - - -	 68.8 47.8 56.5 38.05 18.6	LandSim manual recommends a value of 10% of pathway length.
Transverse dispersivity (m) - Run 1 - Run 2 - Run 3 - Run 4 - Run 5	Uniform	 0.12 0.015 0.27 0.465 0.293	 - - - - -	 20.64 14.34 16.95 11.42 5.57	LandSim manual recommends a value of 3% of pathway length.

The conservative assumption has been made that retardation does not occur along the aquifer pathway.

4.4.8 Background Groundwater Concentrations

Background groundwater concentrations have been based on the baseline monitoring and are shown in Table 4-13 below. Where baseline concentrations are below the limit of detection a value of zero has been adopted. Where concentrations have been detected a triangular distribution has been used with the most likely value equal to the average measured concentration and minimum and maximum equal to the minimum and maximum measured concentration.

Table 4-13 Modelled background groundwater concentrations

Substance	PDF type	Units	Min	Most likely	Max
Arsenic	Single	$mg.L^{-1}$	-	0 [1]	-
Cadmium	Single	$mg.L^{-1}$	-	0	-
Total Chromium	Triangular	$mg.L^{-1}$	0.0002	0.0007	0.0018
Copper	Single	$mg.L^{-1}$	-	0	-
Lead	Single	$mg.L^{-1}$	-	0	-
Mercury	Single	$mg.L^{-1}$	-	0	-
Nickel	Triangular	$mg.L^{-1}$	0.0002	0.00093	0.002
Selenium	Single	$mg.L^{-1}$	-	0 [2]	-
Zinc	Triangular	$mg.L^{-1}$	0.0015	0.00213	0.0037
Chloride	Triangular	$mg.L^{-1}$	5.6	11.0	16.2
Fluoride	Single	$mg.L^{-1}$	-	0	-
Sulphate	Triangular	$mg.L^{-1}$	4.3	13.5	19.6

Notes: 1. Based on data in Golder Associates (2008a)

2. No analytical data available for selenium in groundwater – assumed to be less than detection limit

4.5 Results

LandSim has been used to predict the concentrations of modelled contaminants at the compliance point, i.e. a hypothetical well immediately down-hydraulic gradient of the landfill. Graphs showing the predicted concentration at the compliance point with time for each of the modelled contaminants are shown in Appendix D. Note that separate graphs are shown for Run 1, Run 2, Run 3, Run 4 and Run 5. Each graph shows a range of percentile concentrations. In line with Environment Agency (England and Wales) guidance (2006) the maximum 95th percentile compliance point concentration for each contaminant has been compared with its compliance value in order to assess risk. Where the maximum 95th percentile concentration is below the compliance value it can be assumed that the risk to groundwater is acceptable for that contaminant.

Tables 4-14 and 4-15 compare the maximum 95th percentile contaminant concentration over the modelled period (20,000 years) with the compliance value for each modelled contaminant. The 99th percentile concentrations are also shown for information.

Table 4-14 Maximum predicted concentrations at compliance point for Run 1 (Cells 1A, 1B, 2 & 6)

Substance	Units	Compliance value ($\mu g.L^{-1}$)	Maximum predicted concentration at compliance point ($\mu g.L^{-1}$)	
			95th percentile	99th percentile
Arsenic	$\mu g.L^{-1}$	1	0.024	0.078
Cadmium	$\mu g.L^{-1}$	0.1	0.0020	0.012
Total Chromium	$\mu g.L^{-1}$	50	1.5	1.7
Copper	$\mu g.L^{-1}$	2000	0.20	0.83
Lead	$\mu g.L^{-1}$	1	0.0052	0.054
Mercury	$\mu g.L^{-1}$	0.01	<1E-07	<1E-07
Nickel	$\mu g.L^{-1}$	20	1.7	1.9
Selenium	$\mu g.L^{-1}$	10	0.12	0.39
Zinc	$\mu g.L^{-1}$	75	3.4	6.3
Chloride	$mg.L^{-1}$	250	33	57
Fluoride	$mg.L^{-1}$	0.8	0.16	0.34
Sulphate	$mg.L^{-1}$	250	100	210

Table 4-15 Maximum predicted concentrations at compliance point for Run 2 (Cells 3, 4 & 5)

Substance	Units	Compliance value (µg.L^{-1})	Maximum predicted concentration at compliance point (µg.L^{-1})	
			95th percentile	99th percentile
Arsenic	µg.L^{-1}	1	0.021	0.090
Cadmium	µg.L^{-1}	0.1	0.0021	0.0076
Total Chromium	µg.L^{-1}	50	1.5	1.7
Copper	µg.L^{-1}	2000	0.15	0.91
Lead	µg.L^{-1}	1	0.0049	0.035
Mercury	µg.L^{-1}	0.01	<1E-07	<1E-07
Nickel	µg.L^{-1}	20	1.7	1.9
Selenium	µg.L^{-1}	10	0.10	0.37
Zinc	µg.L^{-1}	75	3.4	5.0
Chloride	mg.L^{-1}	250	30	51
Fluoride	mg.L^{-1}	0.8	0.13	0.25
Sulphate	mg.L^{-1}	250	88	160

Table 4-16 Maximum predicted concentrations at compliance point for Run 3 (Areas C1A, C2, B1, B2 and Processing area)

Substance	Units	Compliance value (µg.L^{-1})	Maximum predicted concentration at compliance point (µg.L^{-1})	
			95th percentile	99th percentile
Arsenic	µg.L^{-1}	1	0.048	0.14
Cadmium	µg.L^{-1}	0.1	0.005	0.018
Total Chromium	µg.L^{-1}	50	1.5	1.7
Copper	µg.L^{-1}	2000	0.25	1
Lead	µg.L^{-1}	1	0.014	0.07
Mercury	µg.L^{-1}	0.01	1.5E-05	1.3E-04
Nickel	µg.L^{-1}	20	1.7	1.9
Selenium	µg.L^{-1}	10	0.07	0.19
Zinc	µg.L^{-1}	75	3.9	7.7
Chloride	mg.L^{-1}	250	18	26
Fluoride	mg.L^{-1}	0.8	0.043	0.094
Sulphate	mg.L^{-1}	250	37	65

Table 4-17 Maximum predicted concentrations at compliance point for Run 4 (Areas B3a, SP1 and SP2)

Substance	Units	Compliance value (µg.L^{-1})	Maximum predicted concentration at compliance point (µg.L^{-1})	
			95th percentile	99th percentile
Arsenic	µg.L^{-1}	1	0.035	0.13
Cadmium	µg.L^{-1}	0.1	0.0045	0.019
Total Chromium	µg.L^{-1}	50	1.5	1.7
Copper	µg.L^{-1}	2000	0.14	0.96
Lead	µg.L^{-1}	1	0.0095	0.051
Mercury	µg.L^{-1}	0.01	1.2E-05	7E-05
Nickel	µg.L^{-1}	20	1.7	1.9
Selenium	µg.L^{-1}	10	0.093	0.32
Zinc	µg.L^{-1}	75	3.6	9.3
Chloride	mg.L^{-1}	250	18	30
Fluoride	mg.L^{-1}	0.8	0.04	0.12
Sulphate	mg.L^{-1}	250	37	81

Table 4-18 Maximum predicted concentrations at compliance point for Run 5 (Areas B3b, B4a & B4b)

Substance	Units	Compliance value (µg.L^{-1})	Maximum predicted concentration at compliance point (µg.L^{-1})	
			95th percentile	99th percentile
Arsenic	µg.L^{-1}	1	0.14	0.42
Cadmium	µg.L^{-1}	0.1	0.02	0.08
Total Chromium	µg.L^{-1}	50	1.5	1.7
Copper	µg.L^{-1}	2000	0.87	3.8
Lead	µg.L^{-1}	1	0.048	0.22
Mercury	µg.L^{-1}	0.01	7.7E-05	3.5E-04
Nickel	µg.L^{-1}	20	1.7	1.9
Selenium	µg.L^{-1}	10	0.24	0.57
Zinc	µg.L^{-1}	75	5.6	15
Chloride	mg.L^{-1}	250	29	43
Fluoride	mg.L^{-1}	0.8	0.10	0.18
Sulphate	mg.L^{-1}	250	74	121

4.6 Risk Evaluation

The modelled 95th percentile concentrations are all below the compliance values, as are the 99th percentile concentrations. As discussed in Section 4.4.2 the highly conservative assumption has been made that the initial concentration of each modelled contaminant in the leachate in the landfill cells throughout the waste is equal to three times the inert WAC. It is highly unlikely that this would occur in reality. Whilst some loads of waste may have leachate concentrations for one contaminant approaching the Site specific waste acceptance criteria, the overall average leachate concentration of each contaminant within the landfill cell will likely be significantly less. The same applies to the Article 27 material. The conservative assumption has been made that all this material has leachate concentrations equal to the WAC for inert waste. In reality, the average leachate concentrations in each of the stockpile area is likely to be significantly less. Thus, the model results can be considered conservative.

Given the model results and the level of conservatism within the source term used it is concluded that raising the waste acceptance criteria for the Site to three times the inert WAC (for the modelled contaminants) would not result in unacceptable impacts to groundwater (or surface water). Based on these results, it is also considered that raising the waste acceptance criteria for barium, molybdenum and tin to three times the inert WAC would also not result in unacceptable risk. It is also concluded that the Article 27 material does not pose an unacceptable risk to the water environment.

5.0 CONCLUSIONS

LandSim modelling has been undertaken in order to quantitatively assess the risk to groundwater arising from leakage of leachate through the basal liner of the proposed engineered inert landfill at the Site. The modelling has demonstrated that even if all the waste imported had initial leachate concentrations of three times the inert WAC for metals, chloride, fluoride and sulphate the risk to groundwater would be acceptable. As such it is considered that the Site specific WAC for these substances could be increased to three times the inert WAC values. The proposed Site specific WAC are presented in Table 5-1 below:

Table 5-1 Proposed site specific WAC for metals, chloride and sulphate

Substance	L/S = 2 L.kg^{-1}	L/S = 10 L.kg^{-1}	Co (percolation test)
	mg.kg^{-1} dry substance	mg.kg^{-1} dry substance	mg.L^{-1}
Arsenic	0.3	1.5	0.18
Barium	21	60	12
Cadmium	0.09	0.12	0.06
Total Chromium	0.6	1.5	0.3
Copper	2.7	6	1.8
Lead	0.6	1.5	0.45
Mercury	0.009	0.03	0.006
Molybdenum	0.9	1.5	0.6
Nickel	0.6	1.2	0.36
Tin	0.06	0.18	0.3
Selenium	0.18	0.3	0.12
Zinc	6	12	3.6
Chloride	1650	2400	1380
Fluoride	12	30	7.5
Sulphate	1680	3000	4500

The modelling has also been conducted to assess the risk to the water environment from the Article 27 material that has been imported to site and that is not contained within landfill cells. The model results indicate that this material does not present an unacceptable risk to the water environment.

REFERENCES

Defra and Environment Agency, 2016. Landfill developments: groundwater risk assessment for leachate. Available at https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate First published 1 February 2016

Environment Agency, 2006. Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination.

EPA, 2010. The Classification of Hazardous and Non-Hazardous Substances in Groundwater. Version 1, December 2010.

EPA, 2011. Guidance on the Authorisation of Discharges to Groundwater. Version 1, December 2011

European Communities (EC), 2003. Council Decision 2003/33/EC on 19 December 2002. Establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC

Fetter, C.W., 1994. Applied Hydrogeology, 3rd Edition. Macmillan. ISBN 0-02-336490-4

Golder Associates, 2003. Consim V2.5.

Golder Associates, 2008a. Summary Report on Ground Investigations at Walshestown Pit, Co. Kildare. Report 07 5071 50230 R01/V1, October 2008

Golder Associates, 2008b. Environmental Impact Statement for the Proposed Pit Restoration, Walshestown, Co. Kildare. December 2008

Golder Associates, 2008c. Waste License Application for the Proposed Pit Restoration, Walshestown, Co. Kildare. December 2008

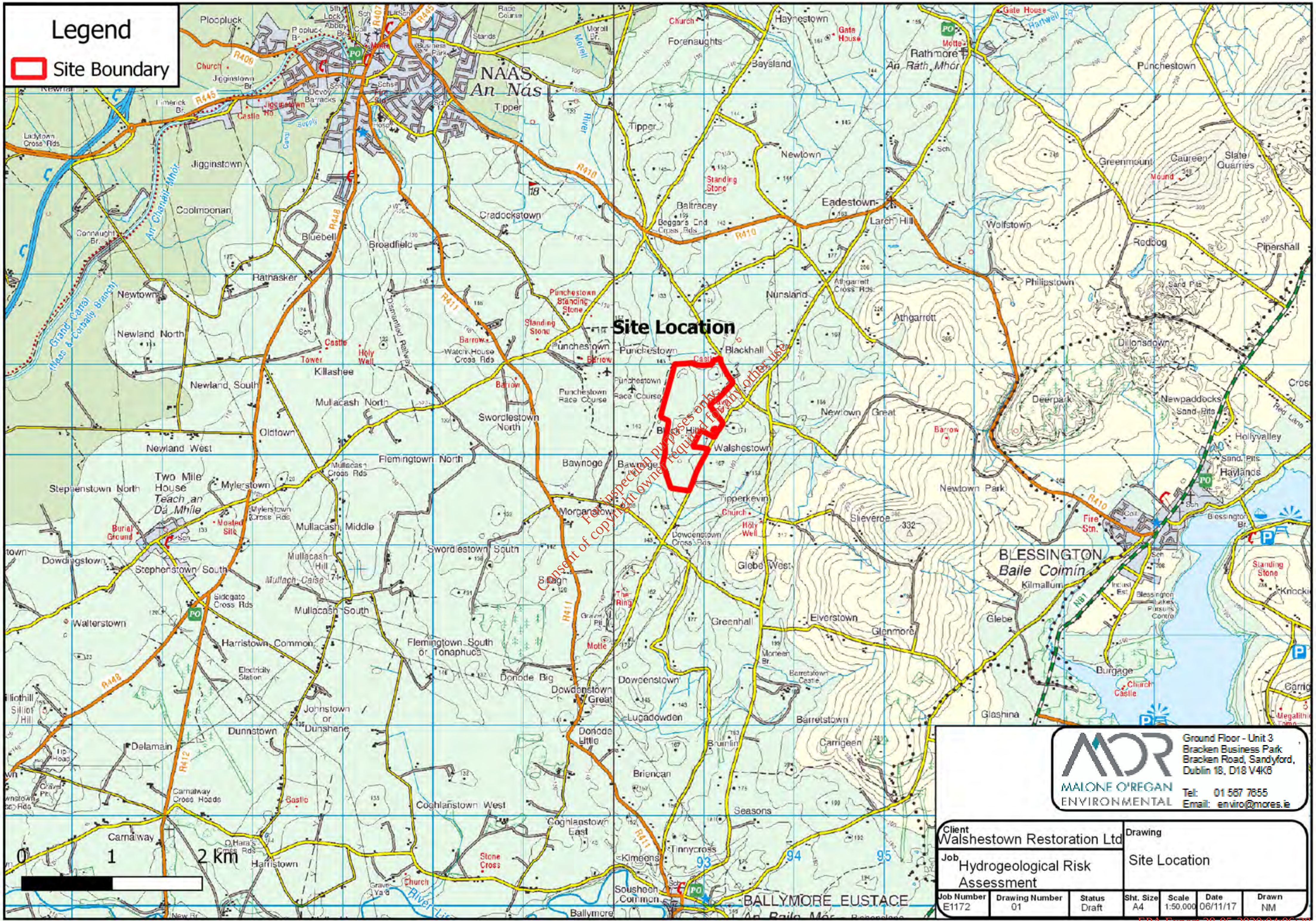
Golder Associates, 2008d. Report on Conceptual Site Model and Water Impact Assessment for Walshestown Pit Restoration. Report 07 5071 50230 R02/V3, November 2008.

Golder Associates, 2011. Report on revised HRA. Report 09507150022.R02.A0, January 2012

MOR, 2016. Construction Quality Assurance (Phase 1 Development) Condition 3.5.5, Walshestown Waste Management Facility, Waste Licence W0254-01. December 2016

US EPA, 2005. Partition Coefficients for Metals in Surface Water, Soil, and Waste by Jerry D. Allison, and Terry L. Allison. EPA/600/R-05/074. US Environmental Protection Agency, Washington, DC. July 2005.

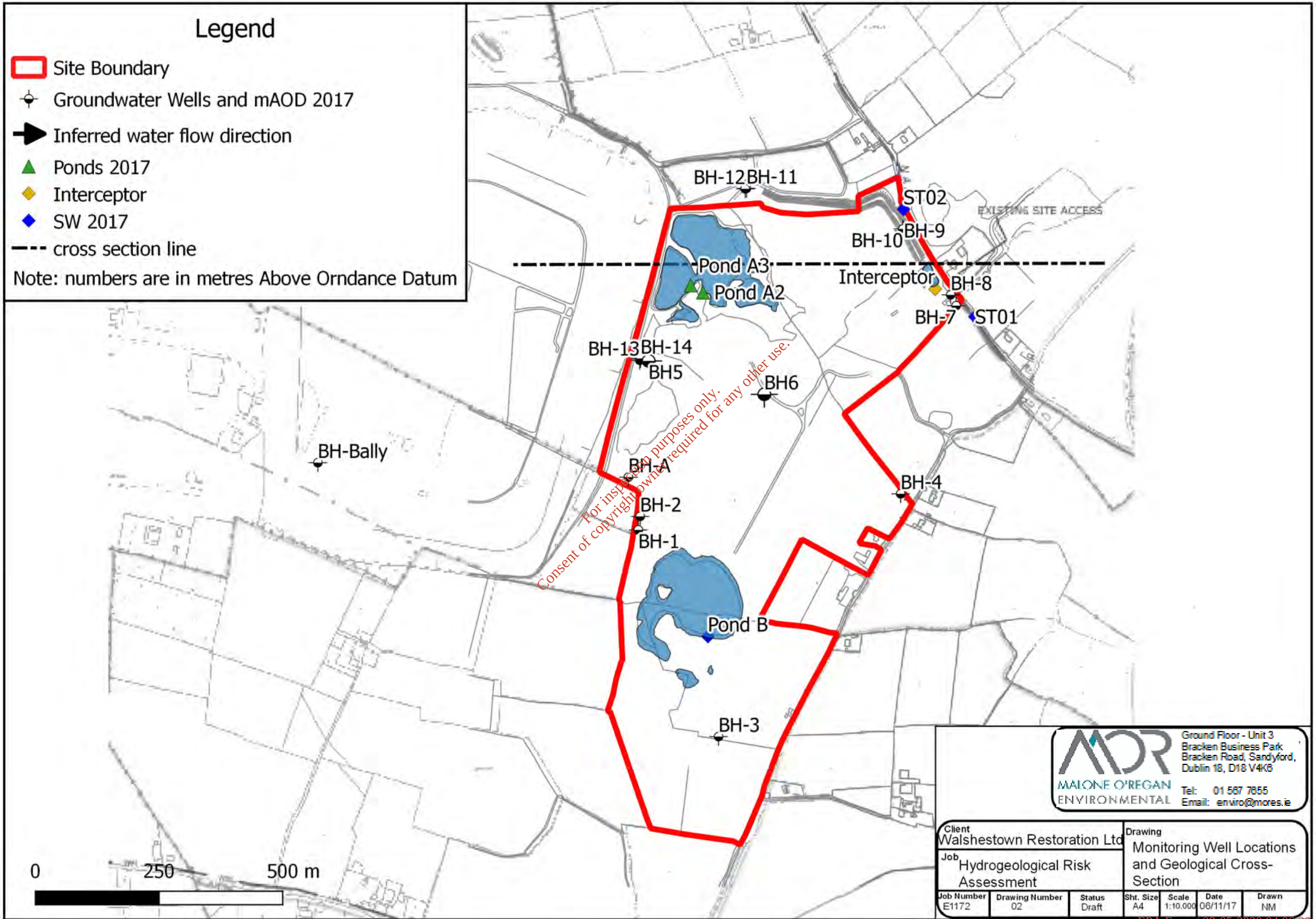
Drawings

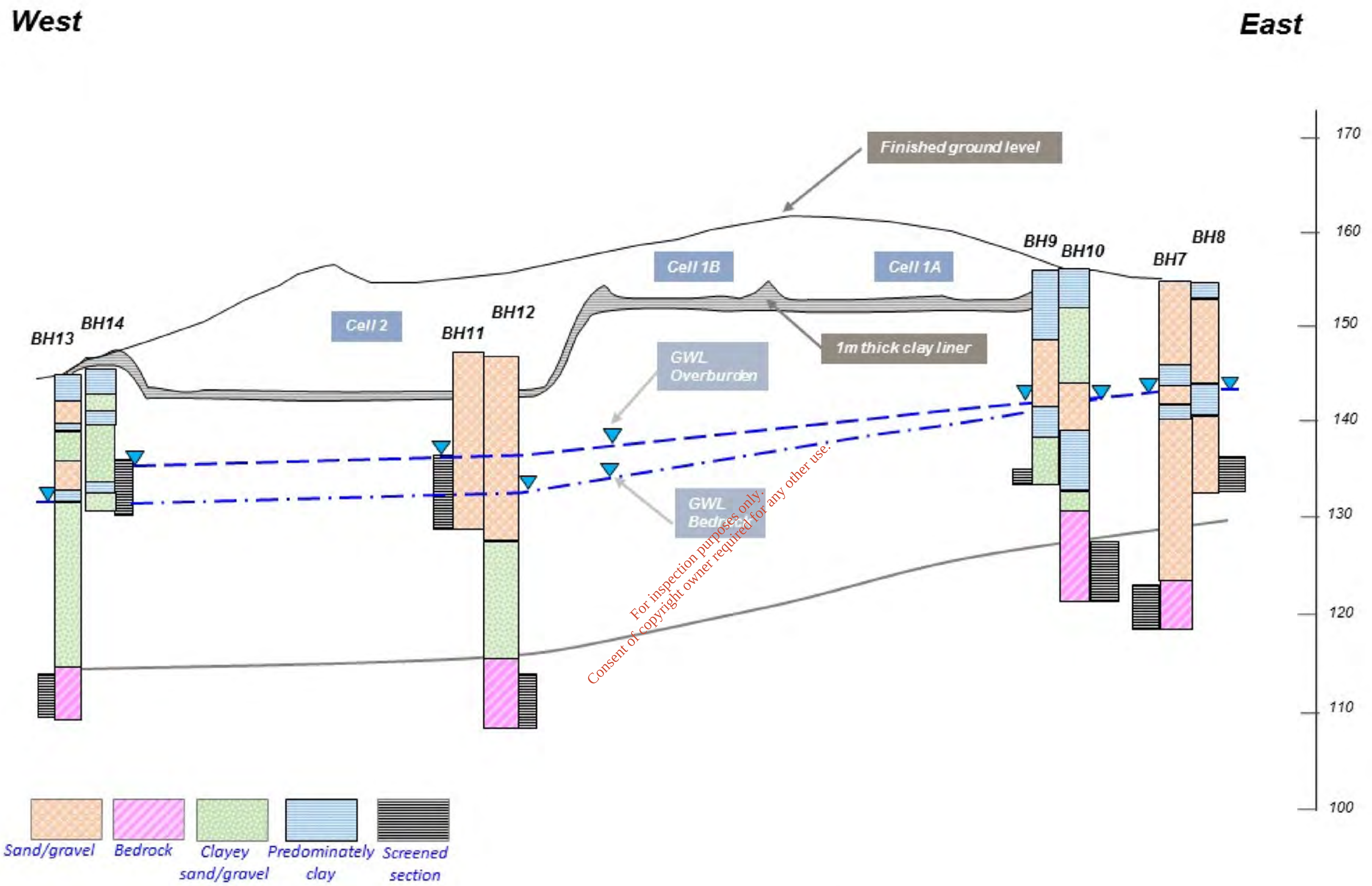


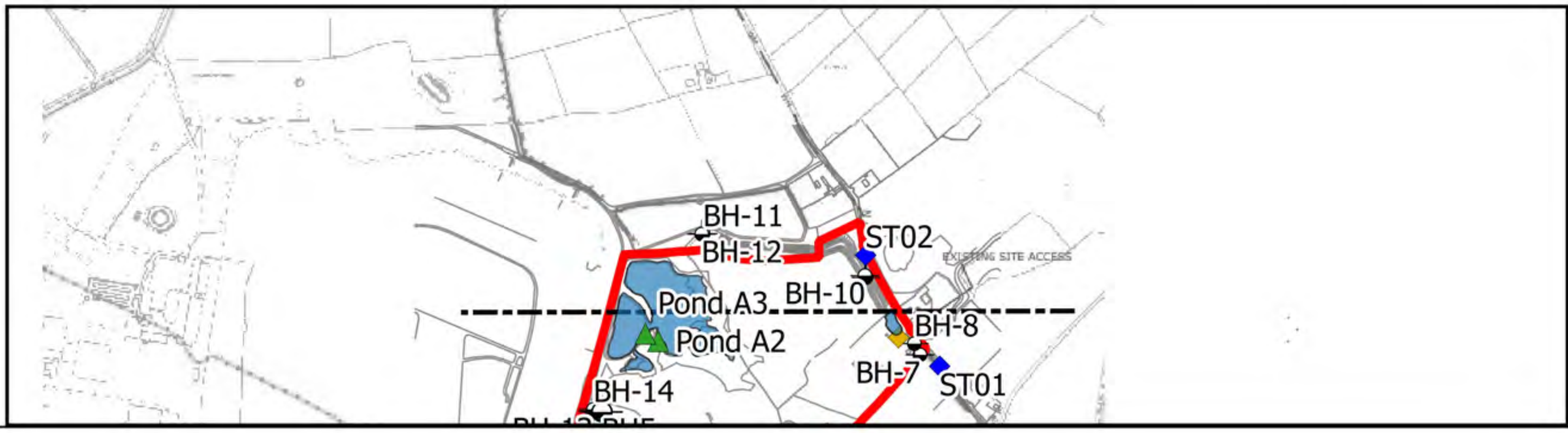
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
Tel: 01 567 7655
Email: enviro@mores.ie
MALONE O'REGAN ENVIRONMENTAL

Client	Drawing
Walshestown Restoration Ltd	
Job: Hydrogeological Risk Assessment	Site Location

Job Number	Drawing Number	Status	Sht. Size	Scale	Date	Drawn
E1172	01	Draft	A4	1:50,000	06/11/17	NM


Legend
Site Boundary
Groundwater Wells and mAOD 2017
Inferred water flow direction
Ponds 2017
Interceptor
SW 2017
cross section line
Note: numbers are in metres Above Orndance Datum
BH-12
BH-11
ST02
EXISTING SITE ACCESS
BH-9
BH-10
Pond A3
Interceptor
BH-8
Pond A2
BH-7
ST01
BH-13
BH-14
BH5
BH6
BH-Bally
BH-A
BH-4
BH-2
BH-1
Pond B
BH-3
0
250
500 m
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
MALONE O'REGAN
ENVIRONMENTAL
Tel: 01 567 7655
Email: enviro@mores.ie
Client
Walshestown Restoration Ltd
Job
Hydrogeological Risk Assessment
Drawing
Monitoring Well Locations and Geological Cross-Section
Job Number E1172
Drawing Number 02
Status Draft
Sht. Size A4
Scale 1:10,000
Date 06/11/17
Drawn NM



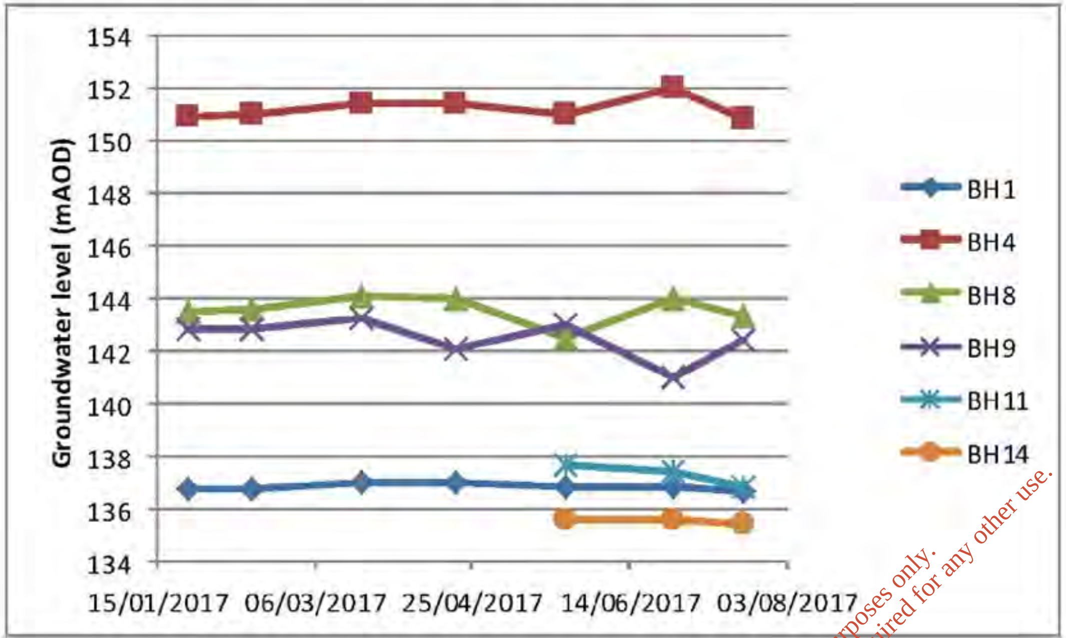


MALONE O'REGAN ENVIRONMENTAL
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
Tel: 01 567 7655
Email: enviro@mores.ie

