# MORFA HAZARDOUS LANDFILL
# PORT TALBOT

# ENVIRONMENTAL PERMIT BW2692IM

## Review of Hydrogeological Risk Assessment

*Report Number 2239r1v1d0622*

*Commissioned by*
Tata Steel UK Limited
Port Talbot Works
Margam
Port Talbot
SA13 2NG

*Prepared by*
Geotechnology Ltd
Ty Coed
Cefn-yr-Allt
Aberdulais
SA10 8HE

**June 2022**

# Table of Contents

# List of Tables



# List of Charts



# List of Figures

# List of Appendices

# 1 INTRODUCTION

Tata Steel UK Limited (Tata Steel) operates the Morfa Hazardous Landfill (MHL) and adjacent Morfa Non-Hazardous Landfill (MNHL). The site of the landfills was originally developed in the 1970's when it held a Control of Pollution Act Licence. This was subsequently amended to become a Waste Management Licence (WML) in the mid 1990's. The implementation of the Landfill Regulations required a Pollution Prevention and Control (PPC) Permit Application to be made. The applications were duly made and PPC Permits for MHL and MNHL were issued by the Natural Resources Wales (the Agency) on 17 December 2004 (Permit Nos. BW2692IM and BV7311IE, respectively). The PPC Permits apply to only part of the original waste management site, with approximately 40% being closed upon the commencement of MNHL. The closed part of the site is referred to as Morfa Closed Landfill (MCL). As of 6 April 2008 the PPC Permits automatically became Environmental Permits due to the introduction of the new Environmental Permitting Regulations (EP) that integrates WML and PPC.

The Permit for each landfill requires Tata Steel to submit a series of separate reports to NRW regarding the environmental performance of each landfill. These reports include three monthly summaries of the monitoring results for landfill gas, leachate, surface and groundwater against the relevant emission limits, assessment limits, and control and trigger levels specified in the Permit. Additionally, a summary review of all monitoring data is required