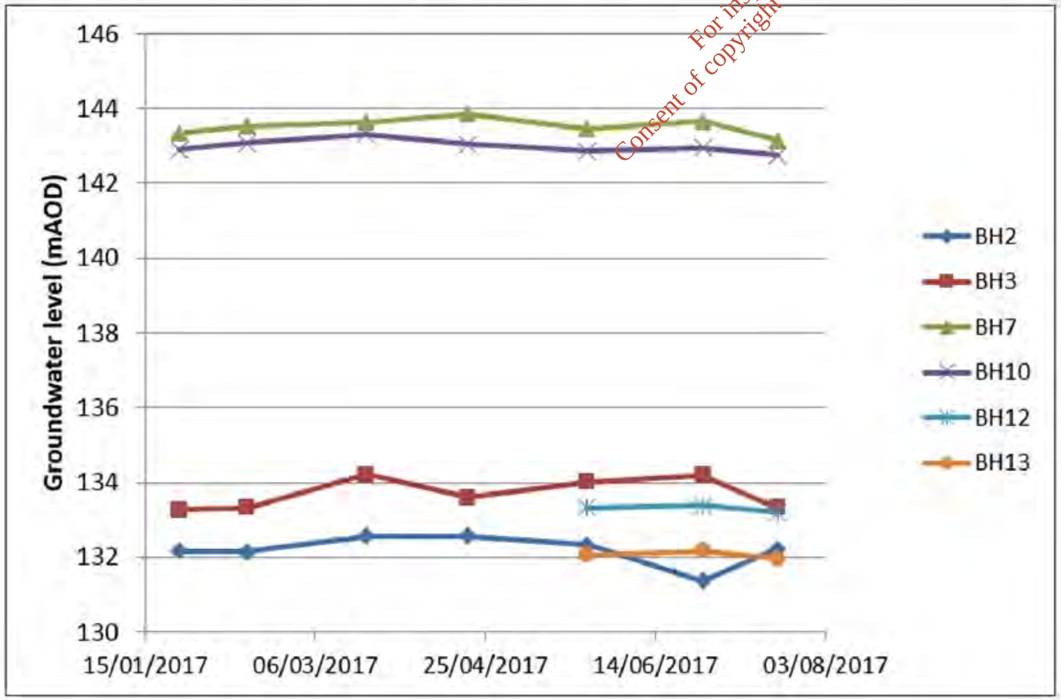
Client: Walshestown Restoration Ltd	Drawing: Geological/hydrogeological cross-section
Job: Hydrogeological Risk Assessment	

Job Number	Drawing Number	Status	Sht. Size	Scale	Date	Drawn
E1172	03	Draft	A4	NTS	06/11/17	NM

Groundwater levels in wells screened within the overburden



Groundwater levels in wells screened within the bedrock



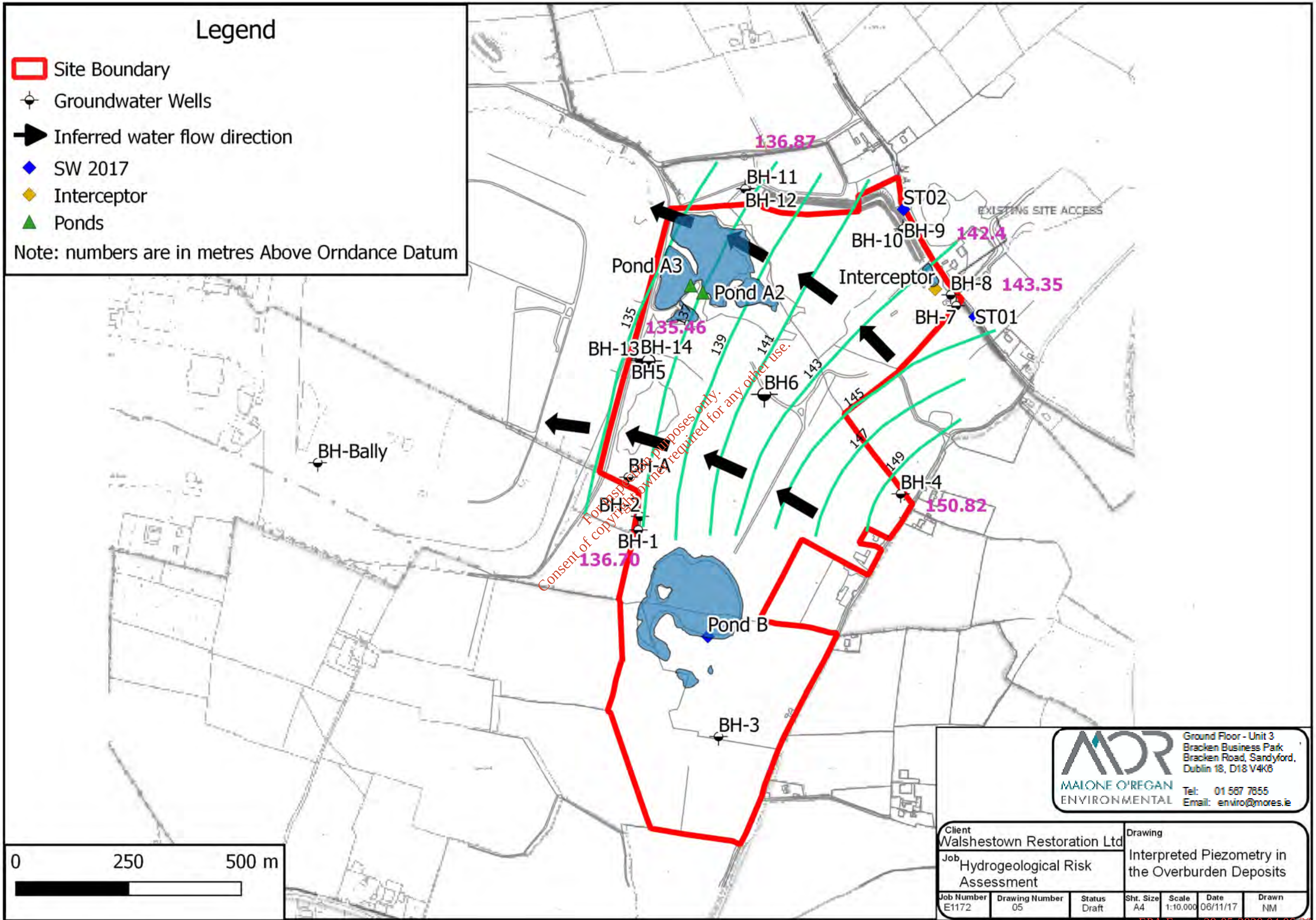
MALONE O'REGAN ENVIRONMENTAL
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
Tel: 01 567 7655
Email: enviro@mores.ie

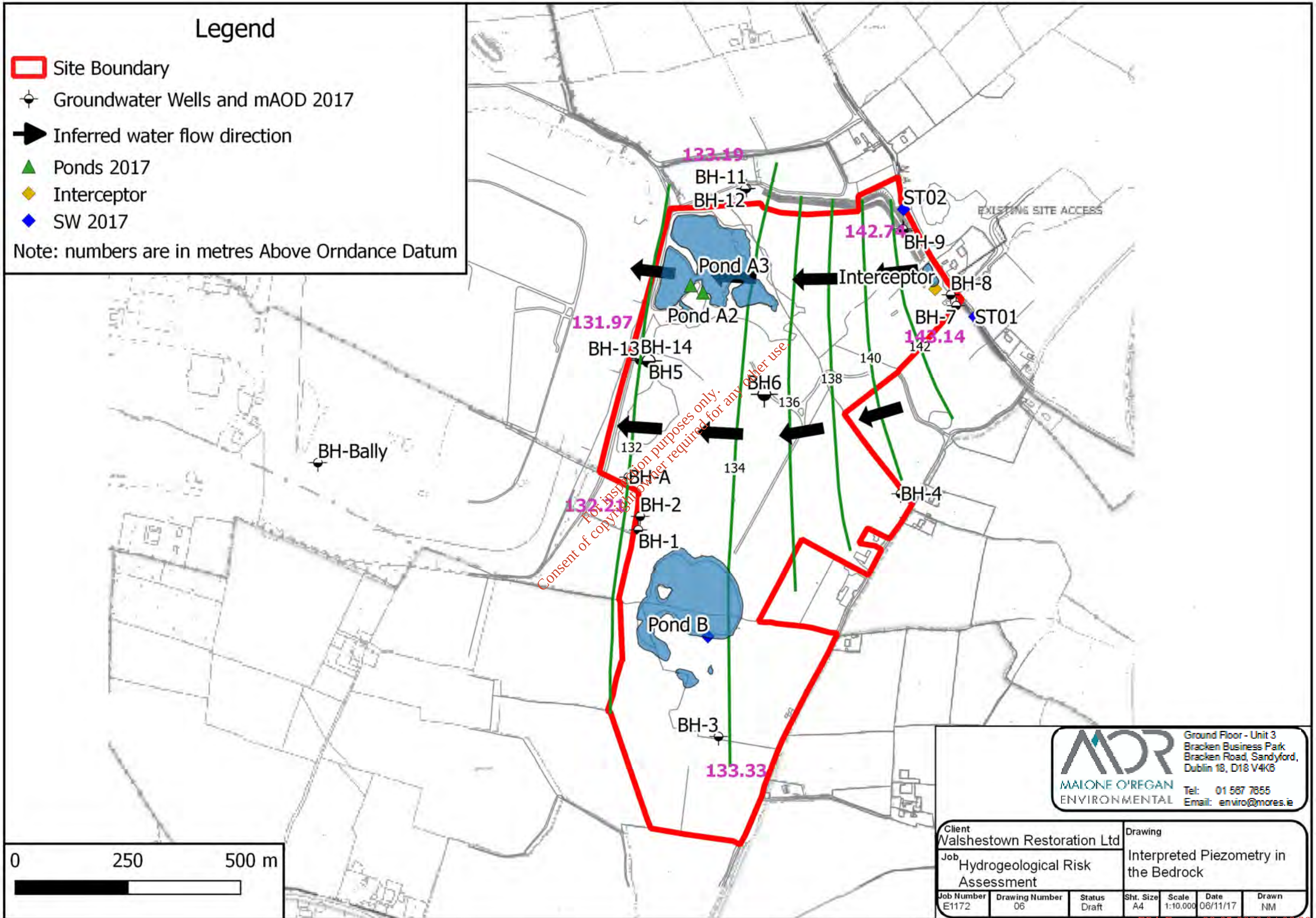
Client
Walshestown Restoration Ltd

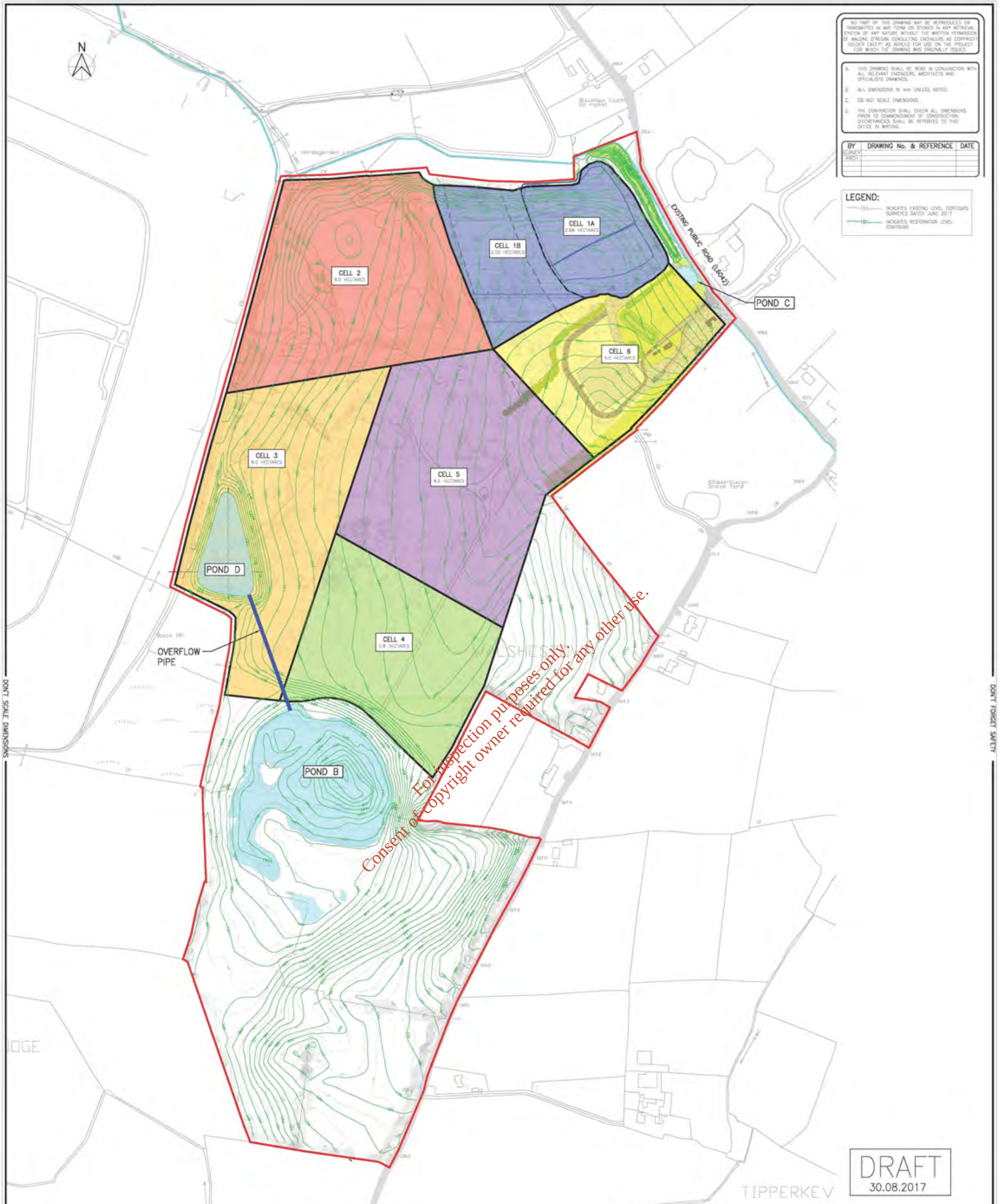
Job
Hydrogeological Risk Assessment

Drawing
Hydrographs of monitored groundwater levels at the Site

Job Number	Drawing Number	Status	Sht. Size	Scale	Date	Drawn
E1172	04	Draft	A4		08/11/17	NM


Legend
Site Boundary
Groundwater Wells
Inferred water flow direction
SW 2017
Interceptor
Ponds
Note: numbers are in metres Above Orndance Datum
136.87
BH-11
BH-12
ST02
EXISTING SITE ACCESS
BH-9
142.4
BH-10
Interceptor
BH-8
143.35
BH-7
ST01
Pond A3
Pond A2
135.46
135
137
139
141
143
145
147
149
BH-13
BH-14
BH5
BH6
BH-Bally
BH-A
BH-2
BH-1
136.70
BH-4
150.82
Pond B
BH-3
0
250
500 m
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
MALONE O'REGAN ENVIRONMENTAL
Tel: 01 567 7655
Email: enviro@mores.ie
Client
Walshestown Restoration Ltd
Job
Hydrogeological Risk Assessment
Drawing
Interpreted Piezometry in the Overburden Deposits
Job Number
E1172
Drawing Number
05
Status
Draft
Sht. Size
A4
Scale
1:10,000
Date
06/11/17
Drawn
NM


Legend
Site Boundary
Groundwater Wells and mAOD 2017
Inferred water flow direction
Ponds 2017
Interceptor
SW 2017
Note: numbers are in metres Above Orndance Datum
133.19
BH-11
BH-12
ST02
EXISTING SITE ACCESS
142.74
BH-9
Pond A3
Interceptor
BH-8
Pond A2
131.97
BH-7
ST01
143.14
142
BH-13
BH-14
BH5
140
138
BH6
136
BH-Bally
132
BH-A
134
BH-4
132.21
BH-2
BH-1
Pond B
BH-3
133.33
0
250
500 m
Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K6
MALONE O'REGAN
ENVIRONMENTAL
Tel: 01 567 7655
Email: enviro@mores.ie
Client
Walshestown Restoration Ltd
Drawing
Interpreted Piezometry in the Bedrock
Job
Hydrogeological Risk Assessment
Job Number
E1172
Drawing Number
06
Status
Draft
Sht. Size
A4
Scale
1:10,000
Date
06/11/17
Drawn
NM



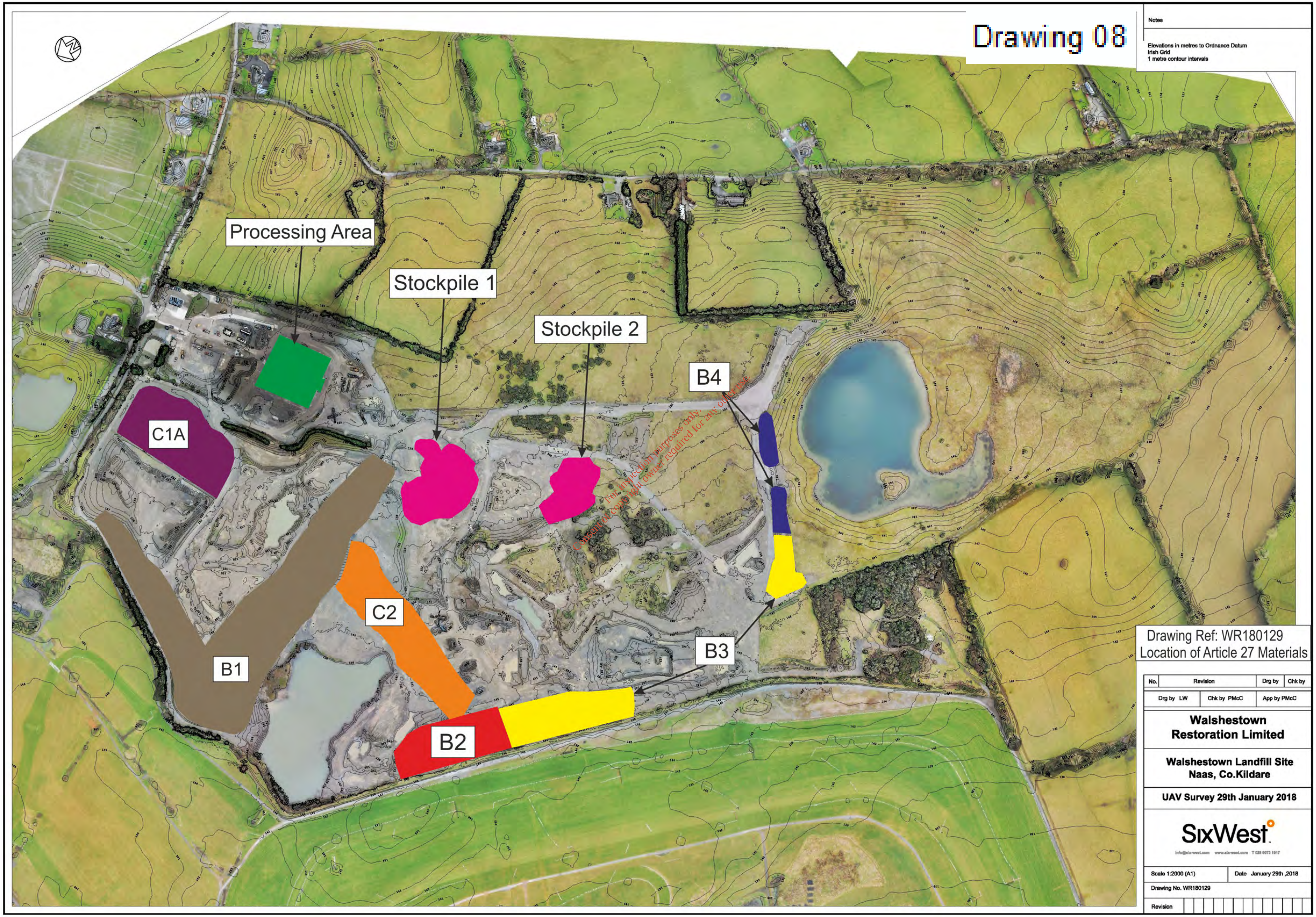
MALONE O'REGAN ENVIRONMENTAL

Ground Floor - Unit 3
Bracken Business Park
Bracken Road, Sandyford,
Dublin 18, D18 V4K8

Tel: 01 567 7655
Email: enviro@mores.ie

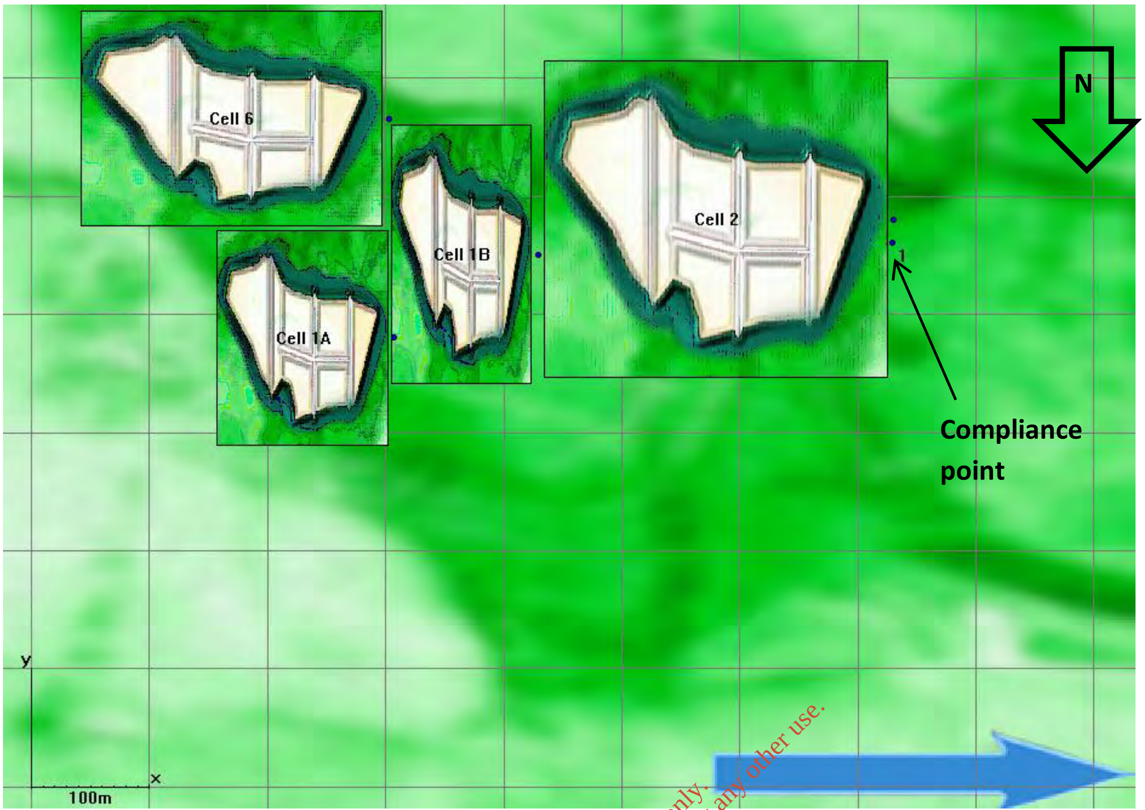
Client	Drawing
Walshestown Restoration Ltd	Proposed Site Layout
Job: Hydrogeological Risk Assessment	

Job Number	Drawing Number	Status	Sht. Size	Scale	Date	Drawn
E1172	07	Draft	A4	NTS	07/11/17	NM

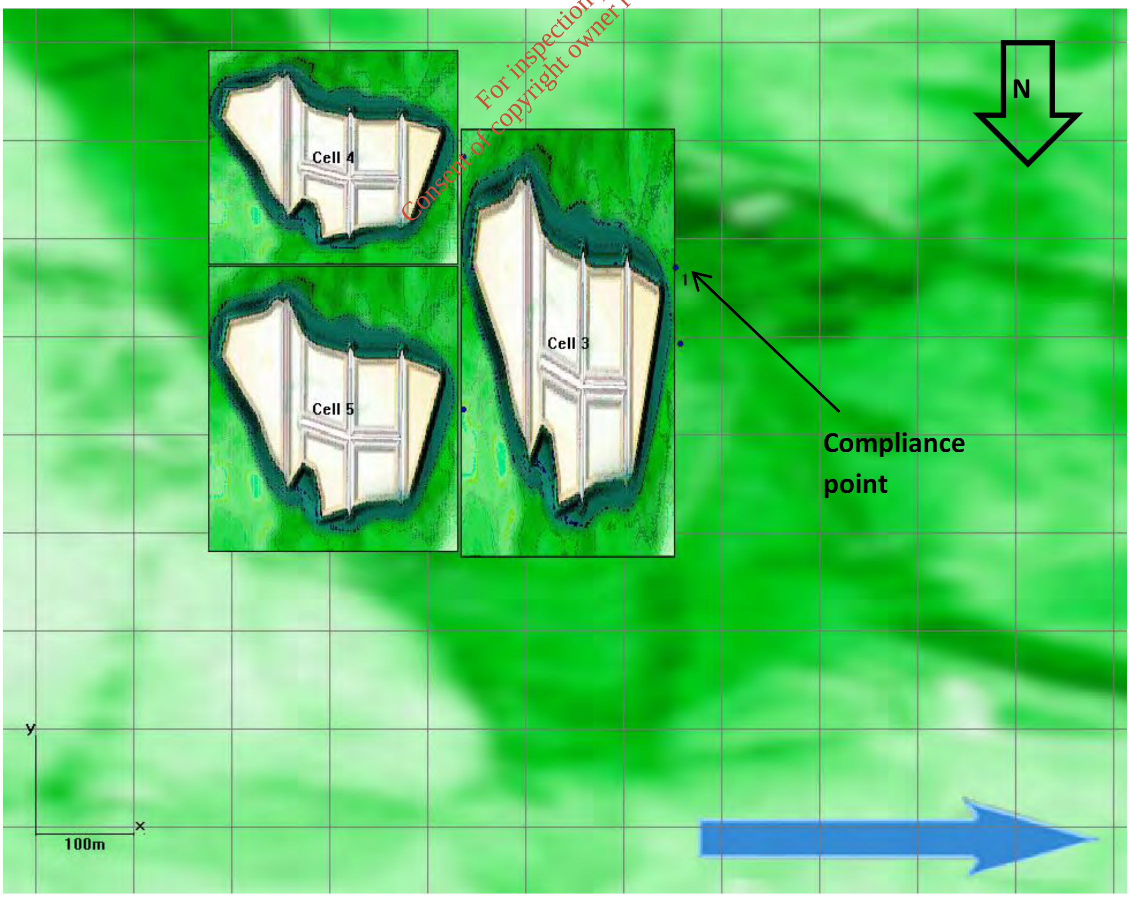

Drawing 08
Notes
Elevations in metres to Ordnance Datum
Irish Grid
1 metre contour intervals
Processing Area
Stockpile 1
Stockpile 2
B4
C1A
C2
B1
B3
B2
Drawing Ref: WR180129
Location of Article 27 Materials
No.
Revision
Drg by
Chk by
Drg by LW
Chk by PMcC
App by PMcC
Walshestown Restoration Limited
Walshestown Landfill Site
Naas, Co.Kildare
UAV Survey 29th January 2018
SixWest
Scale 1:2000 (A1)
Date January 29th ,2018
Drawing No. WR180129
Revision

Drawing 9: Configuration of modelled cells in LandSim

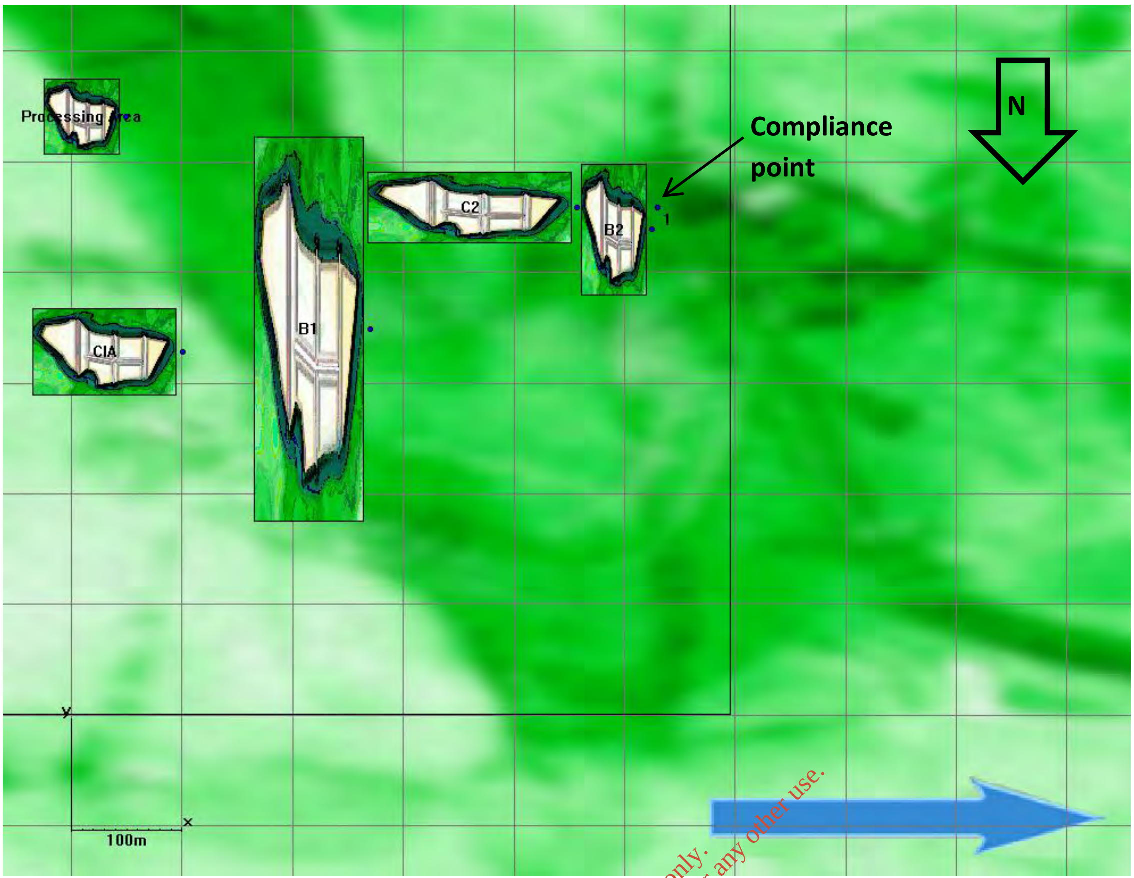
Run 1



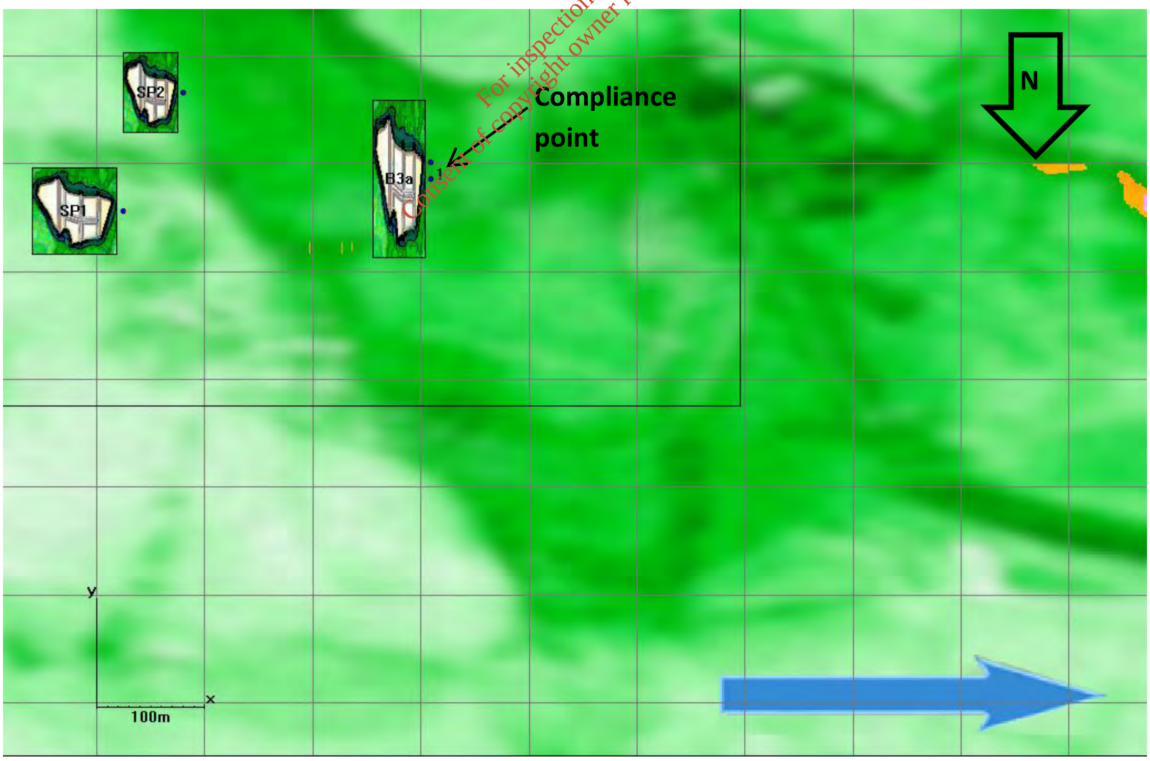
Run 2



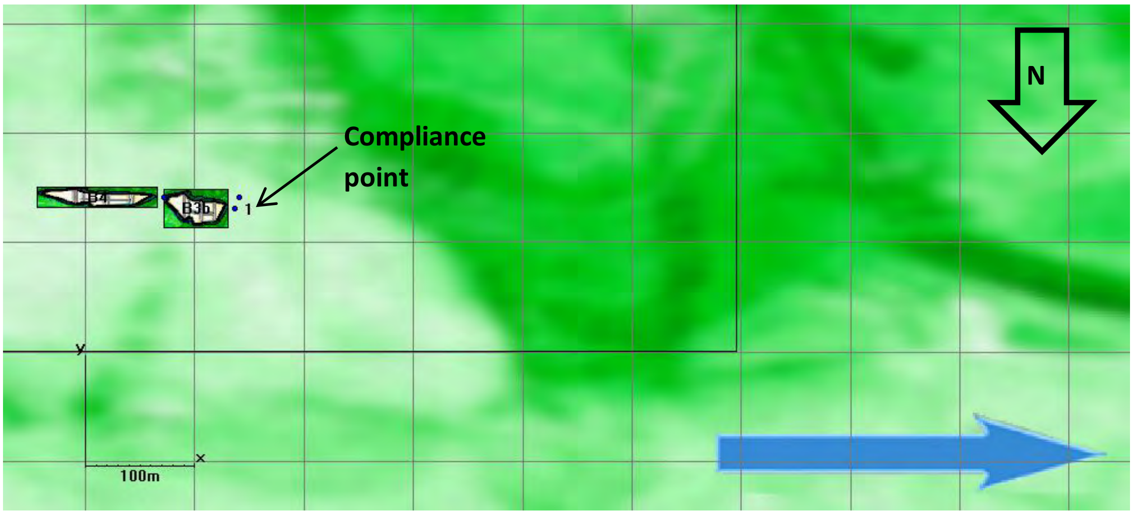
Run 3


Processing area
B1
C2
B2
CIA
Compliance
point
N
1
100m

Run 4


SP2
SP1
B3a
Compliance
point
N
100m

Run 5

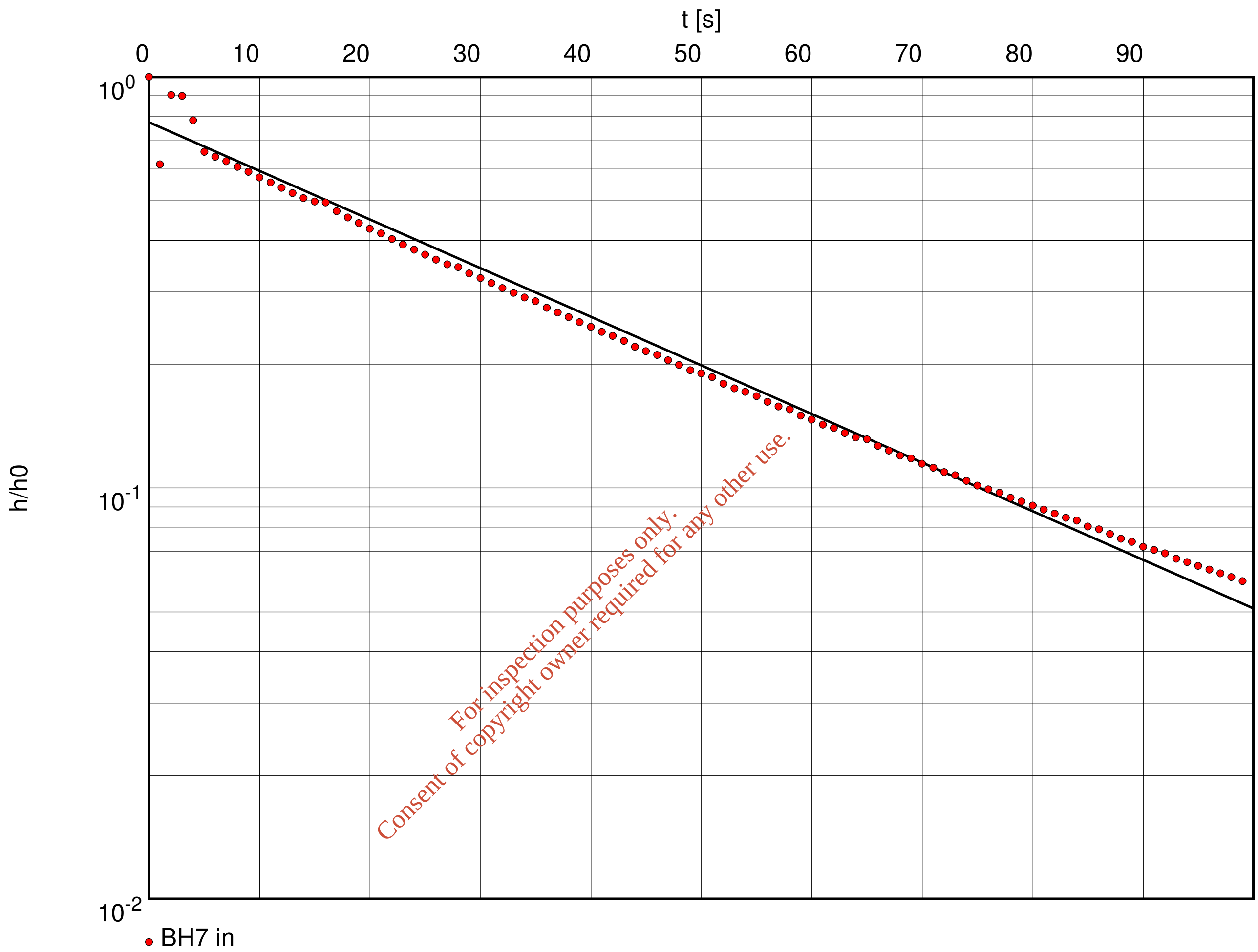


Appendices

Appendix A

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

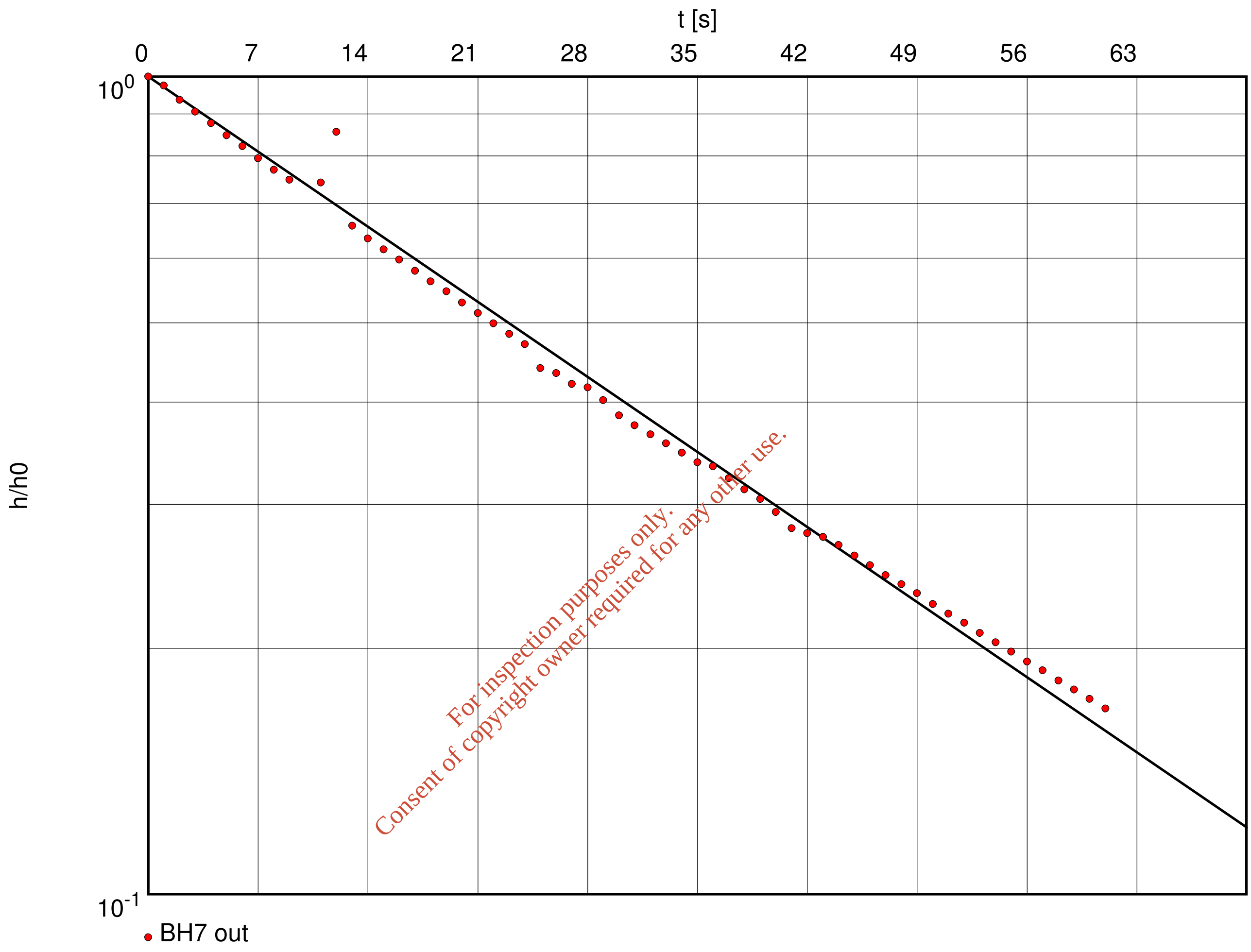
Slug Test No.	Test conducted on: 18/10/17
BH7 slug in	



Hydraulic conductivity [m/s]: 9.22×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

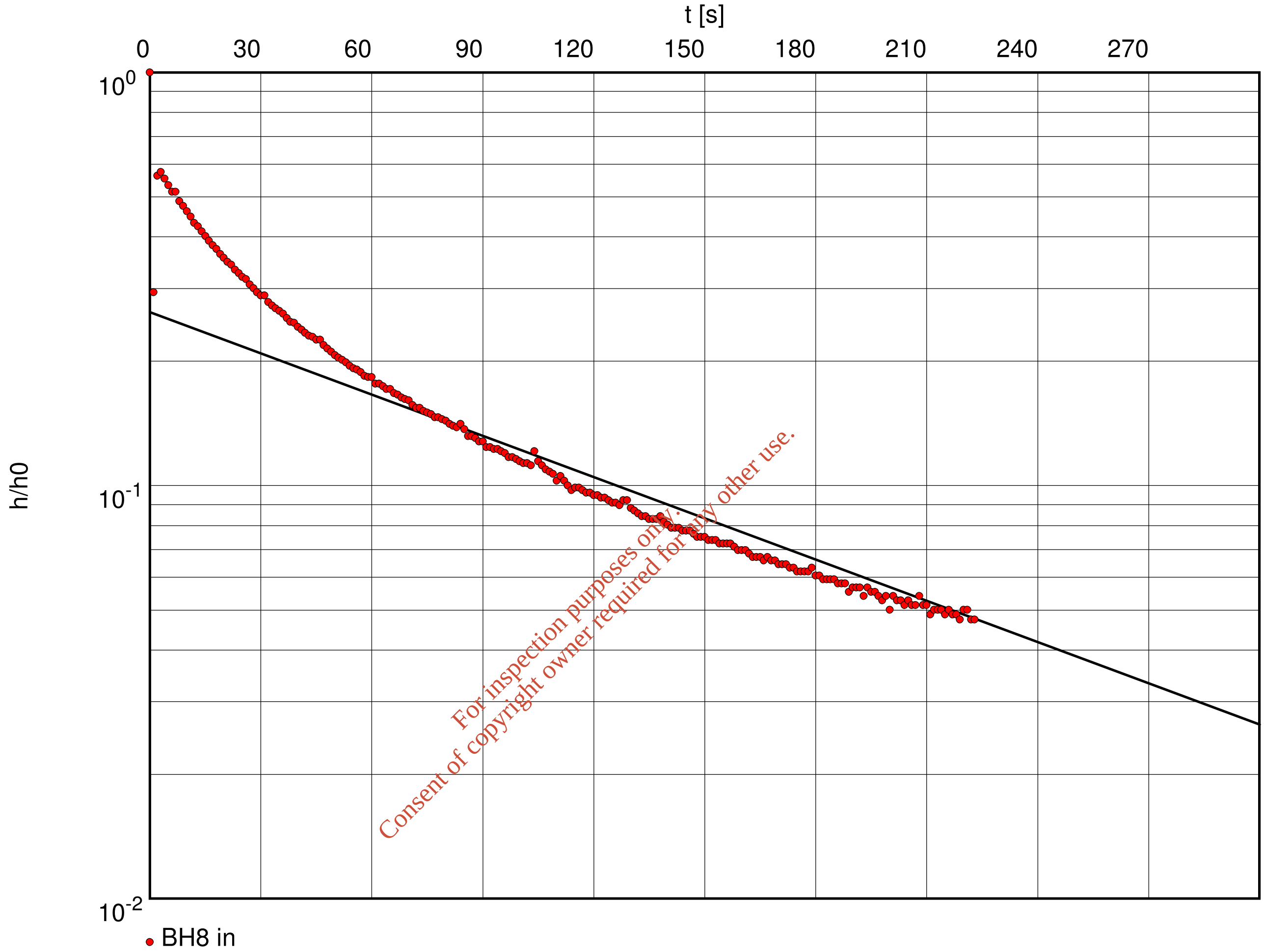
Slug Test No.	Test conducted on: 18/10/17
BH7 slug out	



Hydraulic conductivity [m/s]: 1.02×10^{-5}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

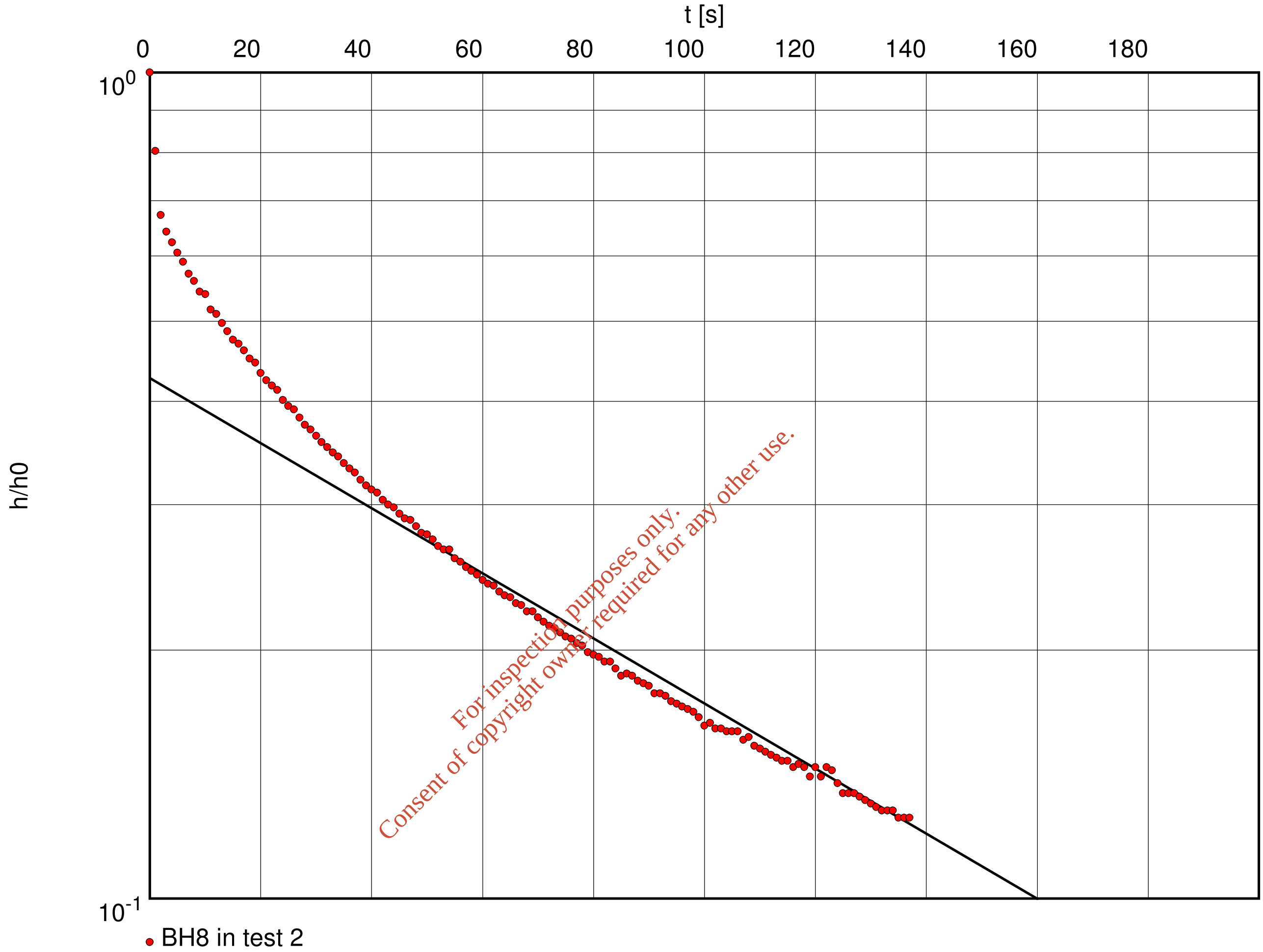
Slug Test No.	Test conducted on: 18/10/17
BH8 slug in	



Hydraulic conductivity [m/s]: 2.39×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

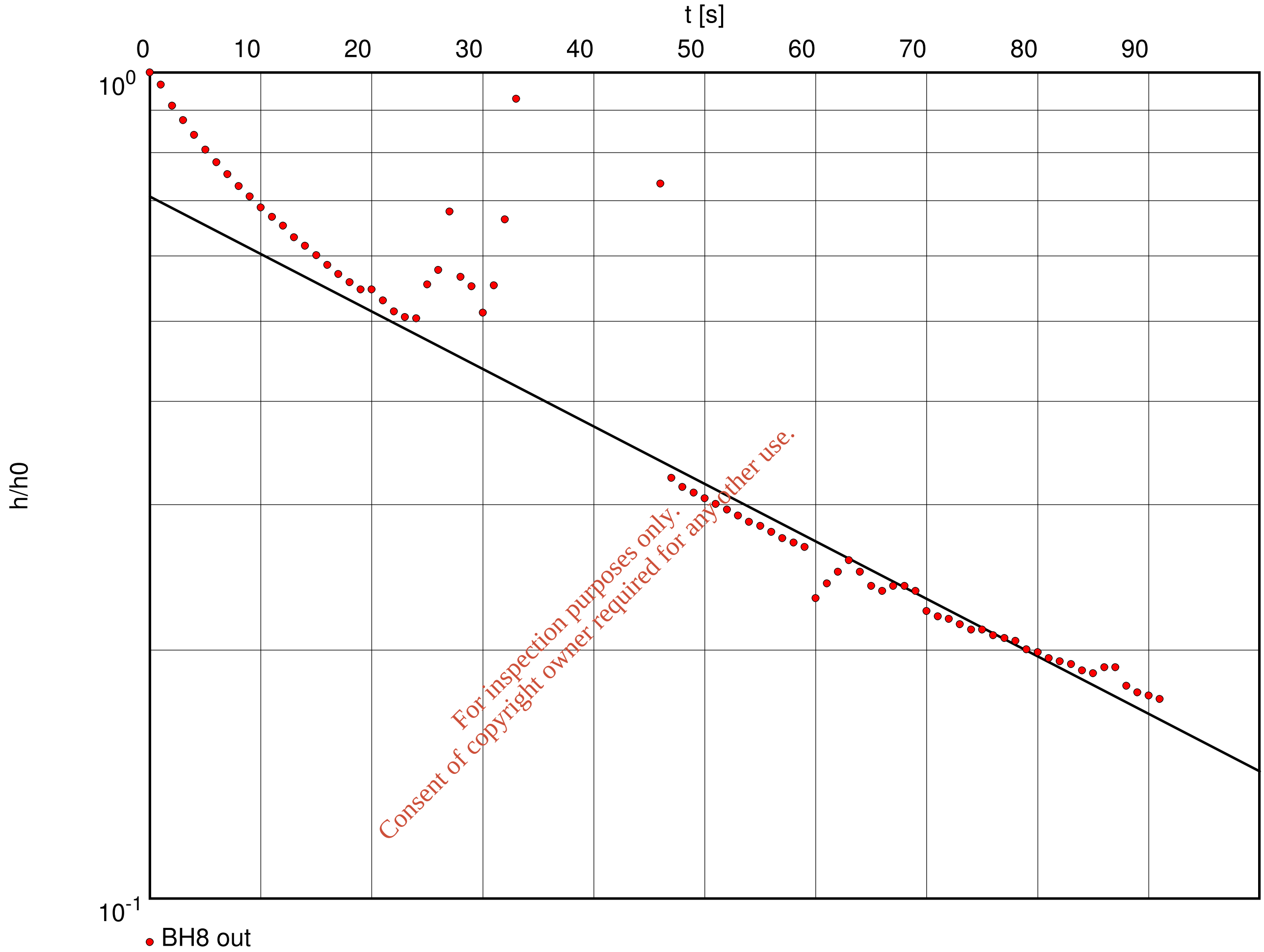
Slug Test No.	Test conducted on: 18/10/17
BH8 slug in test2	



Hydraulic conductivity [m/s]: 2.83×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

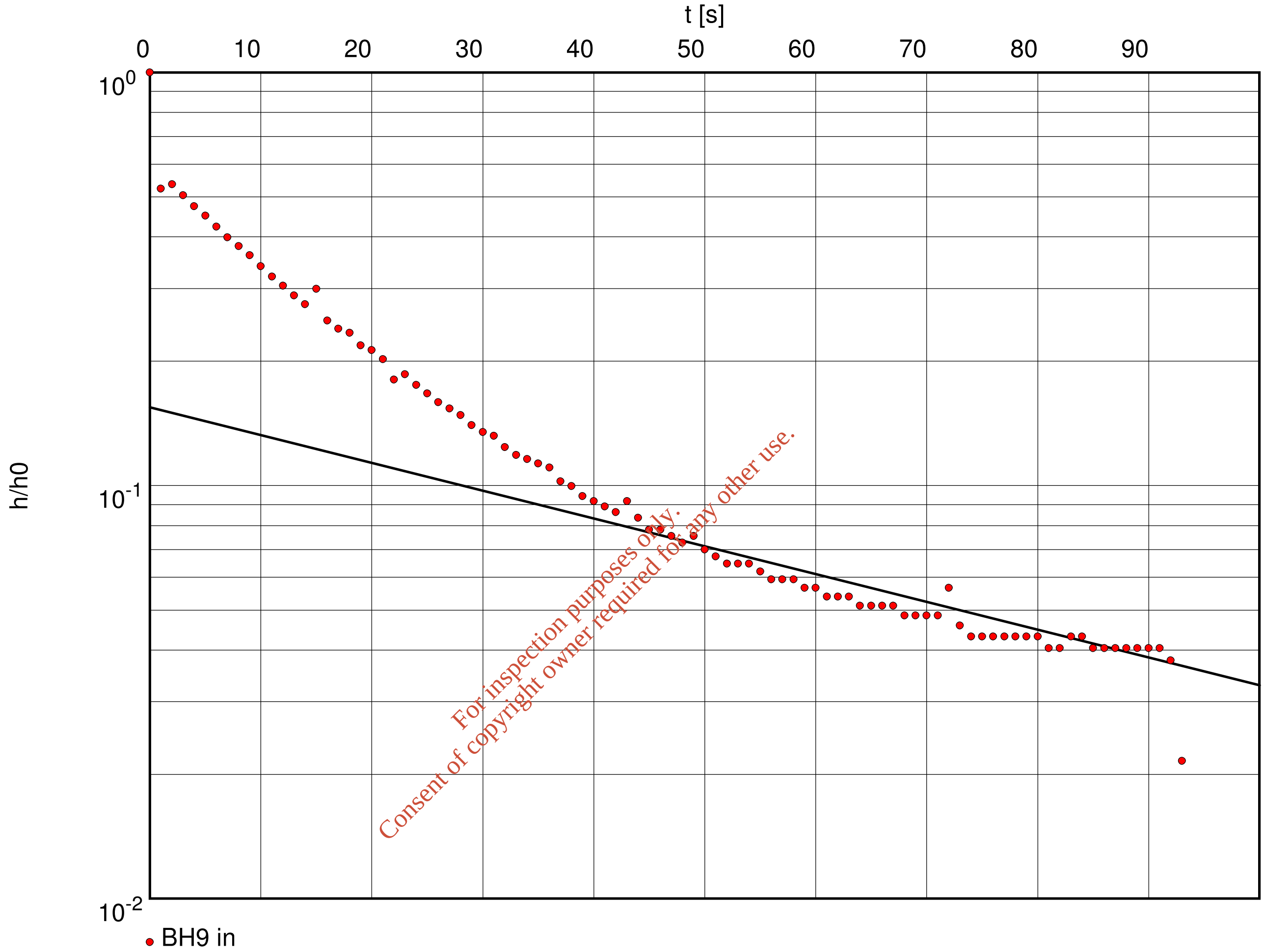
Slug Test No.	Test conducted on: 18/10/17
BH8 slug out	



Hydraulic conductivity [m/s]: 5.01×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

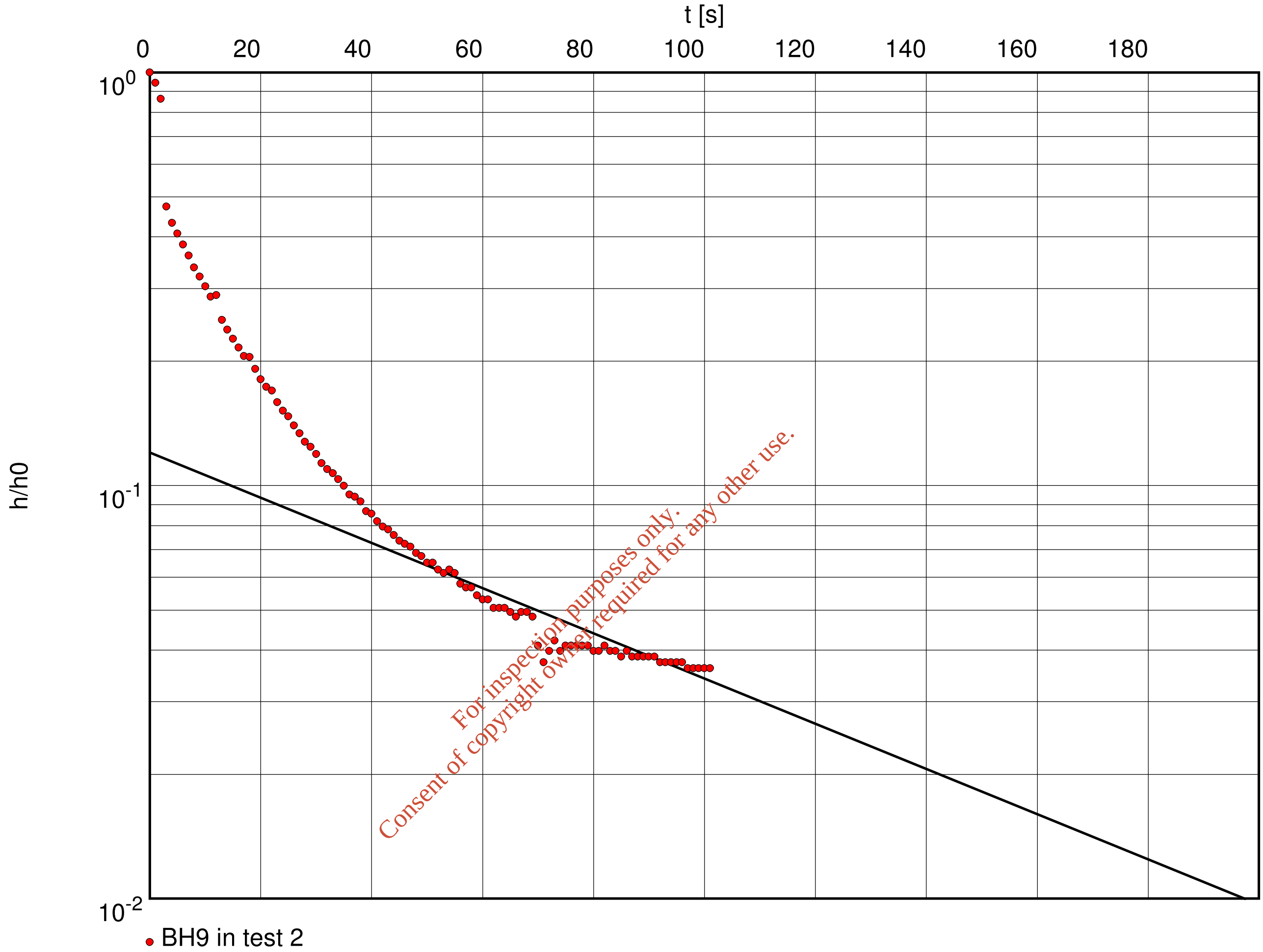
Slug Test No.	Test conducted on: 18/10/17
BH9 slug in	



Hydraulic conductivity [m/s]: 4.88×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

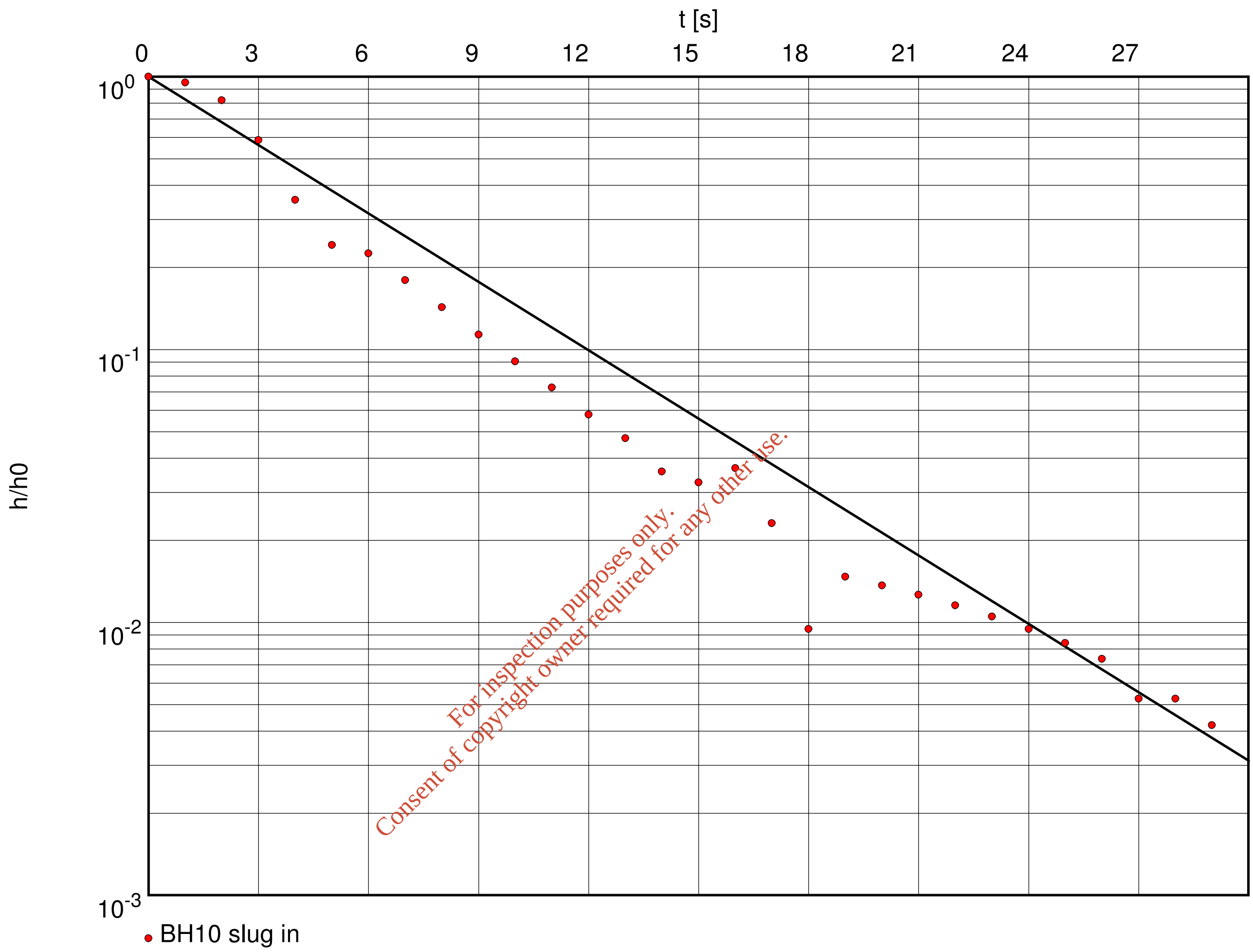
Slug Test No.	Test conducted on: 18/10/17
BH9 slug in test 2	



Hydraulic conductivity [m/s]: 3.96×10^{-6}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

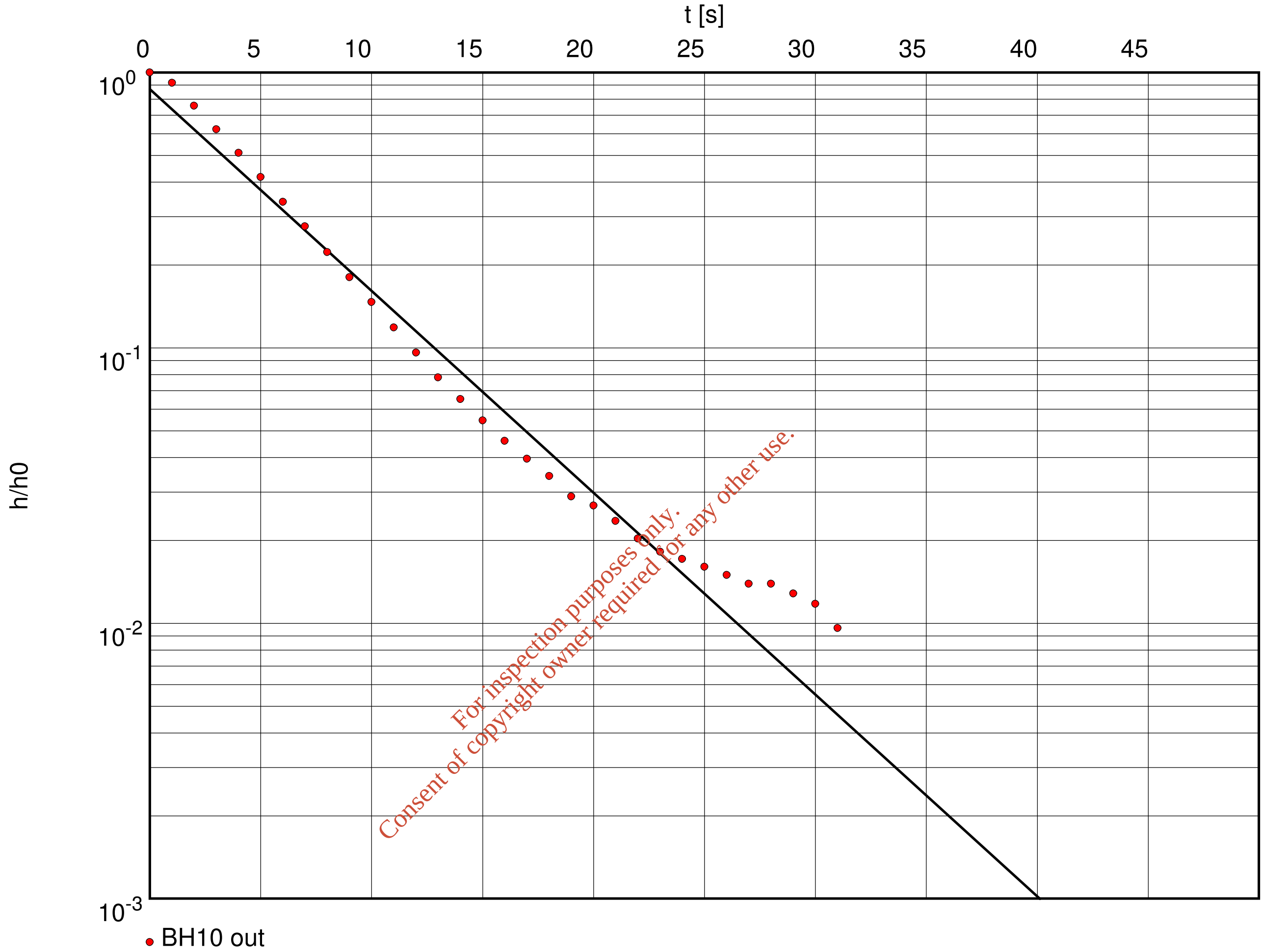
Slug Test No.	Test conducted on: 18/10/17
BH10 slug in	



Hydraulic conductivity [m/s]: 3.61×10^{-5}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

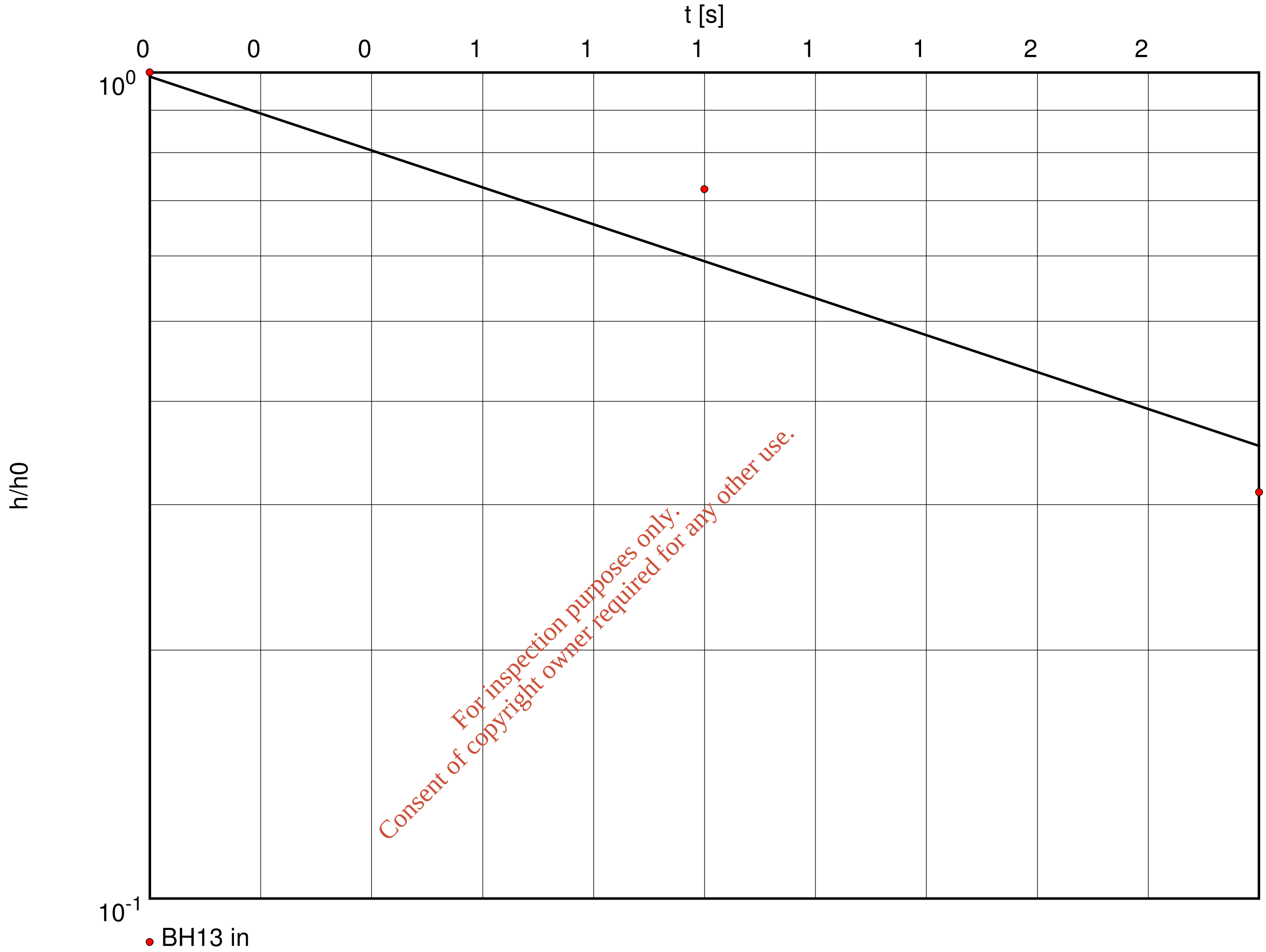
Slug Test No.	Test conducted on: 18/10/17
BH10 slug out	



Hydraulic conductivity [m/s]: 3.83×10^{-5}

	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

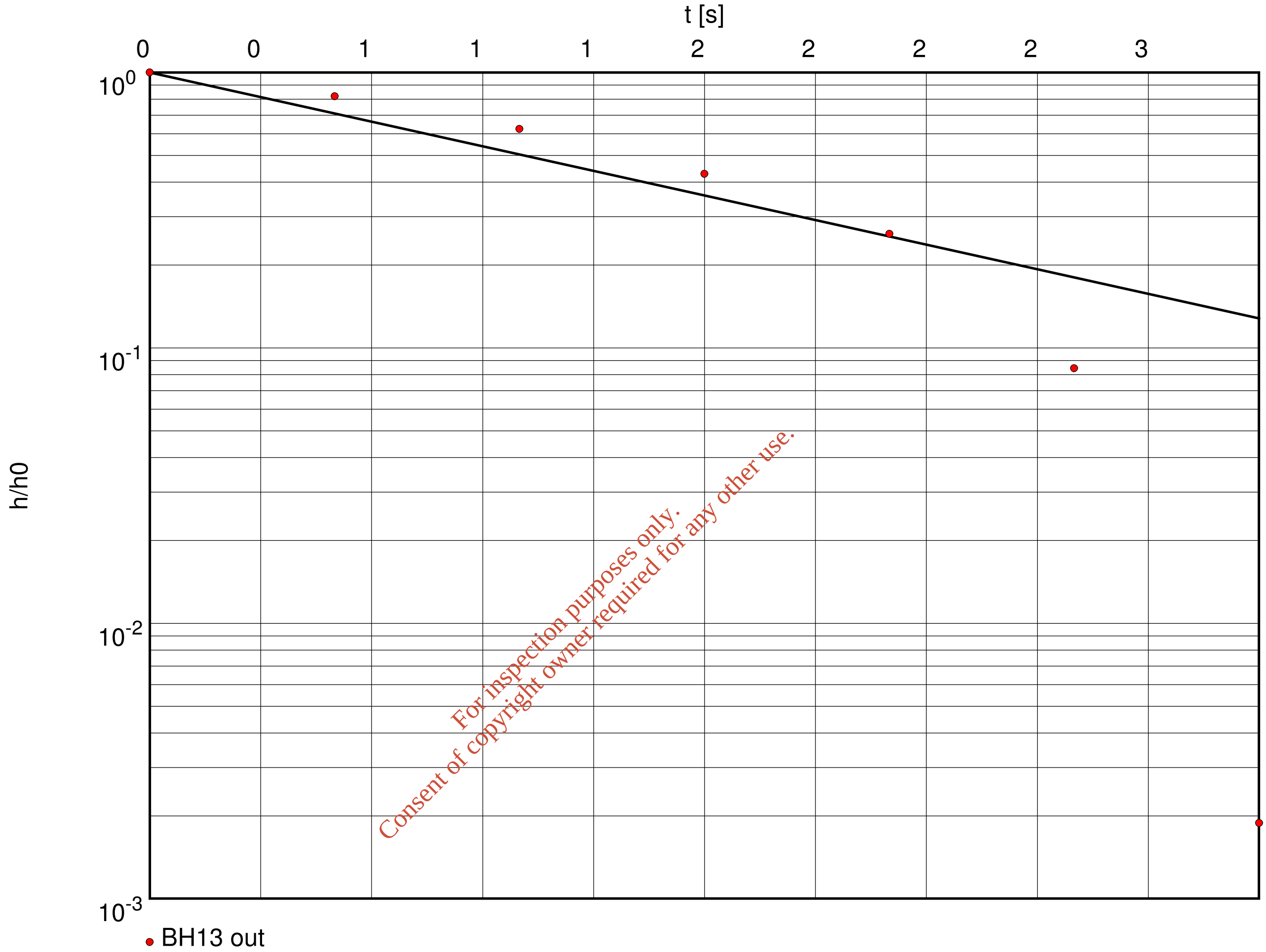
Slug Test No.	Test conducted on: 23/10/17
BH13 slug in	



Hydraulic conductivity [m/s]: 1.38×10^{-4}

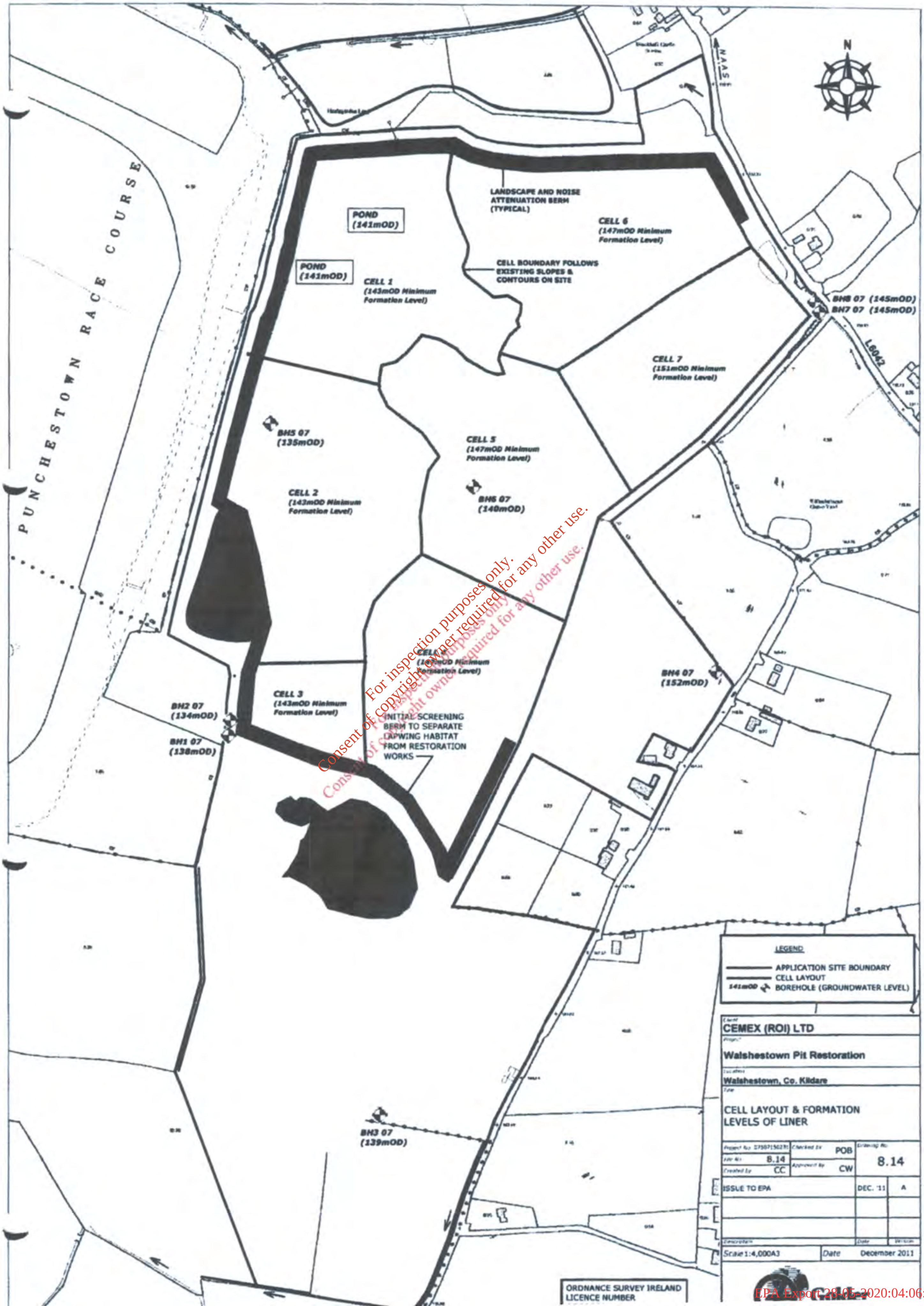
	slug/bail test analysis BOUWER-RICE's method	Date: 01.11.2017	Page 1
		Project: Walshestown	
		Evaluated by: FC	

Slug Test No.	Test conducted on: 23/10/17
BH13 slug out	



Hydraulic conductivity [m/s]: 1.84×10^{-4}

Appendix B



PUNCHESTOWN RACE COURSE
NAAS
N
L6042
LANDSCAPE AND NOISE ATTENUATION BERM (TYPICAL)
POND (141mOD)
POND (141mOD)
CELL 1 (143mOD Minimum Formation Level)
CELL 6 (147mOD Minimum Formation Level)
CELL BOUNDARY FOLLOWS EXISTING SLOPES & CONTOURS ON SITE
BH8 07 (145mOD)
BH7 07 (145mOD)
CELL 7 (151mOD Minimum Formation Level)
BH5 07 (135mOD)
CELL 5 (147mOD Minimum Formation Level)
CELL 2 (142mOD Minimum Formation Level)
BH6 07 (140mOD)
BH4 07 (152mOD)
CELL 3 (143mOD Minimum Formation Level)
INITIAL SCREENING BERM TO SEPARATE LAPWING HABITAT FROM RESTORATION WORKS
BH2 07 (134mOD)
BH1 07 (138mOD)
BH3 07 (139mOD)
LEGEND
APPLICATION SITE BOUNDARY
CELL LAYOUT
141mOD BOREHOLE (GROUNDWATER LEVEL)
CEMEX (ROI) LTD
Walshestown Pit Restoration
Walshestown, Co. Kildare
CELL LAYOUT & FORMATION LEVELS OF LINER
POB
8.14
CC
CW
8.14
ISSUE TO EPA
DEC. '11
A
Scale 1:4,000A3
Date
December 2011
ORDNANCE SURVEY IRELAND LICENCE NUMBER

Appendix C

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Nickel
c (kg/l): -0.1479

Non-Volatile
m (kg/l): 0.0987

Sulphate
c (kg/l): 0.1209

Non-Volatile
m (kg/l): 0.0166

Zinc
c (kg/l): 0.0561

Non-Volatile
m (kg/l): 0.0403

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Chloride	TRIANGULAR(5.6,11,16.2)
Chromium	TRIANGULAR(0.0002,0.0007,0.0018)
Nickel	TRIANGULAR(0.0002,0.00093,0.002)
Sulphate	TRIANGULAR(4.3,13.5,19.6)
Zinc	TRIANGULAR(0.0015,0.00213,0.0037)

Phase: Cell 1A

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	140
Cell length (m):	134
Cell top area (ha):	2.68
Cell base area (ha):	1.876
Number of cells:	1
Total base area (ha):	1.876
Total top area (ha):	2.68
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(1,5,8)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18) *Substance to be treated as List 1*
Cadmium	SINGLE(0.06) *Substance to be treated as List 1*
Chloride	SINGLE(1380) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.3) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(1.8) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(7.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.45) *Substance to be treated as List 1*
Mercury	SINGLE(0.006) *Substance to be treated as List 1*
Nickel	SINGLE(0.36) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(4500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(3.6) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner
Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvioglacial sands, gravels & silts pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(10,13)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(1,1.3)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvioglacial sands, gravels & silts pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(427,573)
Pathway width (m):	SINGLE(190)

Phase: Cell 1B

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	160
Cell length (m):	110
Cell top area (ha):	2.52
Cell base area (ha):	1.76
Number of cells:	1
Total base area (ha):	1.76
Total top area (ha):	2.52
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(1,5,8)
Field capacity (fraction):	UNIFORM(0.11,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants
All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Substance to be treated as List 1
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvio glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(13,14.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(1.3,1.45)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(305,425)
Pathway width (m):	SINGLE(220)

Phase: Cell 2

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	220
Cell length (m):	254
Cell top area (ha):	8
Cell base area (ha):	5.588
Number of cells:	1
Total base area (ha):	5.588
Total top area (ha):	8
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(1,7,12)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Substance to be treated as List 1
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(5,7)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.5,0.7)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(4,296)
Pathway width (m):	SINGLE(190)

Phase: Cell 6

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	160
Cell length (m):	197
Cell top area (ha):	4.5
Cell base area (ha):	3.152
Number of cells:	1
Total base area (ha):	3.152
Total top area (ha):	4.5
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(3,10,15)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Substance to be treated as List 1
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.92e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(7,13)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.7,1.3)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(432,688)
Pathway width (m):	SINGLE(220)

Bedrock pathway parameters

No Vertical Pathway

Bedrock pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(15,17)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	UNIFORM(0.016,0.03)
Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)
Pathway porosity (fraction):	UNIFORM(0.2,0.3)

Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.4,68.8)
Pathway transverse dispersivity (m):	UNIFORM(0.12,20.64)

Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Bedrock pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Nickel	Non-Volatile
c (kg/l): -0.1479	m (kg/l): 0.0987
Sulphate	Non-Volatile
c (kg/l): 0.1209	m (kg/l): 0.0166
Zinc	Non-Volatile
c (kg/l): 0.0561	m (kg/l): 0.0403

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Chloride	TRIANGULAR(5.6,11,16.2)
Chromium	TRIANGULAR(0.0002,0.0007,0.0018)
Nickel	TRIANGULAR(0.0002,0.00093,0.002)
Sulphate	TRIANGULAR(4.3,13.5,19.6)
Zinc	TRIANGULAR(0.0015,0.00213,0.0037)

Phase: Cell 4

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	217
Cell length (m):	187
Cell top area (ha):	5.8
Cell base area (ha):	4.0579
Number of cells:	1
Total base area (ha):	4.0579
Total top area (ha):	5.8
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(1,7,10)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Data are spot measurements of Leachate Quality
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvioglacial sands, gravels & silts pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(1,8)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry

Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.1,0.8)

Justification for Unsat Zone Dispersion Properties

Unjustified value

Retardation parameters for Fluvioglacial sands, gravels & silts pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(222,478)
Pathway width (m):	SINGLE(220)

Phase: Cell 5

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	225
Cell length (m):	264
Cell top area (ha):	8.5
Cell base area (ha):	5.94
Number of cells:	1
Total base area (ha):	5.94
Total top area (ha):	8.5
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(6,11,18)
Field capacity (fraction):	UNIFORM(0.11,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Data are spot measurements of Leachate Quality
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvio glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(2,8)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.2,0.8)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(222,478)
Pathway width (m):	SINGLE(290)

Phase: Cell 3

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	156
Cell length (m):	360
Cell top area (ha):	8
Cell base area (ha):	5.616
Number of cells:	1
Total base area (ha):	5.616
Total top area (ha):	8
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	TRIANGULAR(1,6,10)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.18)
	Data are spot measurements of Leachate Quality
Cadmium	SINGLE(0.06)
	Substance to be treated as List 1
Chloride	SINGLE(1380)
	Data are spot measurements of Leachate Quality
Chromium	SINGLE(0.3)
	Data are spot measurements of Leachate Quality
Copper	SINGLE(1.8)
	Data are spot measurements of Leachate Quality
Fluoride	SINGLE(7.5)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.45)
	Substance to be treated as List 1
Mercury	SINGLE(0.006)
	Substance to be treated as List 1
Nickel	SINGLE(0.36)
	Data are spot measurements of Leachate Quality
Sulphate	SINGLE(4500)
	Data are spot measurements of Leachate Quality
Zinc	SINGLE(3.6)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.67,1.89,2.13)
Pathway moisture content (fraction):	TRIANGULAR(0.082,0.13,0.16)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	TRIANGULAR(1.97e-010,5.87e-010,2.12e-009)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Liner Kd Values by Species
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(4,8)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.4,0.8)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species
Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(0.5,219.5)
Pathway width (m):	SINGLE(440)

Bedrock pathway parameters

No Vertical Pathway

Bedrock pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(15,17)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	UNIFORM(0.016,0.03)
Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)
Pathway porosity (fraction):	UNIFORM(0.2,0.3)

Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.4,68.8)
Pathway transverse dispersivity (m):	UNIFORM(0.12,20.64)

Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Bedrock pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Nickel
c (kg/l): -0.1479
Non-Volatile
m (kg/l): 0.0987

Selenium
c (kg/l): -0.062
Non-Volatile
m (kg/l): 0.1063

Sulphate
c (kg/l): 0.1209
Non-Volatile
m (kg/l): 0.0166

Zinc
c (kg/l): 0.0561
Non-Volatile
m (kg/l): 0.0403

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Chloride	TRIANGULAR(5.6,11,16.2)
Chromium	TRIANGULAR(0.0002,0.0007,0.0018)
Nickel	TRIANGULAR(0.0002,0.00093,0.002)
Sulphate	TRIANGULAR(4.3,13.5,19.6)
Zinc	TRIANGULAR(0.0015,0.00213,0.0037)

Phase: CIA

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	80
Cell length (m):	130.5
Cell top area (ha):	1.045
Cell base area (ha):	1.044
Number of cells:	1
Total base area (ha):	1.044
Total top area (ha):	1.045
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.1)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvioglacial sands, gravels & silts pathway parameters
Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(5.4,6.4)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.54,0.64)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvioglacial sands, gravels & silts pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(434.75,565.25)
Pathway width (m):	SINGLE(80)

Phase: B1

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	348.2
Cell length (m):	100
Cell top area (ha):	3.483
Cell base area (ha):	3.482
Number of cells:	1
Total base area (ha):	3.482
Total top area (ha):	3.483
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.5)
Field capacity (fraction):	UNIFORM(0.11,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0.1,16.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.01,1.65)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(265,365)
Pathway width (m):	SINGLE(348.2)

Phase: C2

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	65
Cell length (m):	185
Cell top area (ha):	1.203
Cell base area (ha):	1.2025
Number of cells:	1
Total base area (ha):	1.2025
Total top area (ha):	1.203
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(2)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0.1,12)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.01,1.2)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(77.5,262.5)
Pathway width (m):	SINGLE(65)

Phase: Processing Area

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	69.63
Cell length (m):	69.63
Cell top area (ha):	0.485
Cell base area (ha):	0.484834
Number of cells:	1
Total base area (ha):	0.484834
Total top area (ha):	0.485
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(1.5)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(12.5,13.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(1.25,1.35)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(485.685,555.315)
Pathway width (m):	SINGLE(69.63)

Phase: B2

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	120
Cell length (m):	60.2
Cell top area (ha):	0.7228
Cell base area (ha):	0.7224
Number of cells:	1
Total base area (ha):	0.7224
Total top area (ha):	0.7228
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.5)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(5.5,11.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.55,1.15)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(9.9,70.1)
Pathway width (m):	SINGLE(120)

Bedrock pathway parameters

No Vertical Pathway

Bedrock pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(15,17)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	UNIFORM(0.016,0.03)
Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)
Pathway porosity (fraction):	UNIFORM(0.2,0.3)

Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.99,56.5)
Pathway transverse dispersivity (m):	UNIFORM(0.27,16.95)

Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Bedrock pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Nickel	Non-Volatile
c (kg/l): -0.1479	m (kg/l): 0.0987
Selenium	Non-Volatile
c (kg/l): -0.062	m (kg/l): 0.1063
Sulphate	Non-Volatile
c (kg/l): 0.1209	m (kg/l): 0.0166
Zinc	Non-Volatile
c (kg/l): 0.0561	m (kg/l): 0.0403

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Chloride	TRIANGULAR(5.6,11,16.2)
Chromium	TRIANGULAR(0.0002,0.0007,0.0018)
Nickel	TRIANGULAR(0.0002,0.00093,0.002)
Sulphate	TRIANGULAR(4.3,13.5,19.6)
Zinc	TRIANGULAR(0.0015,0.00213,0.0037)

Phase: SP1

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	82
Cell length (m):	80
Cell top area (ha):	0.656628
Cell base area (ha):	0.656
Number of cells:	1
Total base area (ha):	0.656
Total top area (ha):	0.656628
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.7)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvioglacial sands, gravels & silts pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(9.3,15.3)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.93,1.53)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvioglacial sands, gravels & silts pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(290,370)
Pathway width (m):	SINGLE(82)

Phase: B3a

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	147.22
Cell length (m):	50
Cell top area (ha):	0.736311
Cell base area (ha):	0.7361
Number of cells:	1
Total base area (ha):	0.7361
Total top area (ha):	0.736311
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.5)
Field capacity (fraction):	UNIFORM(0.11,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(4.5,13.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.45,1.35)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(5,55)
Pathway width (m):	SINGLE(147.22)

Phase: SP2

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	75
Cell length (m):	52.28
Cell top area (ha):	0.392235
Cell base area (ha):	0.3921
Number of cells:	1
Total base area (ha):	0.3921
Total top area (ha):	0.392235
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(1.2)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(7.8,14.8)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.78,1.48)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(233.86,286.14)
Pathway width (m):	SINGLE(75)

Bedrock pathway parameters

No Vertical Pathway

Bedrock pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(15,17)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	UNIFORM(0.016,0.03)
Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)
Pathway porosity (fraction):	UNIFORM(0.2,0.3)

Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(1.55,38.05)
Pathway transverse dispersivity (m):	UNIFORM(0.465,11.42)

Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Bedrock pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Nickel	Non-Volatile
c (kg/l): -0.1479	m (kg/l): 0.0987
Selenium	Non-Volatile
c (kg/l): -0.062	m (kg/l): 0.1063
Sulphate	Non-Volatile
c (kg/l): 0.1209	m (kg/l): 0.0166
Zinc	Non-Volatile
c (kg/l): 0.0561	m (kg/l): 0.0403

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Chloride	TRIANGULAR(5.6,11,16.2)
Chromium	TRIANGULAR(0.0002,0.0007,0.0018)
Nickel	TRIANGULAR(0.0002,0.00093,0.002)
Sulphate	TRIANGULAR(4.3,13.5,19.6)
Zinc	TRIANGULAR(0.0015,0.00213,0.0037)

Phase: B4

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	20
Cell length (m):	111.6
Cell top area (ha):	0.223293
Cell base area (ha):	0.2232
Number of cells:	1
Total base area (ha):	0.2232
Total top area (ha):	0.223293
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.5)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(2.5,10.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.25,1.05)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(74.2,185.8)
Pathway width (m):	SINGLE(20)

Phase: B3b

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(207.5,20.75)
Infiltration to waste (mm/year):	NORMAL(782.4,78.2)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Unjustified value

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	36
Cell length (m):	60.5
Cell top area (ha):	0.217921
Cell base area (ha):	0.2178
Number of cells:	1
Total base area (ha):	0.2178
Total top area (ha):	0.217921
Head of Leachate when surface water breakout occurs (m)	SINGLE(1)
Waste porosity (fraction)	UNIFORM(0.37,0.55)
Final waste thickness (m):	SINGLE(3.5)
Field capacity (fraction):	UNIFORM(0.1,0.35)
Waste dry density (kg/l)	UNIFORM(1.25,1.75)

Justification for Landfill Geometry
Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.06) *Substance to be treated as List 1*
Cadmium	SINGLE(0.02) *Substance to be treated as List 1*
Chloride	SINGLE(460) *Data are spot measurements of Leachate Quality*
Chromium	SINGLE(0.1) *Data are spot measurements of Leachate Quality*
Copper	SINGLE(0.6) *Data are spot measurements of Leachate Quality*
Fluoride	SINGLE(2.5) *Data are spot measurements of Leachate Quality*
Lead	SINGLE(0.15) *Substance to be treated as List 1*
Mercury	SINGLE(0.002) *Substance to be treated as List 1*
Nickel	SINGLE(0.12) *Data are spot measurements of Leachate Quality*
Selenium	SINGLE(0.04) *Data are spot measurements of Leachate Quality*
Sulphate	SINGLE(1500) *Data are spot measurements of Leachate Quality*
Zinc	SINGLE(1.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(0)

Justification for Specified Head
Unjustified value

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Unjustified value

Fluvio-glacial sands and gravels pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(2.5,10.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.2)
Pathway Density (kg/l):	UNIFORM(1.15,2.1)

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s): TRIANGULAR(6.9e-007,4.7e-005,0.001)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m): UNIFORM(0.25,1.05)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Fluvio-glacial sands and gravels pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Arsenic	LOGTRIANGULAR(2,2512,19953)
Cadmium	LOGTRIANGULAR(1.26,794,100000)
Chloride	SINGLE(0)
Chromium	LOGTRIANGULAR(10,7943,50120)
Copper	LOGTRIANGULAR(1.26,501,3981)
Fluoride	SINGLE(0)
Lead	LOGTRIANGULAR(5,15849,100000)
Mercury	LOGTRIANGULAR(158,6310,630957)
Nickel	LOGTRIANGULAR(10,1259,6310)
Selenium	LOGTRIANGULAR(0.5,10,251)
Sulphate	SINGLE(0)
Zinc	LOGTRIANGULAR(0.1,1259,100000)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(9.75,70.25)
Pathway width (m):	SINGLE(36)

Bedrock pathway parameters

No Vertical Pathway

Bedrock pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(15,17)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	UNIFORM(0.016,0.03)
Pathway hydraulic conductivity values (m/s):	TRIANGULAR(6.9e-007,4.7e-005,0.001)
Pathway porosity (fraction):	UNIFORM(0.2,0.3)

Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(0.975,18.6)
Pathway transverse dispersivity (m):	UNIFORM(0.293,5.57)

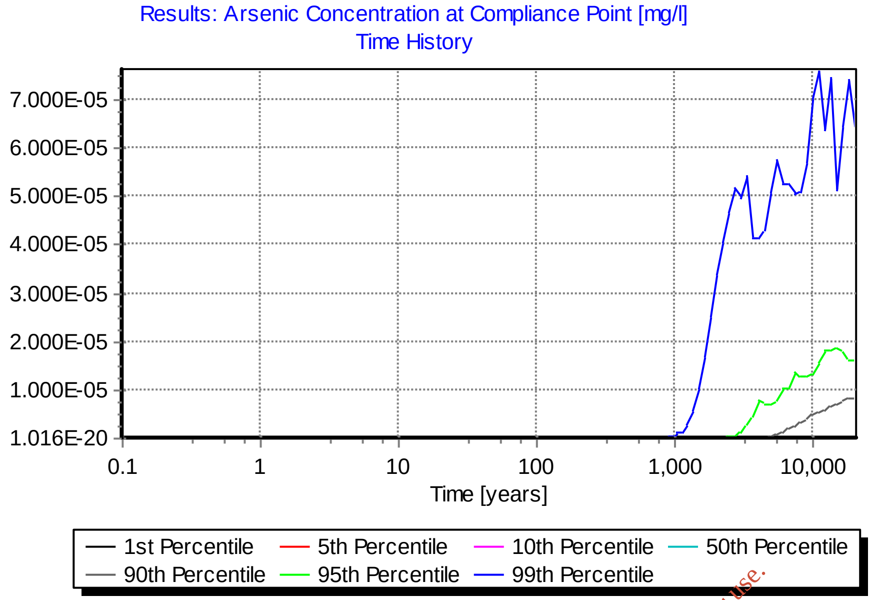
Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Bedrock pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

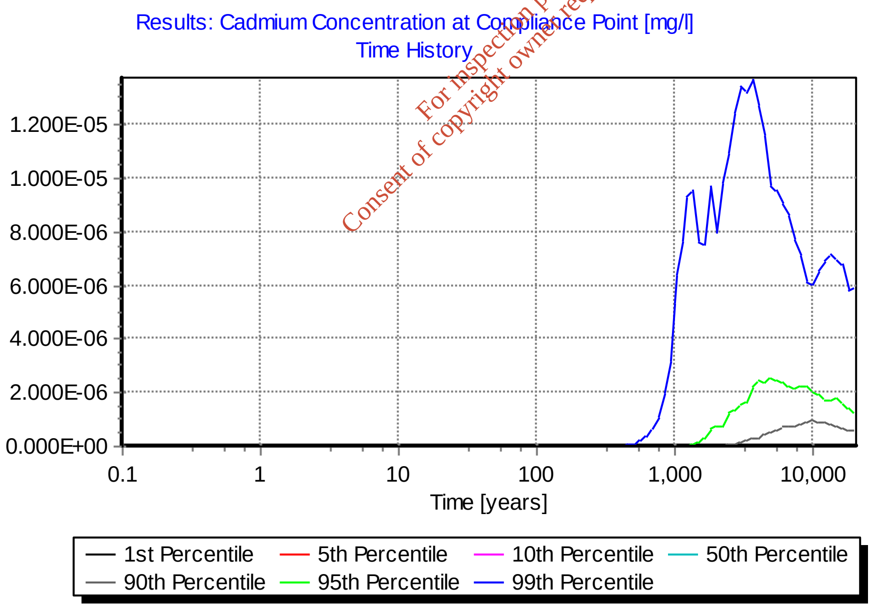
Appendix D

Appendix D: LandSim Results

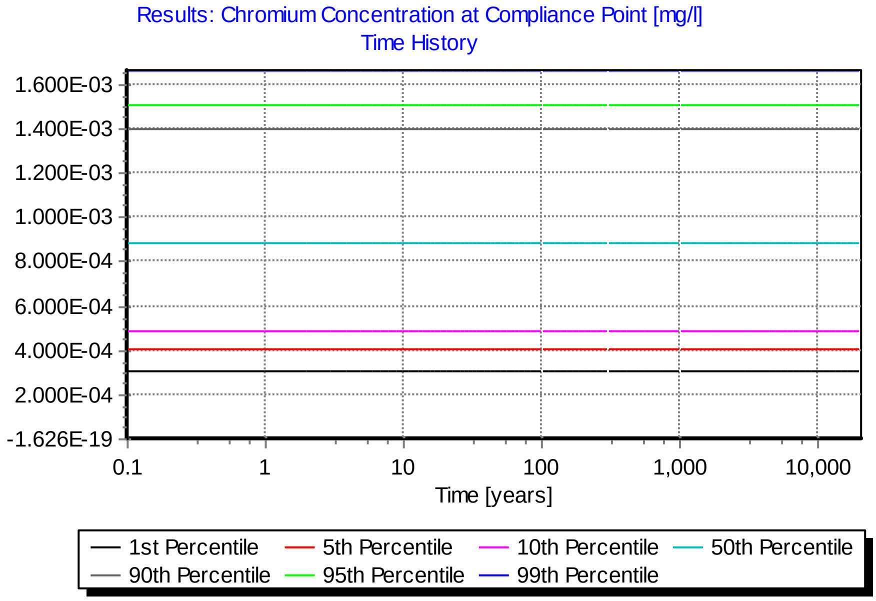
Run 1 (Cells 1A, 1B, 2 & 6)



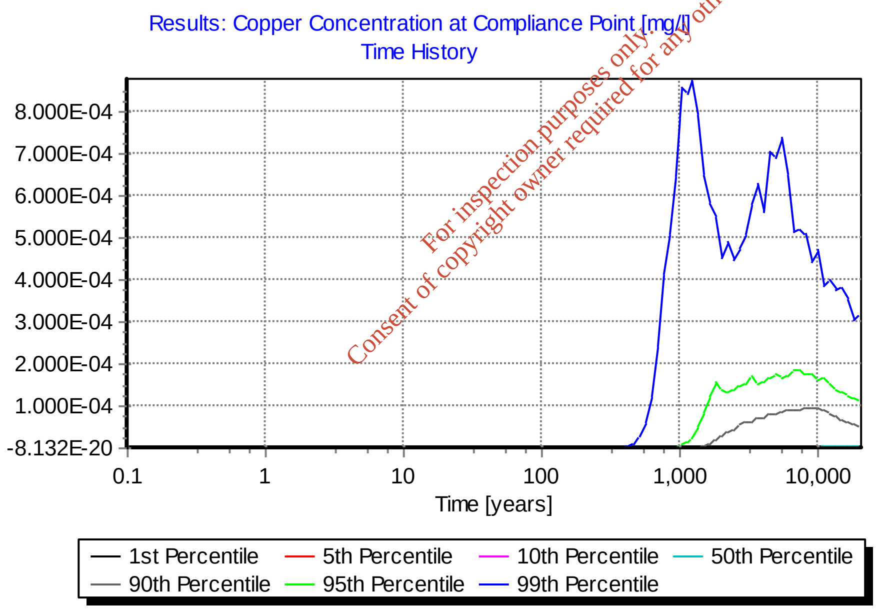
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08



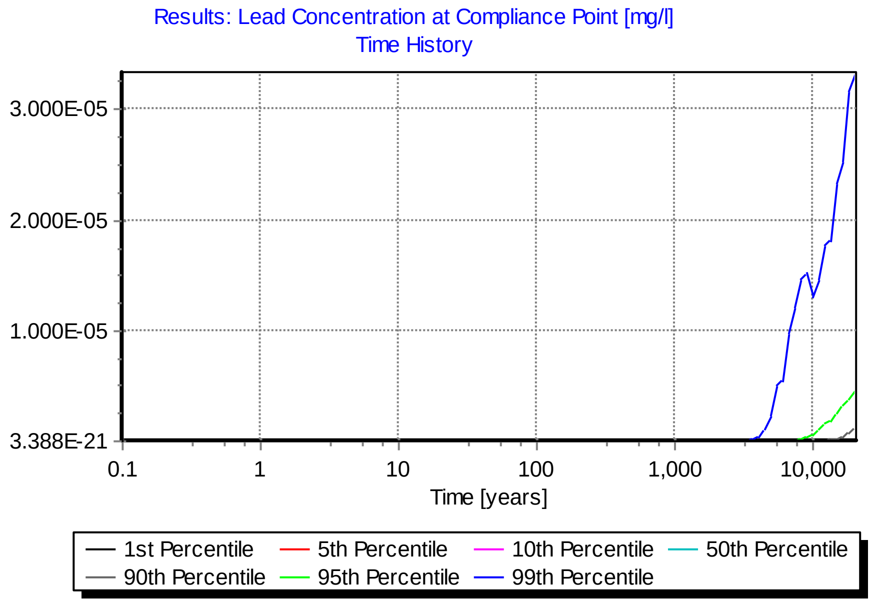
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08



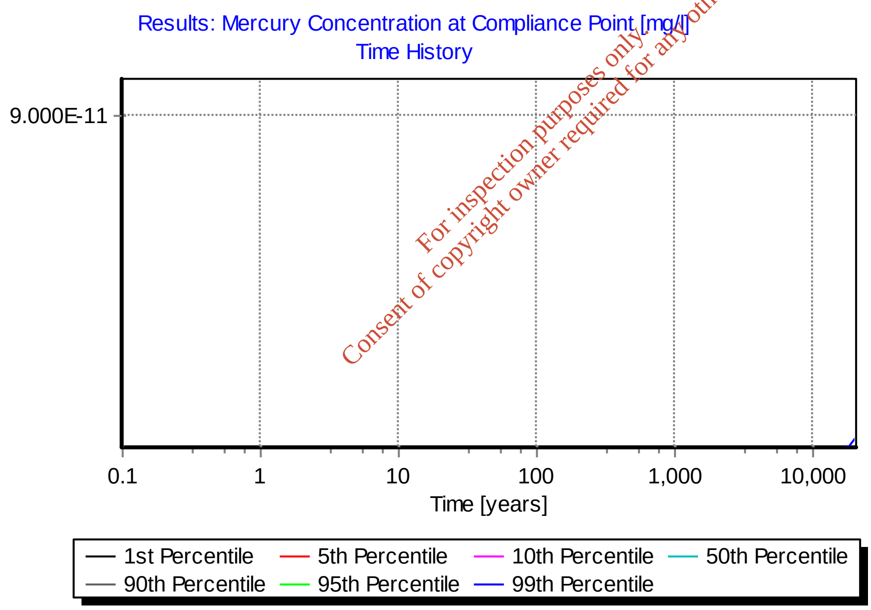
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08



ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

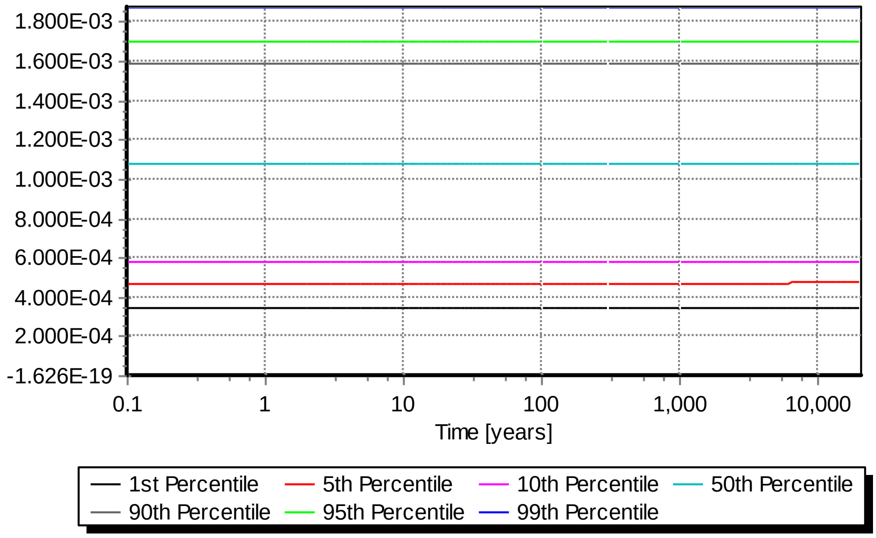


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08



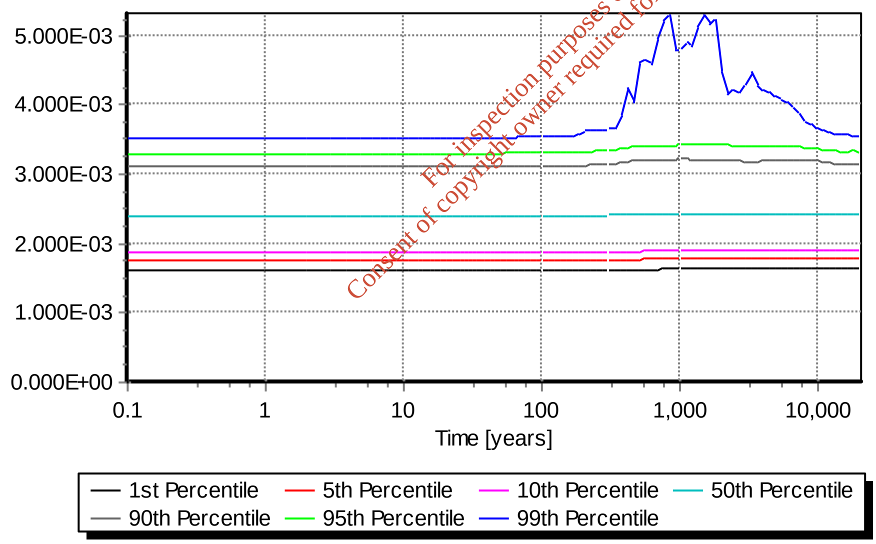
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

Results: Nickel Concentration at Compliance Point [mg/l]
Time History



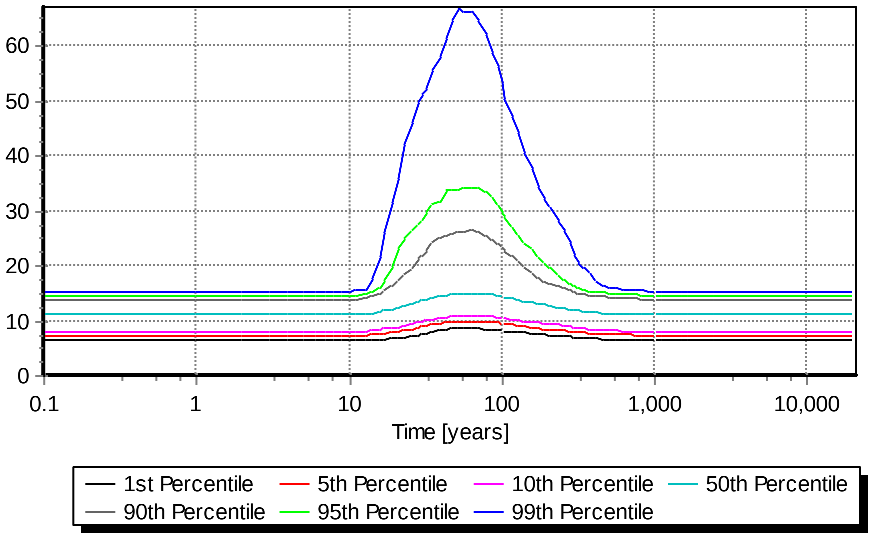
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

Results: Zinc Concentration at Compliance Point [mg/l]
Time History



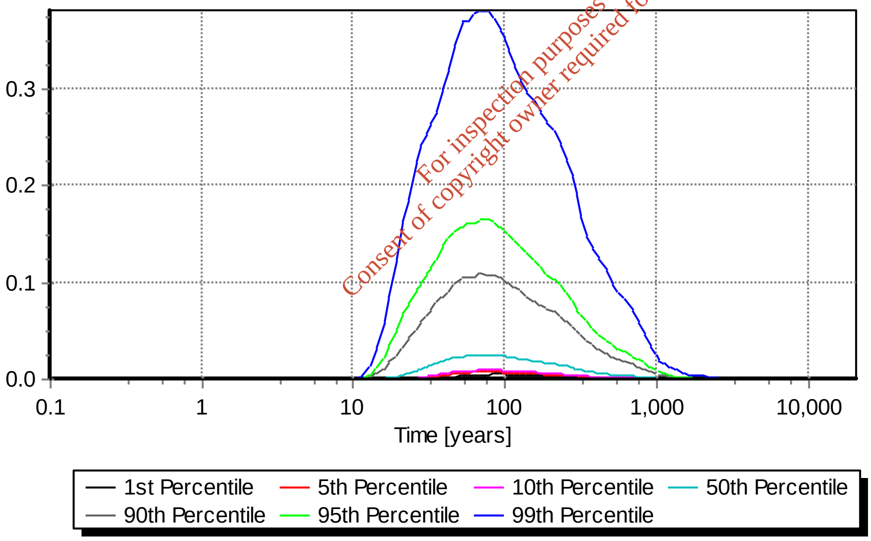
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

Results: Chloride Concentration at Compliance Point [mg/l]
Time History



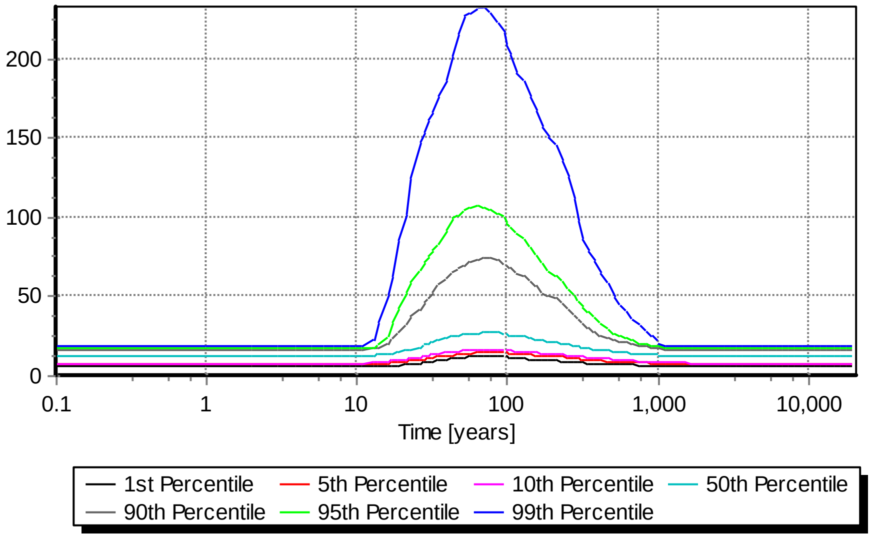
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

Results: Fluoride Concentration at Compliance Point [mg/l]
Time History



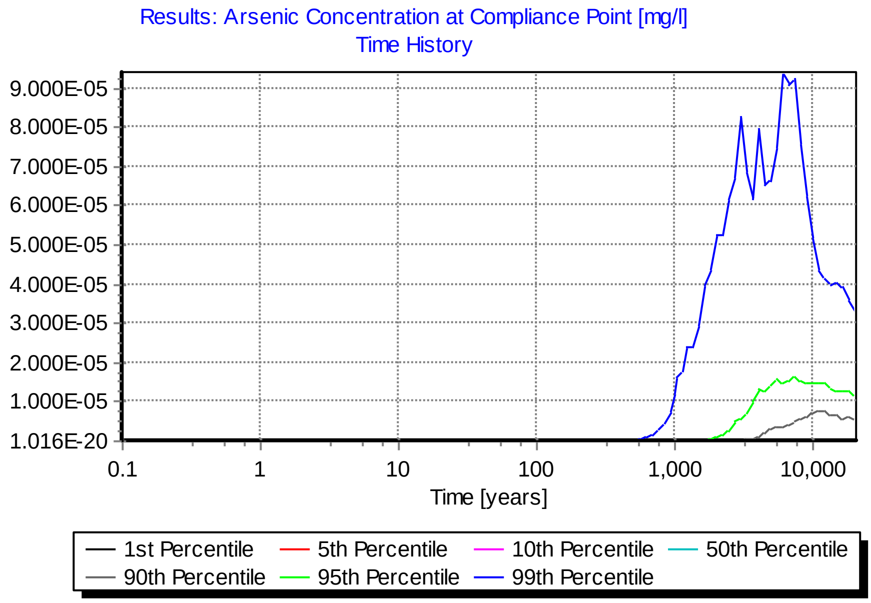
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

Results: Sulphate Concentration at Compliance Point [mg/l]
Time History

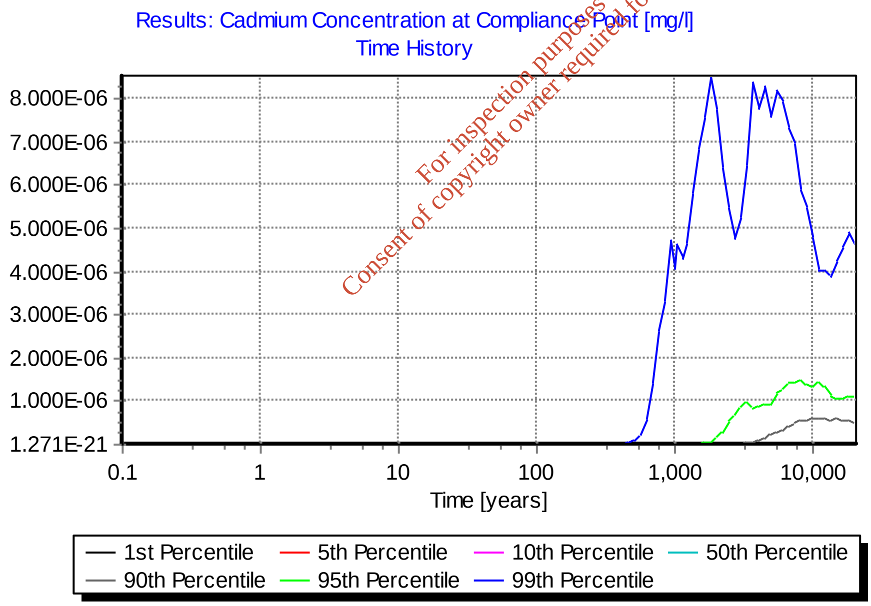


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:20:08

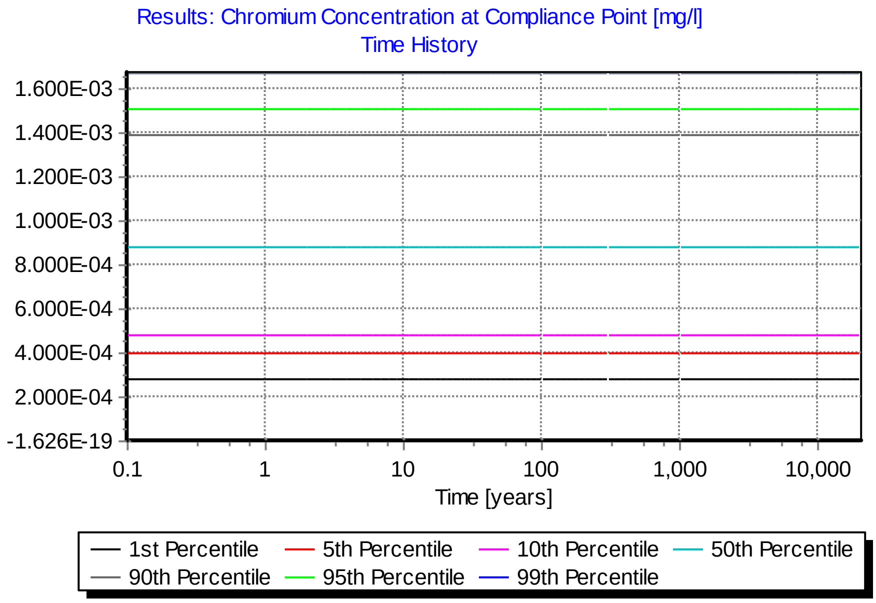
Run 2 (Cells 3, 4 & 5)



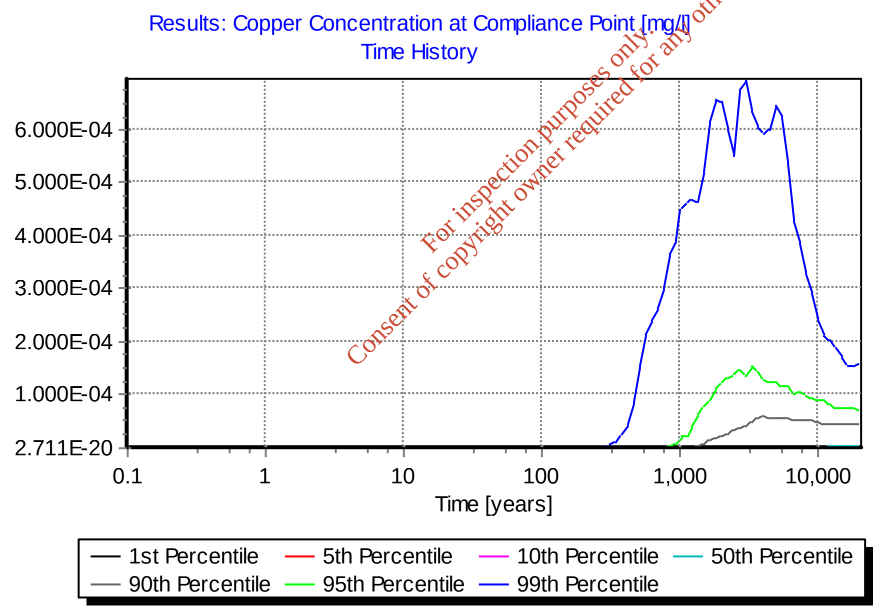
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56



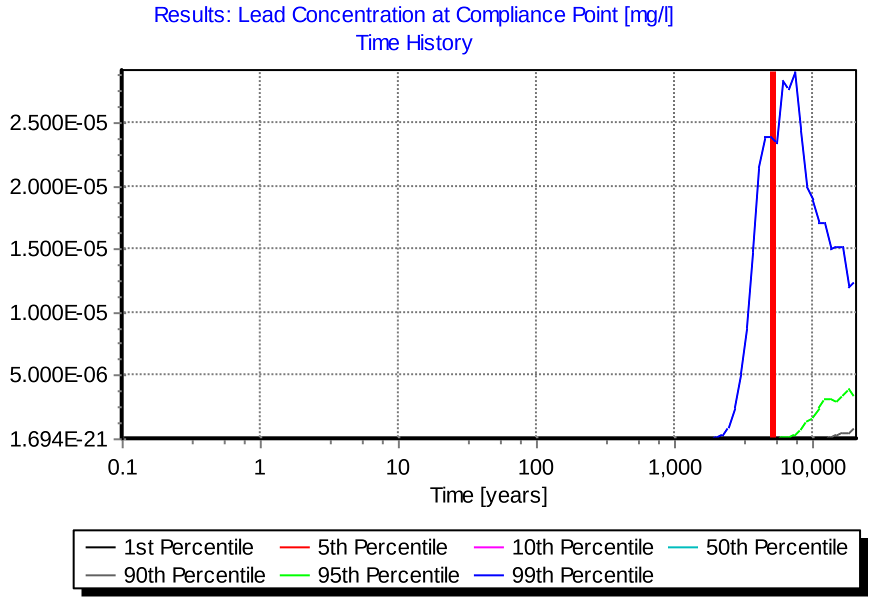
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56



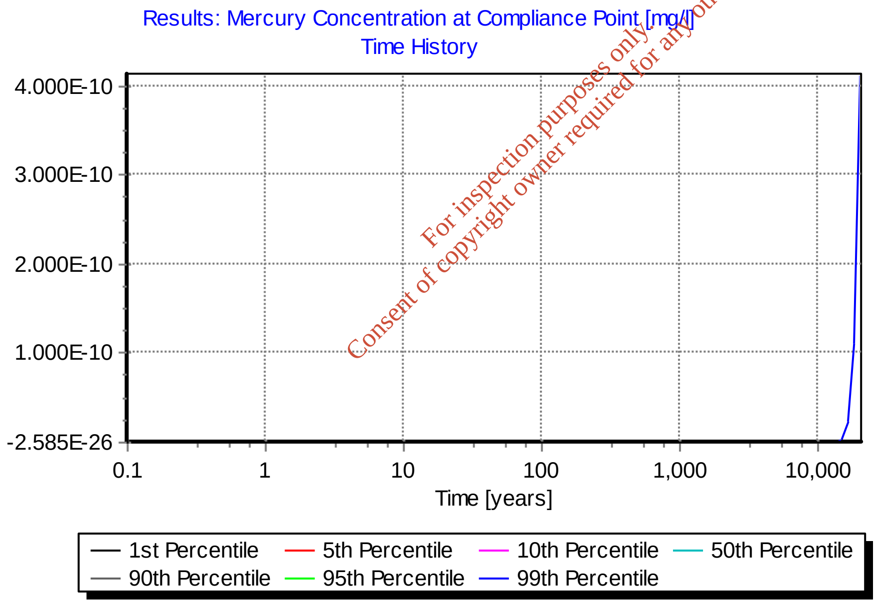
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56



ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56

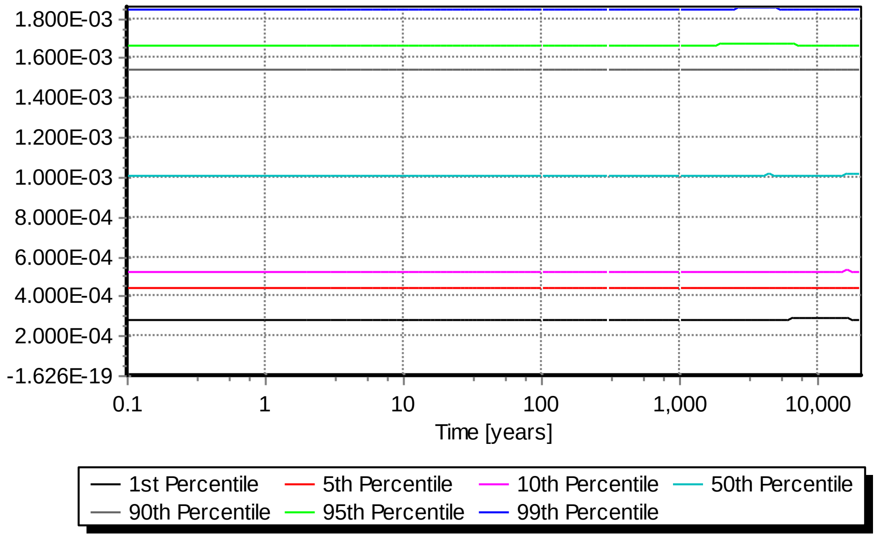


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56



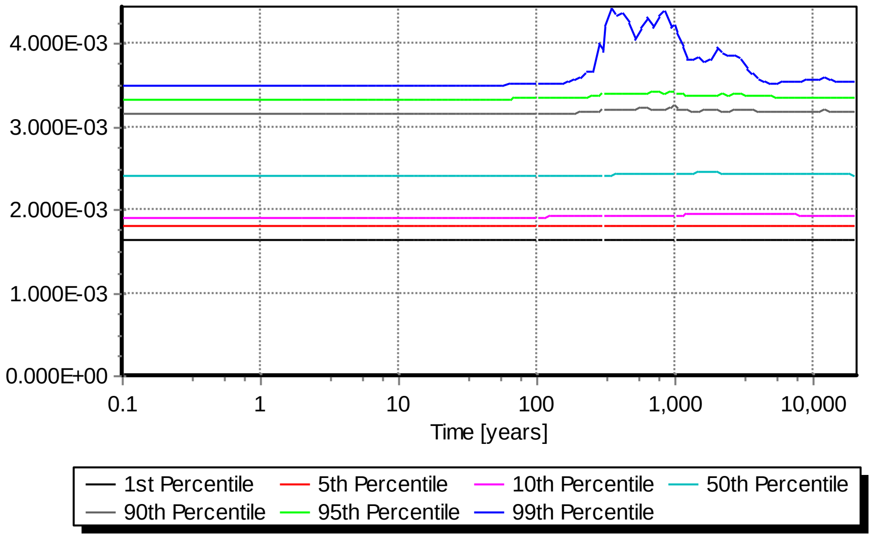
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56

Results: Nickel Concentration at Compliance Point [mg/l]
Time History



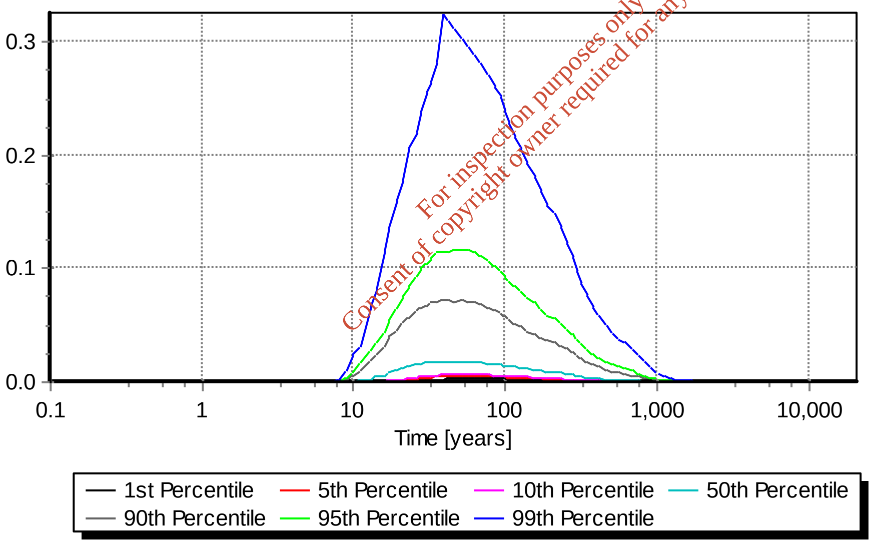
ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run.
06/11/2017 18:17:56

Results: Zinc Concentration at Compliance Point [mg/l]
Time History

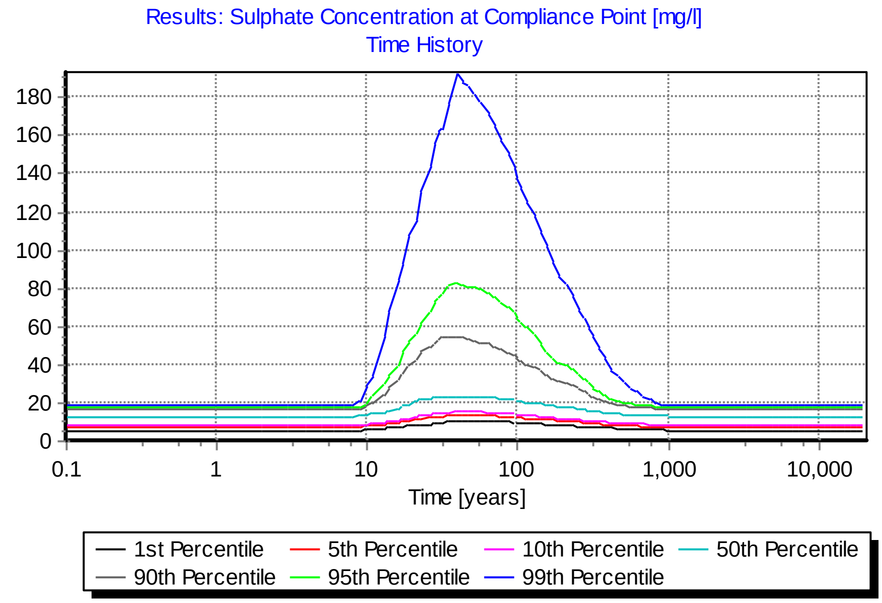


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56

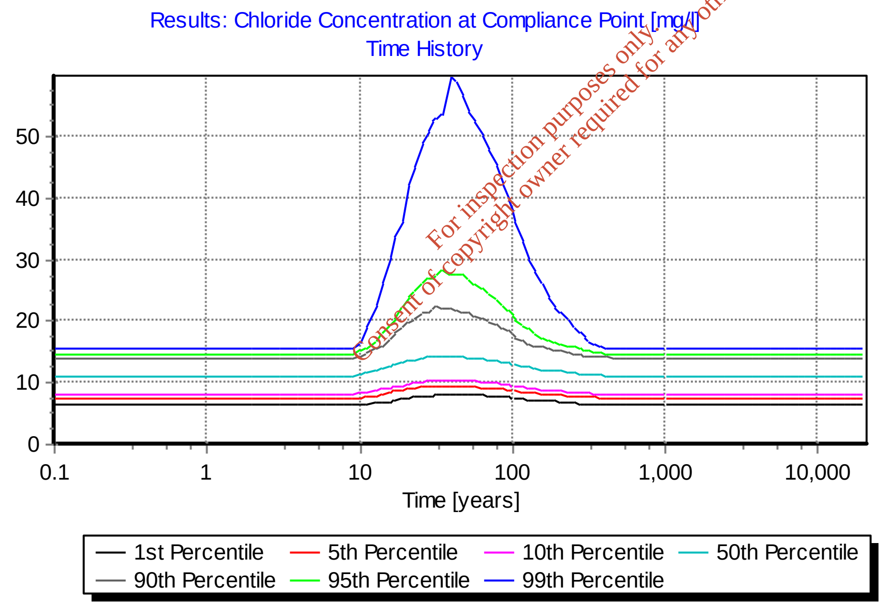
Results: Fluoride Concentration at Compliance Point [mg/l]
Time History



ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run
06/11/2017 18:17:56

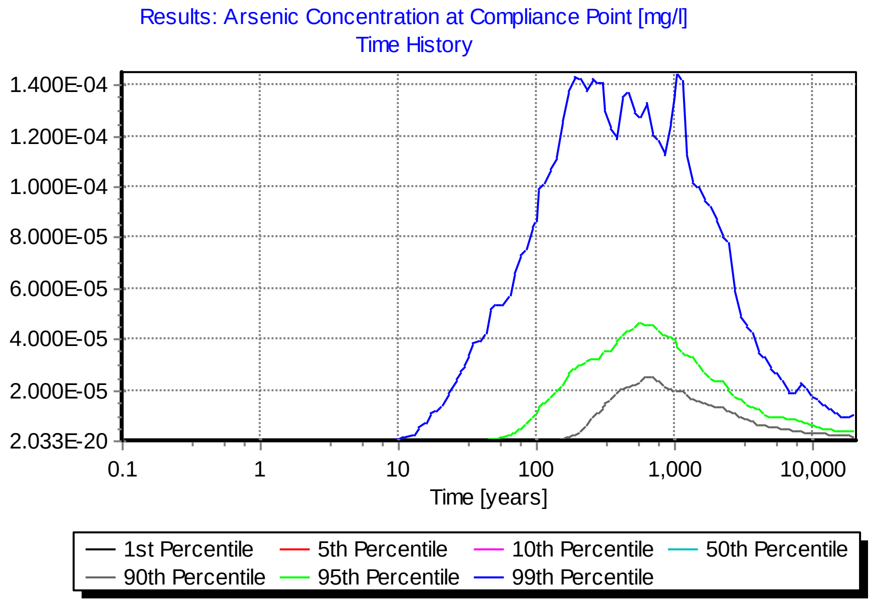


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run.
06/11/2017 18:17:56

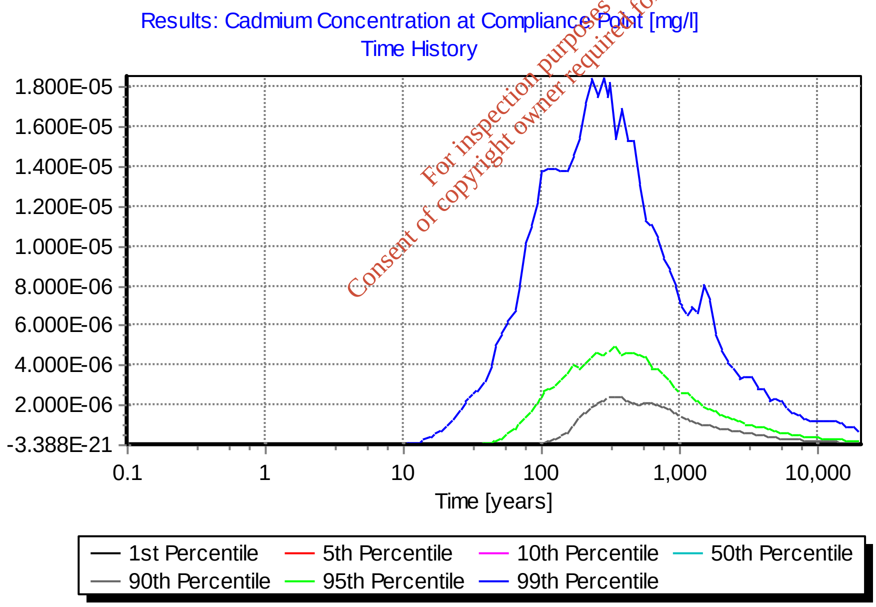


ers\Simon\Documents\Firth Consultants\projects\MOR\Walshestown\LandSim\walshestown run.
06/11/2017 18:17:56

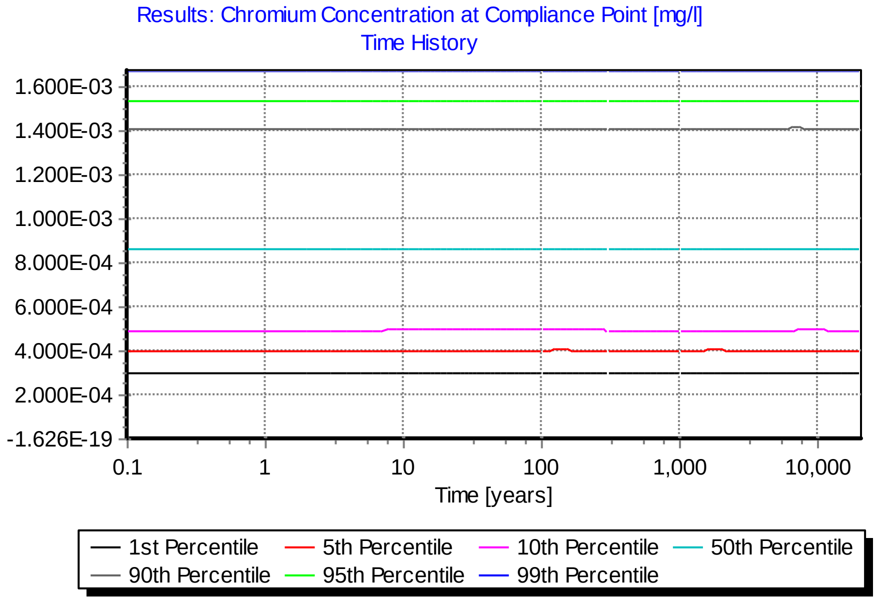
Run 3 (Areas C1A, C2, B1, B2 & Process Area)



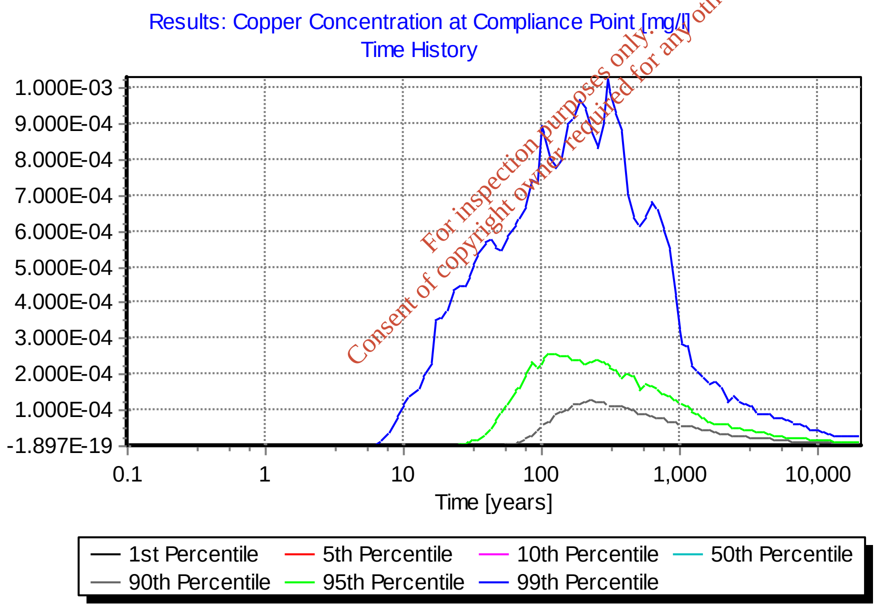
SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52



SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

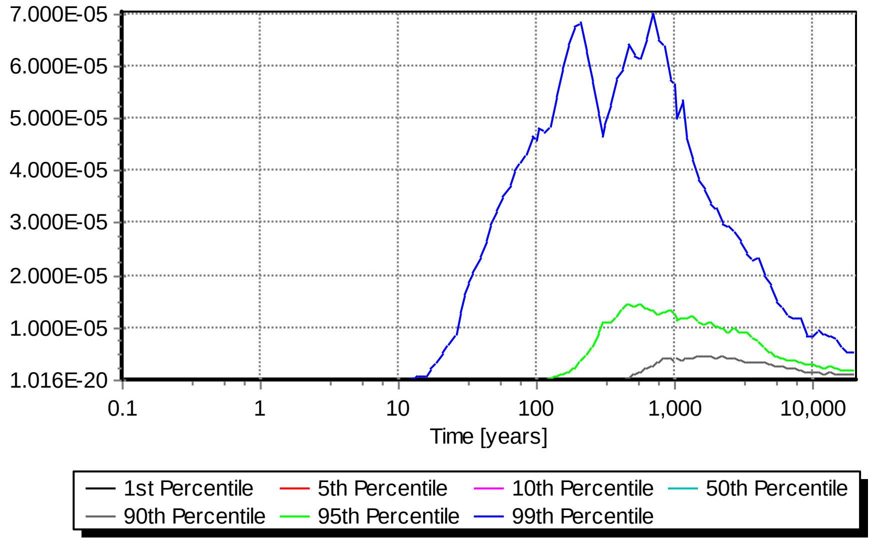


SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52



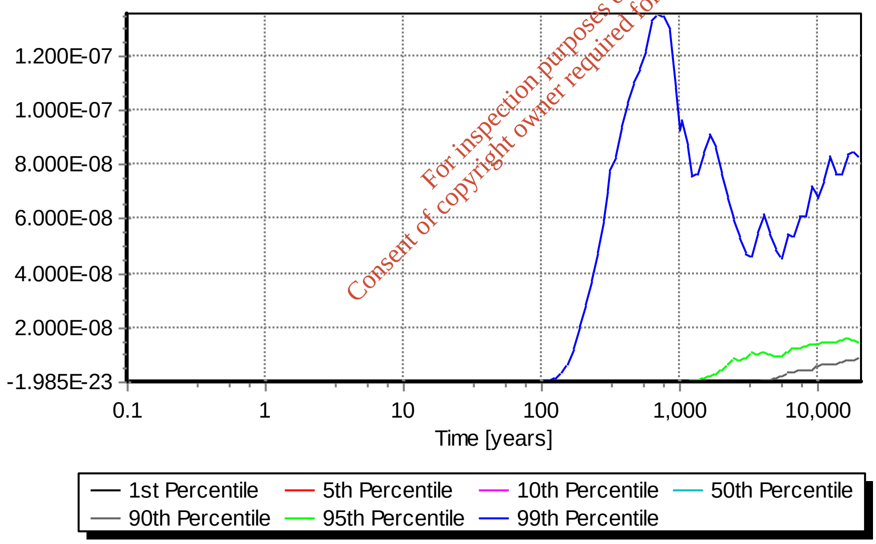
SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

Results: Lead Concentration at Compliance Point [mg/l]
Time History

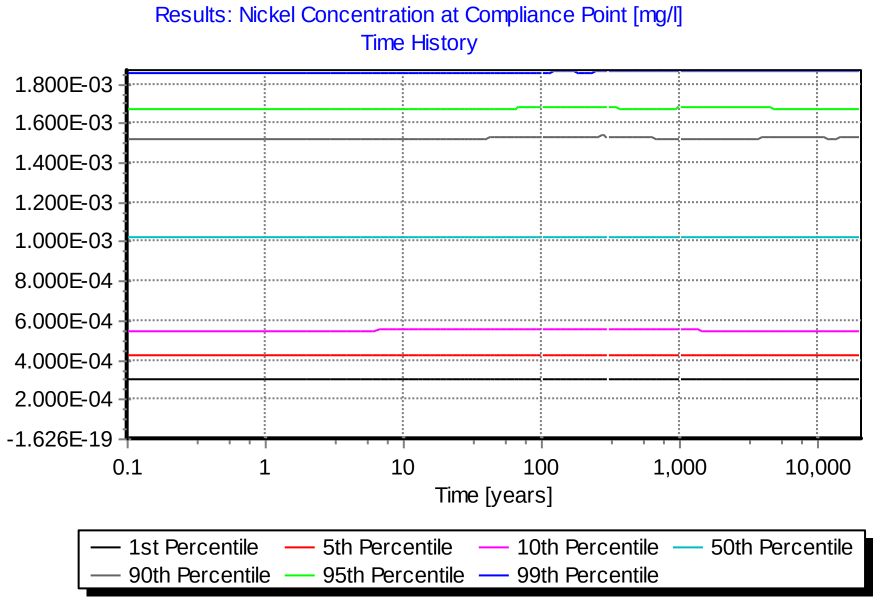


SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

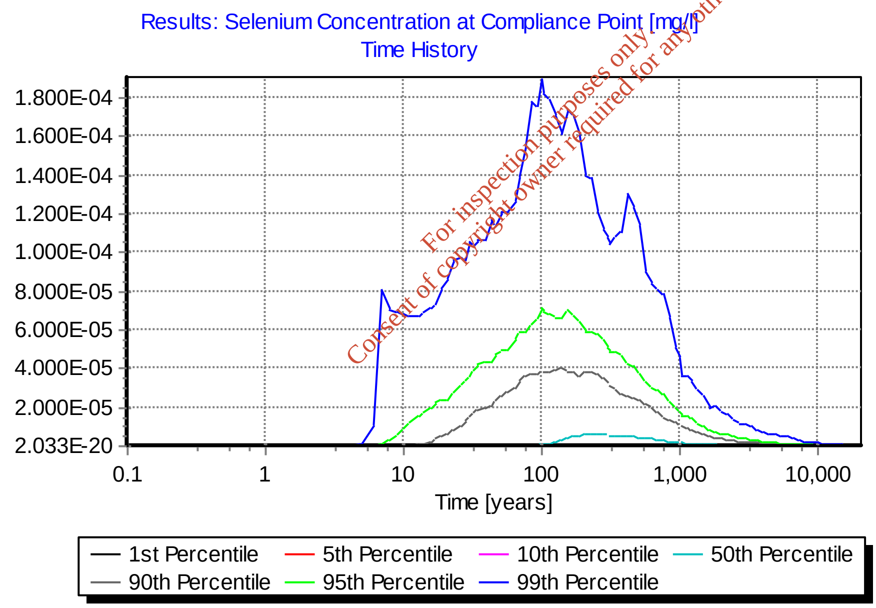
Results: Mercury Concentration at Compliance Point [mg/l]
Time History



SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

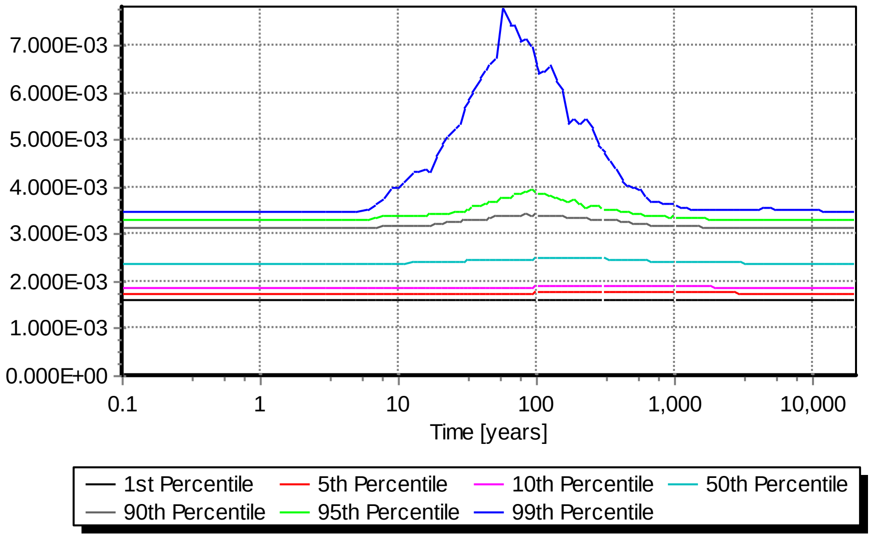


SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52



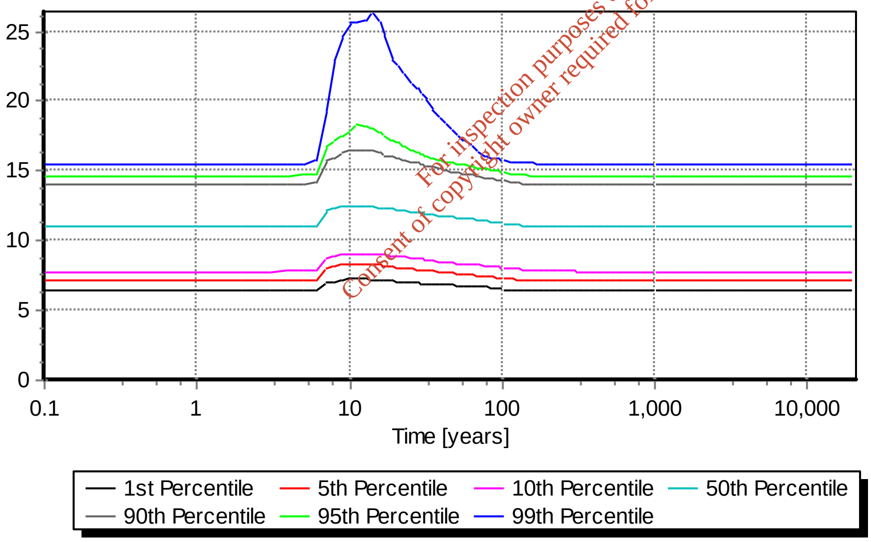
SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

Results: Zinc Concentration at Compliance Point [mg/l]
Time History

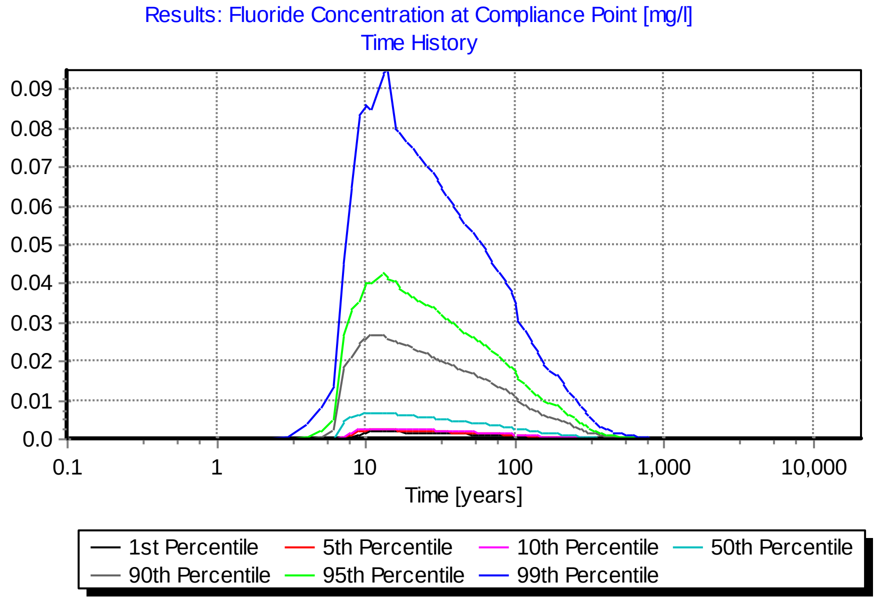


SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

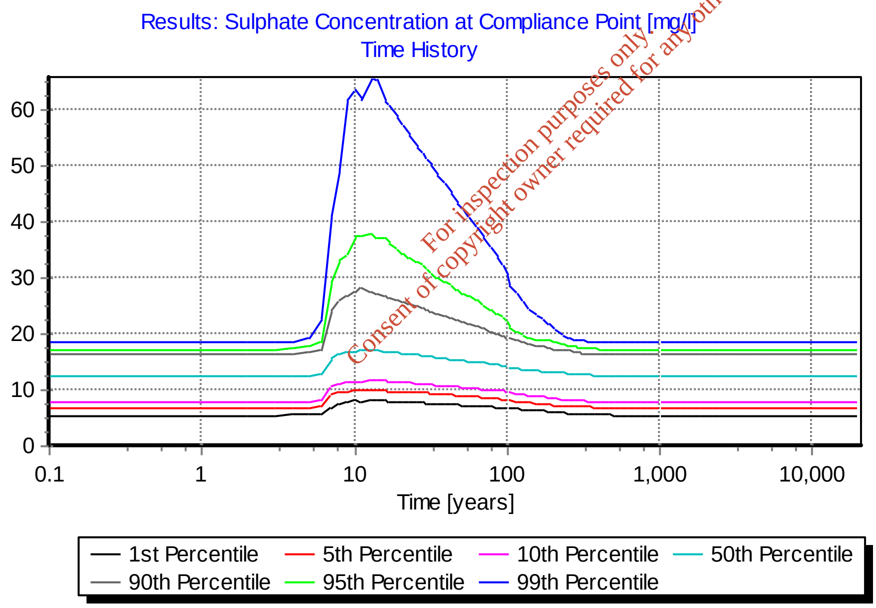
Results: Chloride Concentration at Compliance Point [mg/l]
Time History



SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

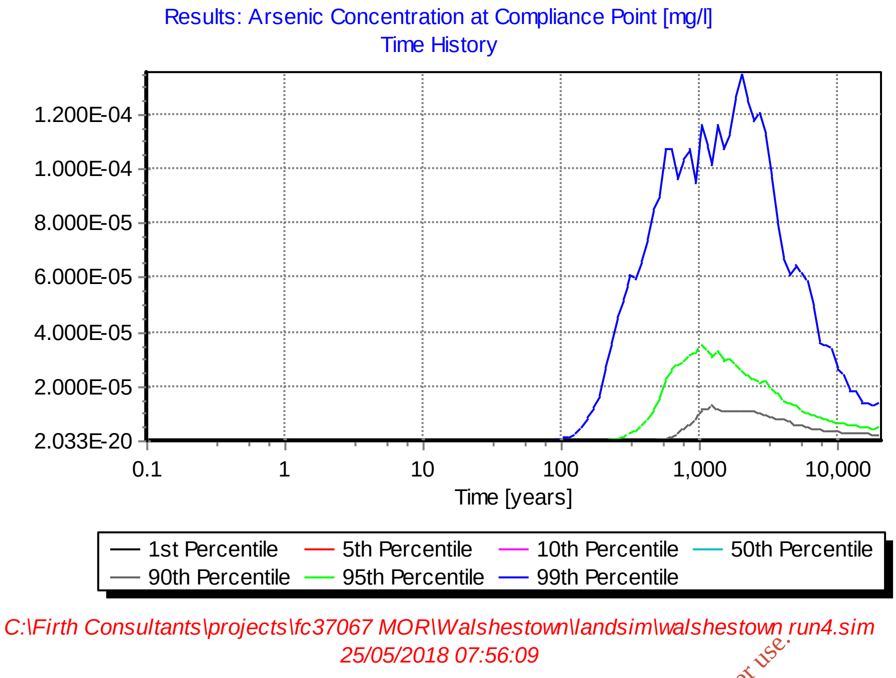


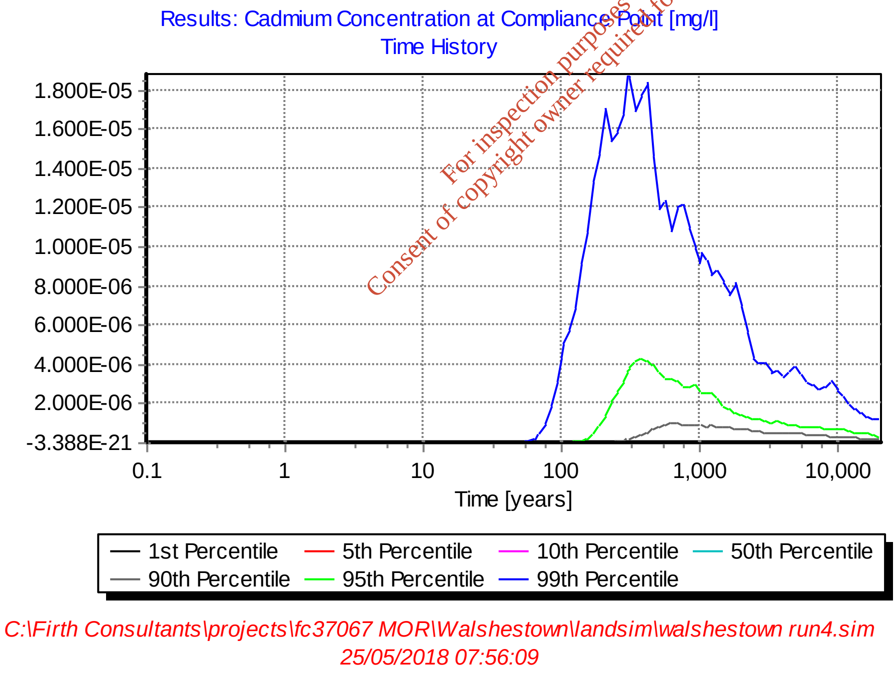
SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52



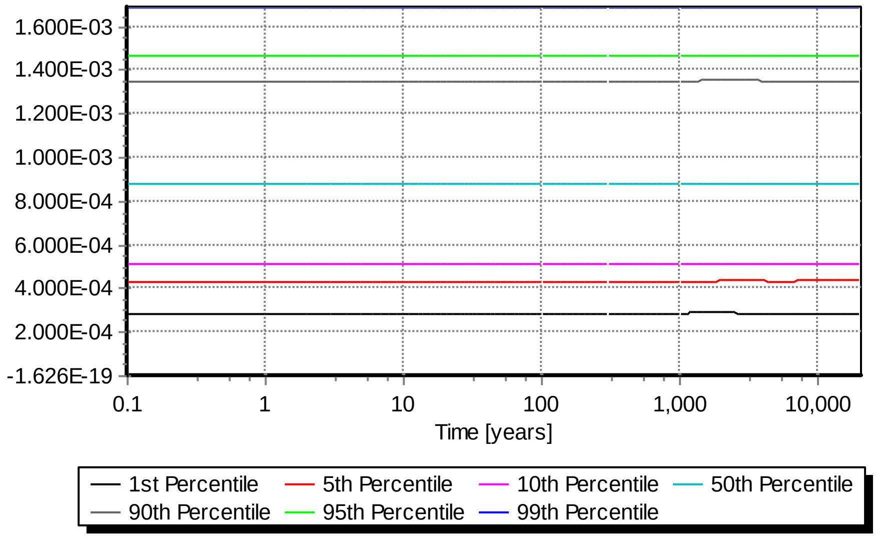
SIMON-PC\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run3.si
25/05/2018 07:06:52

Run 4 (Areas B3a, SP1 & SP2)



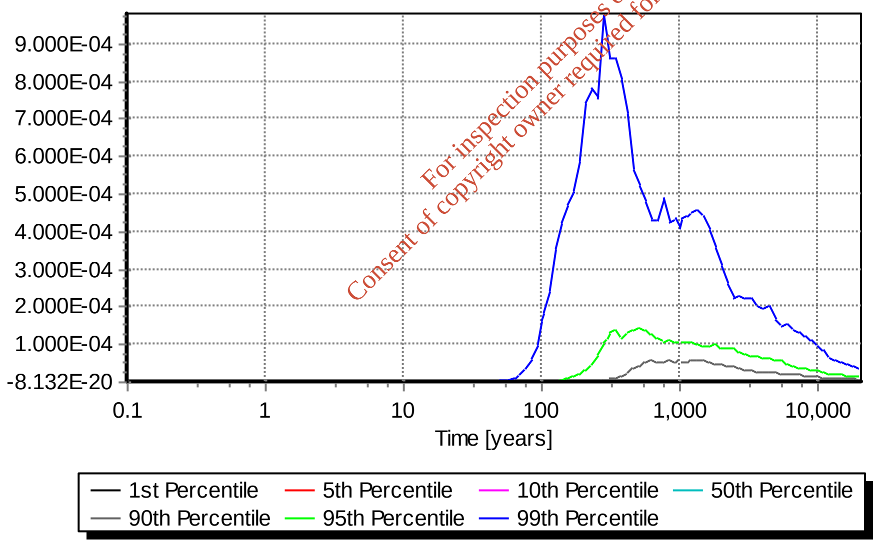


Results: Chromium Concentration at Compliance Point [mg/l]
Time History

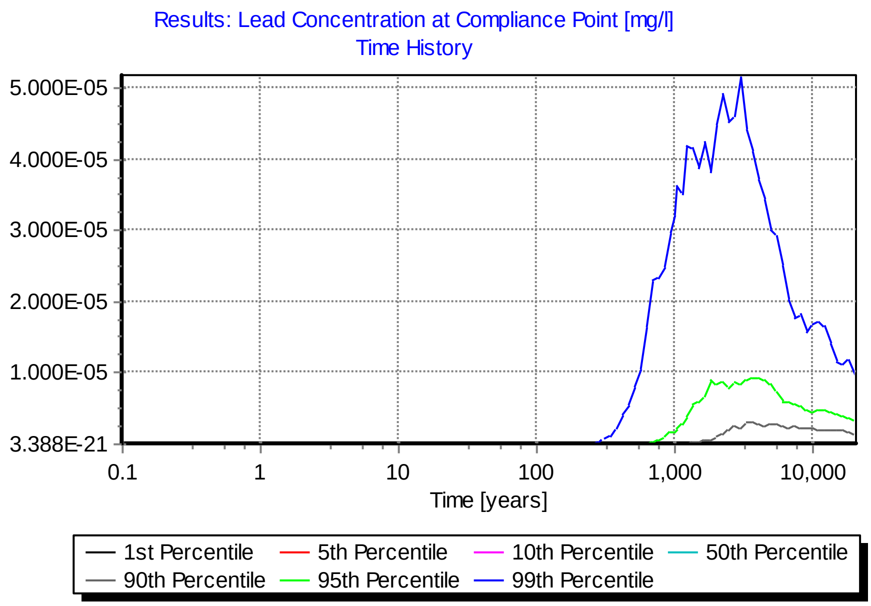


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

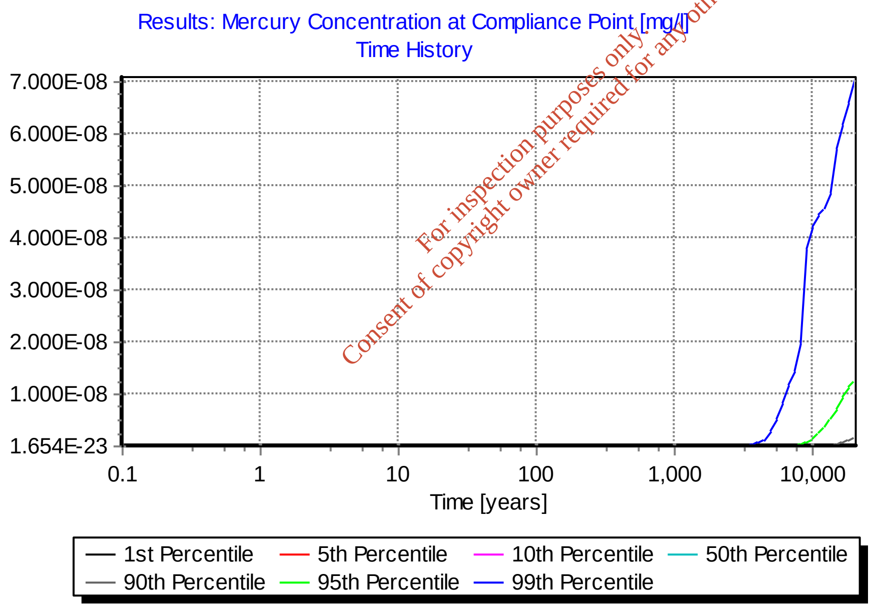
Results: Copper Concentration at Compliance Point [mg/l]
Time History



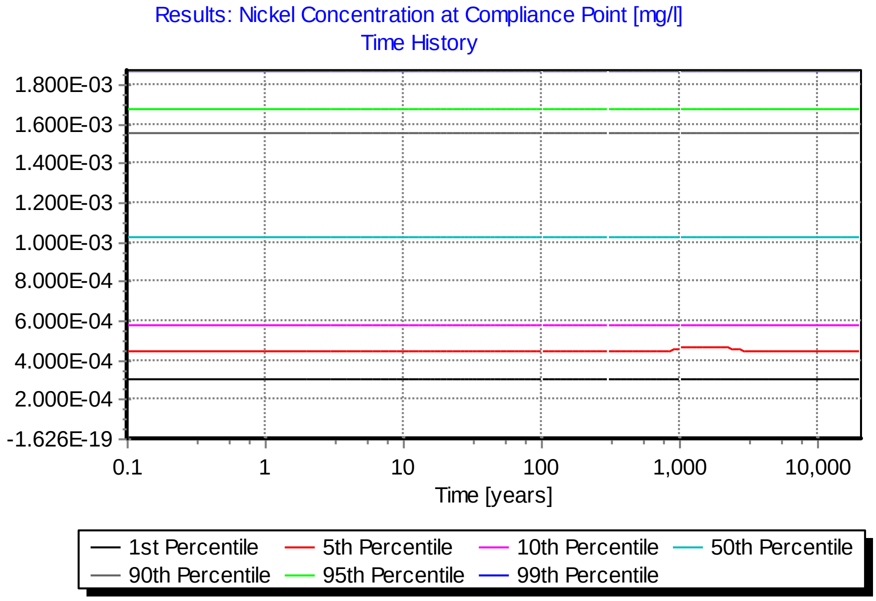
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09



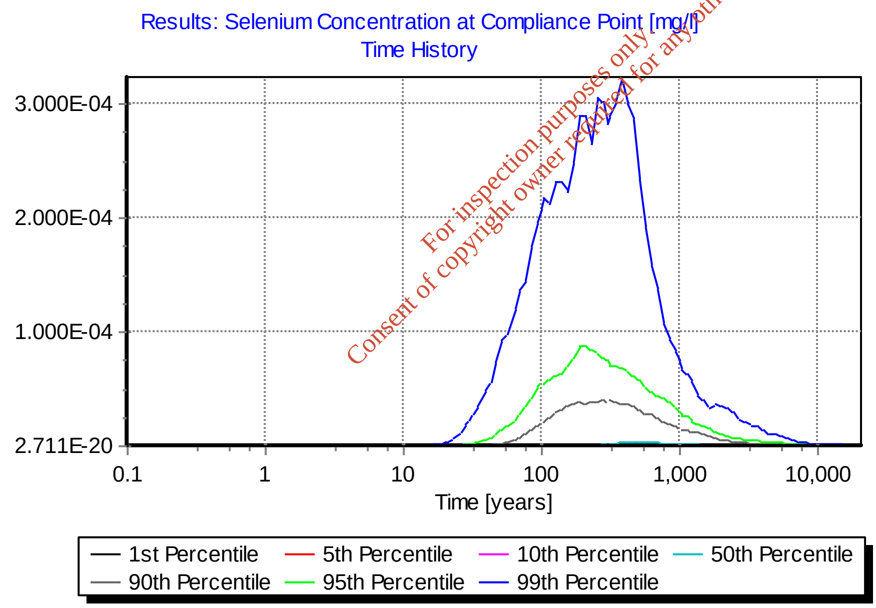
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09



C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

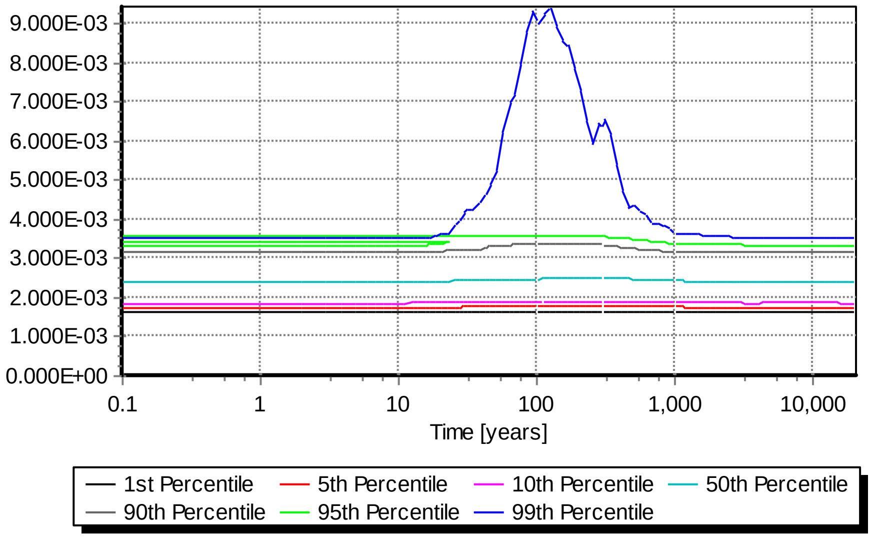


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09



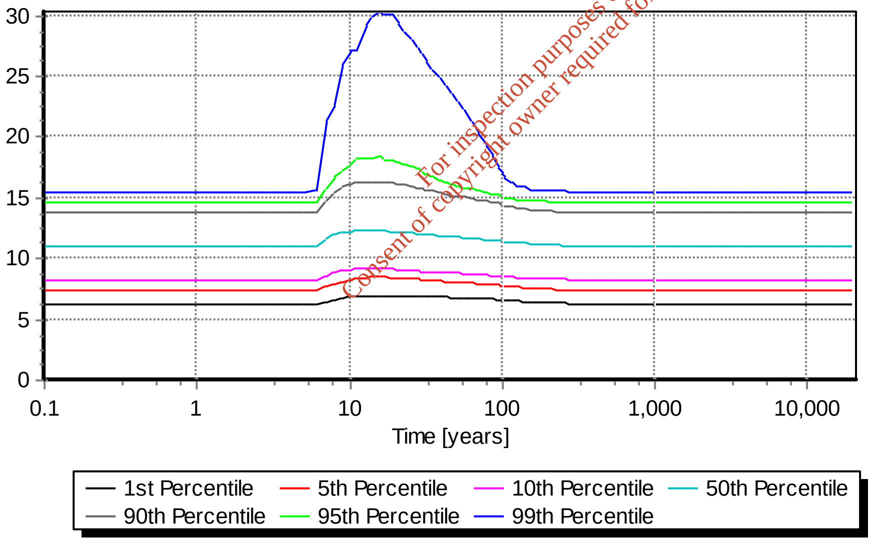
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

Results: Zinc Concentration at Compliance Point [mg/l]
Time History



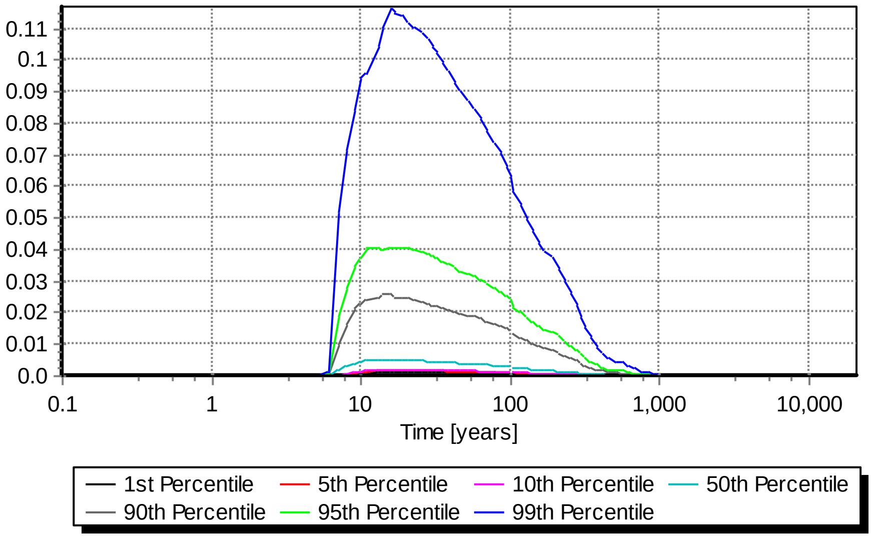
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

Results: Chloride Concentration at Compliance Point [mg/l]
Time History



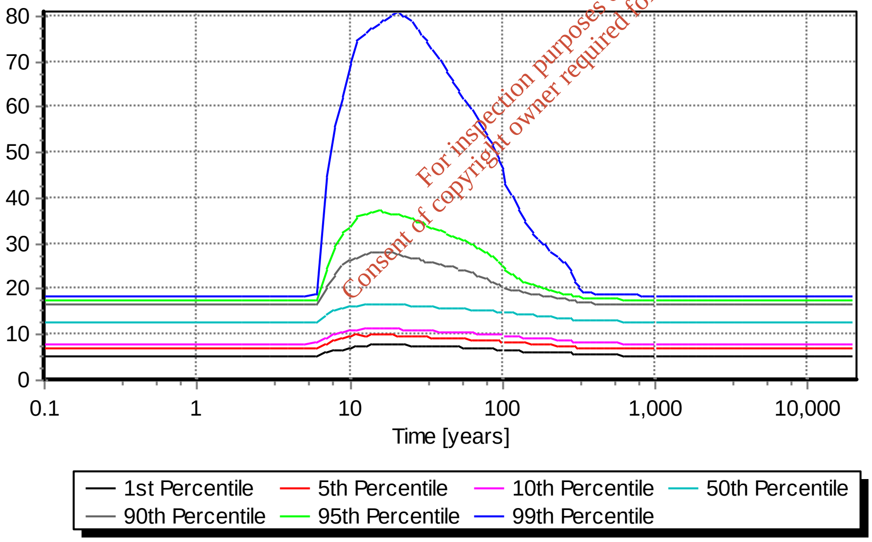
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

Results: Fluoride Concentration at Compliance Point [mg/l]
Time History



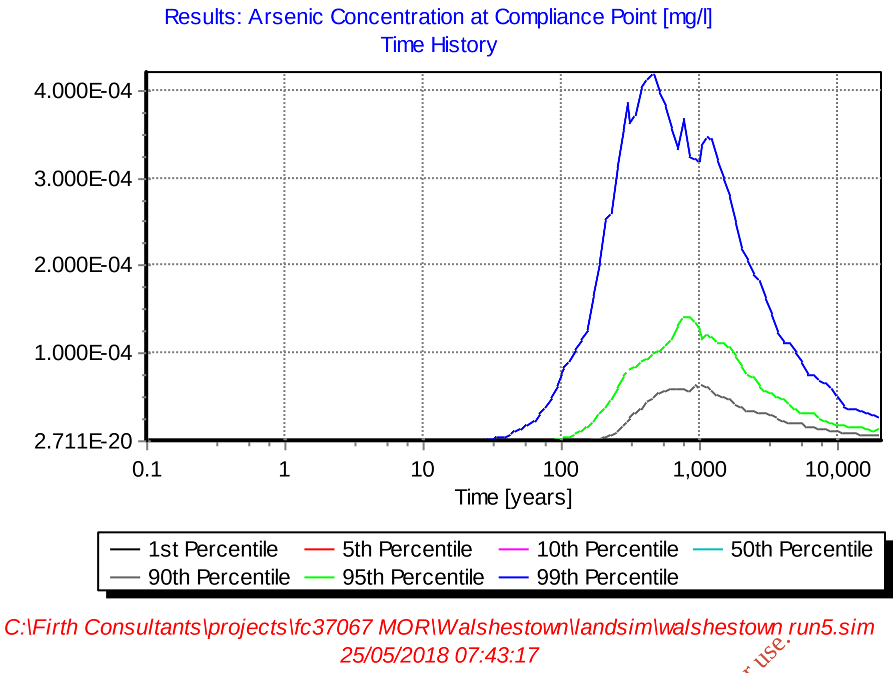
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

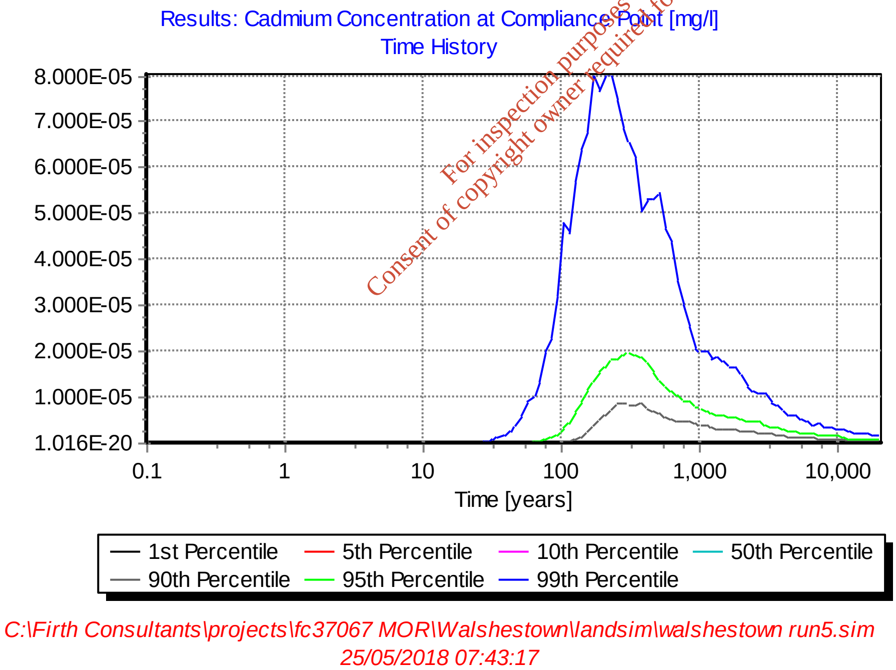
Results: Sulphate Concentration at Compliance Point [mg/l]
Time History

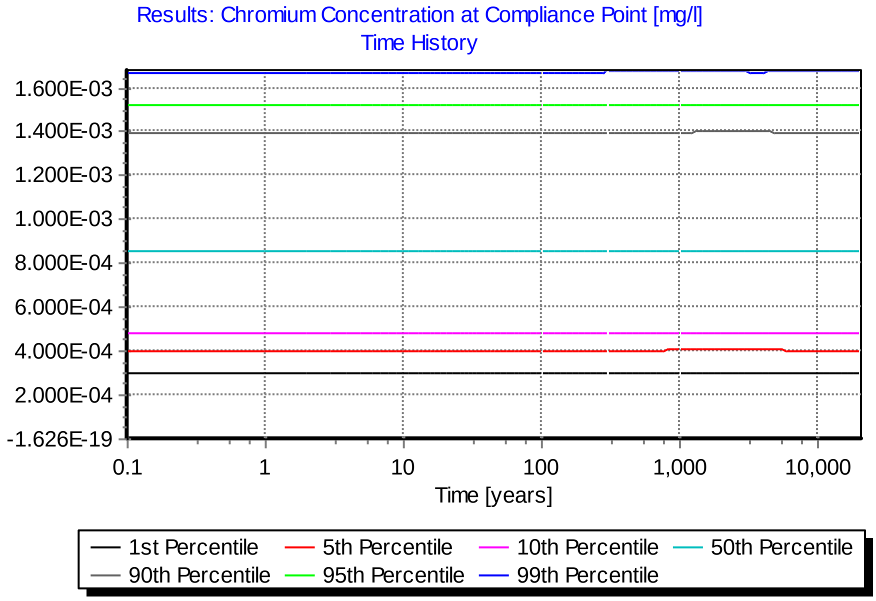


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run4.sim
25/05/2018 07:56:09

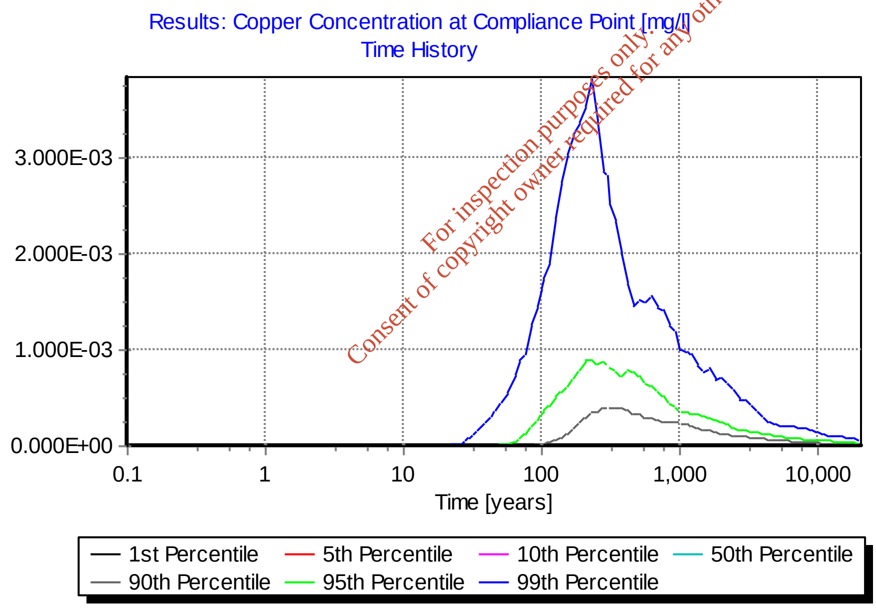
Run 5 (Areas B3b & B4)





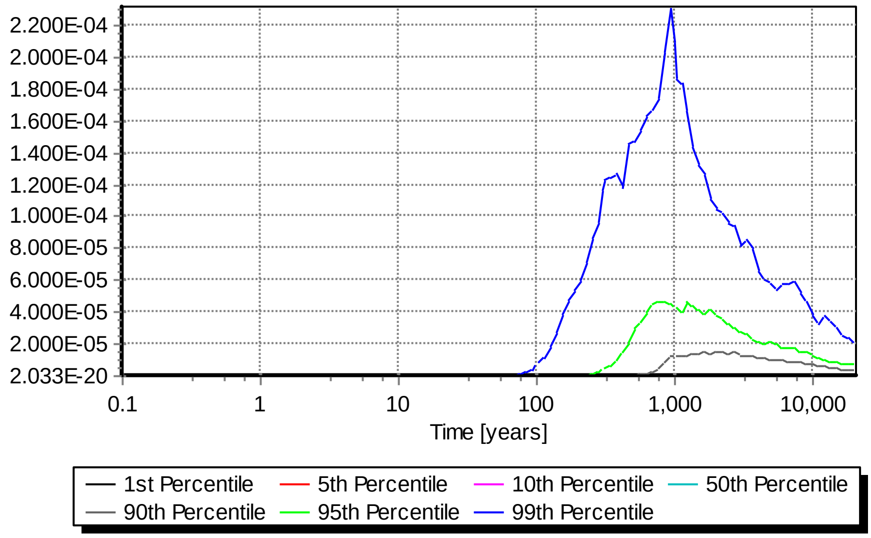


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17



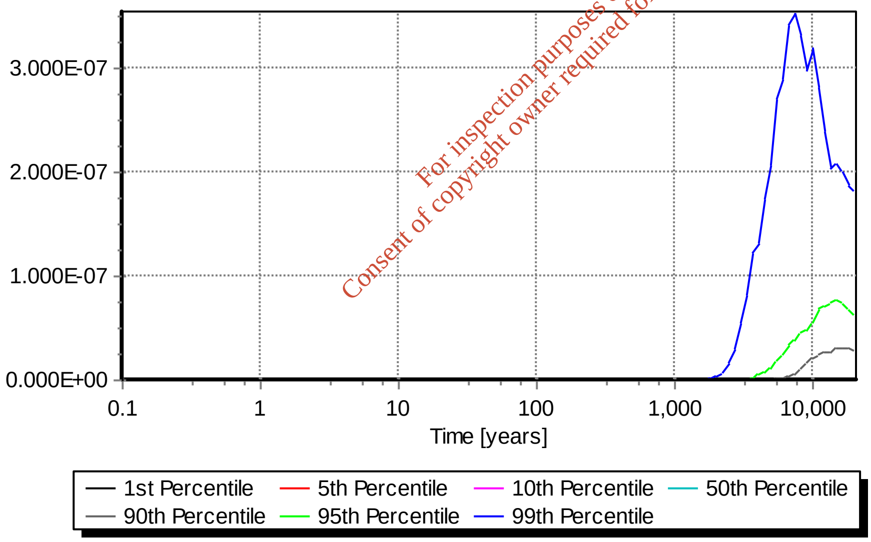
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17

Results: Lead Concentration at Compliance Point [mg/l]
Time History

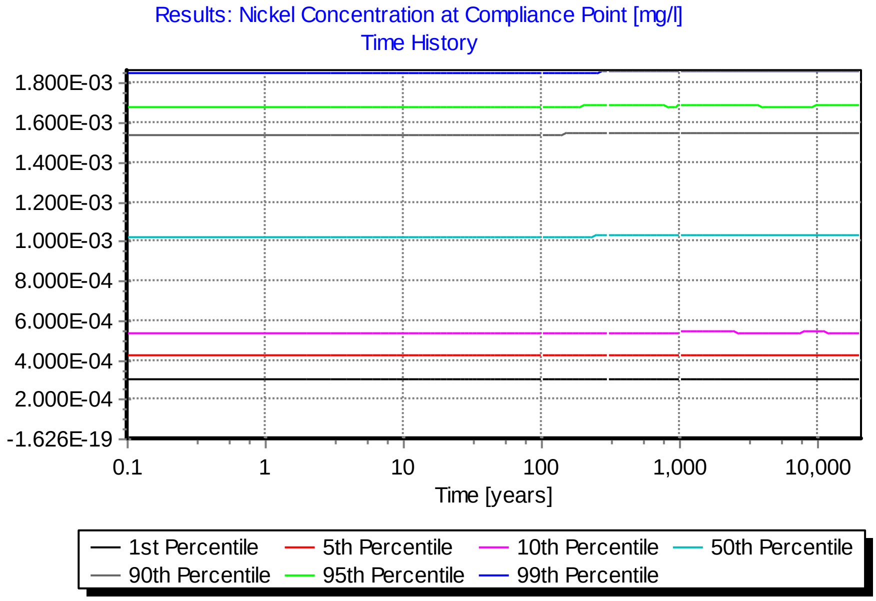


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17

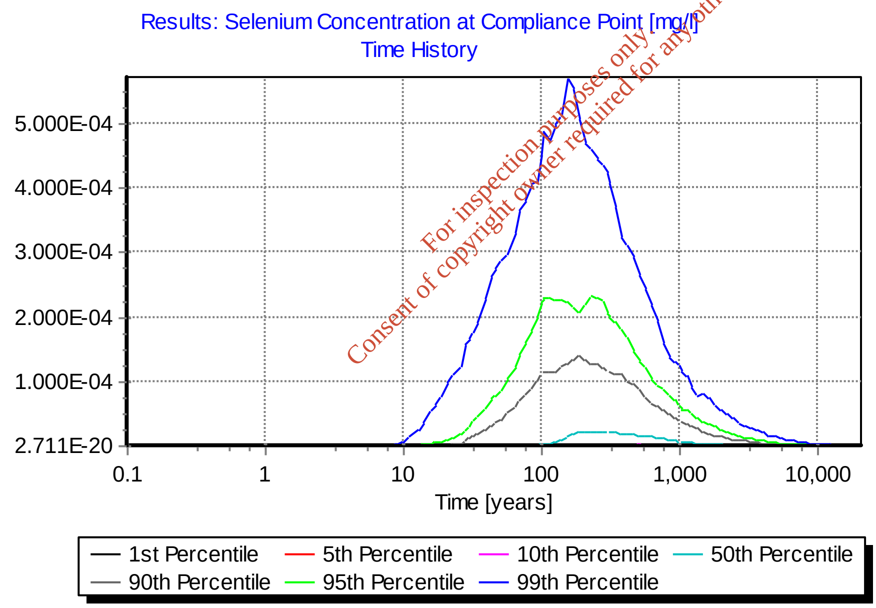
Results: Mercury Concentration at Compliance Point [mg/l]
Time History



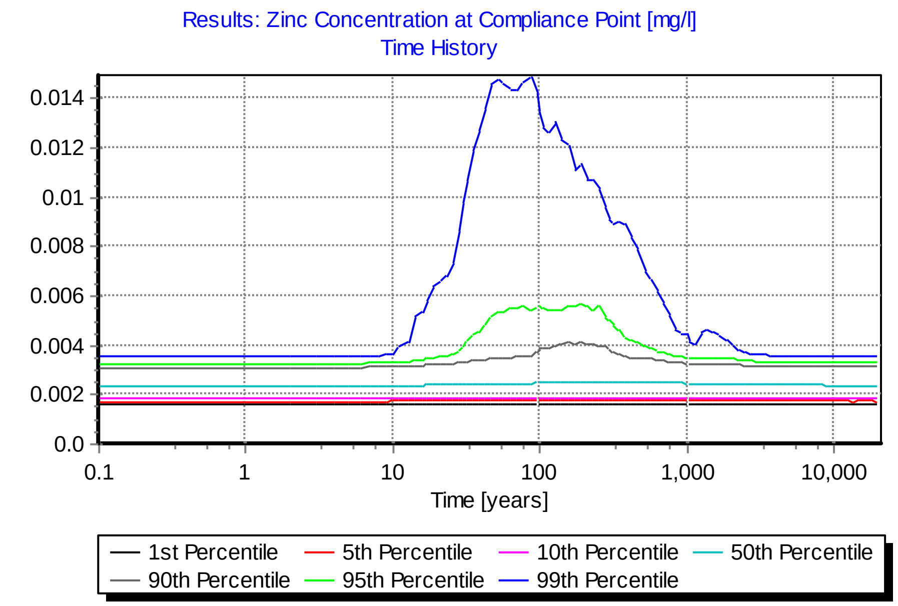
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17



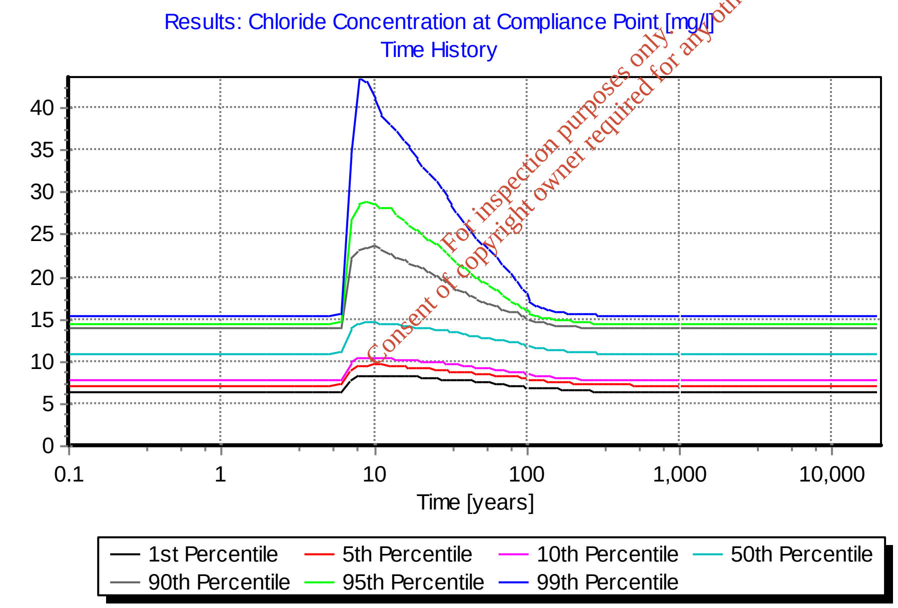
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17



C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17

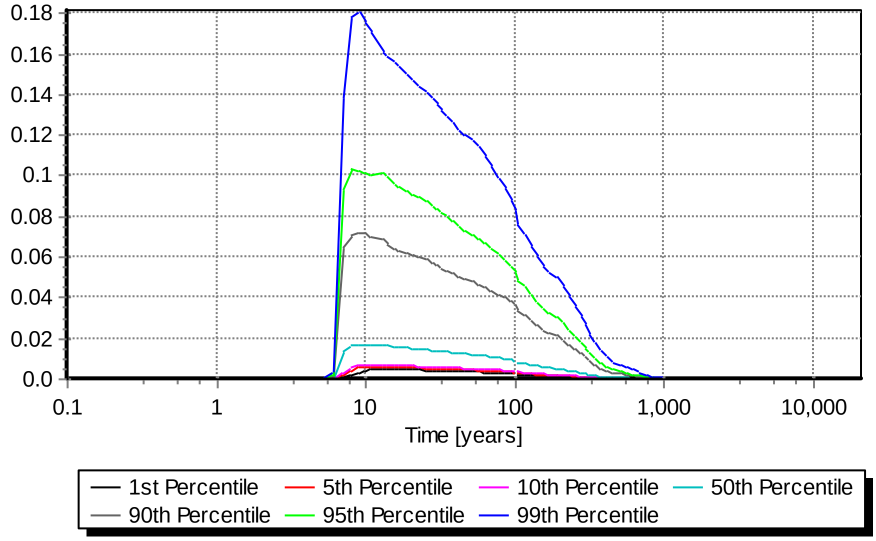


C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17



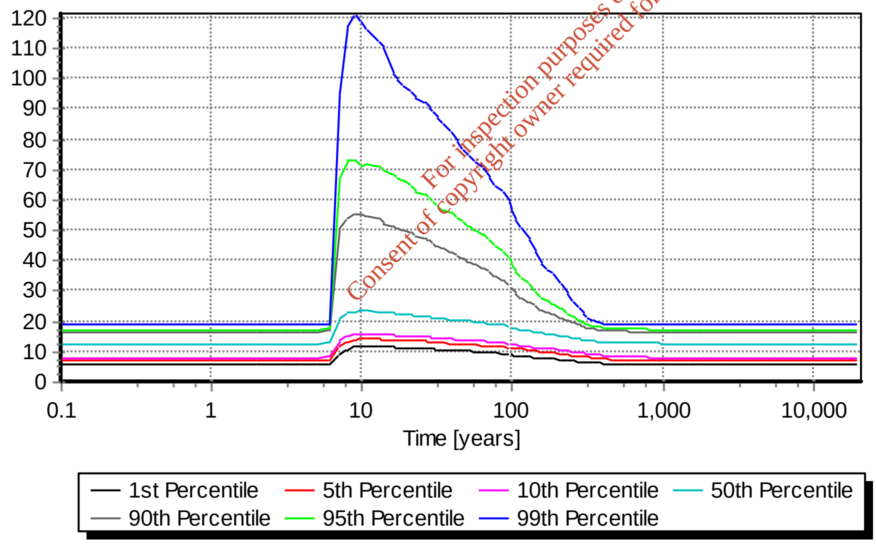
C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17

Results: Fluoride Concentration at Compliance Point [mg/l]
Time History



C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17

Results: Sulphate Concentration at Compliance Point [mg/l]
Time History



C:\Firth Consultants\projects\fc37067 MOR\Walshestown\landsim\walshestown run5.sim
25/05/2018 07:43:17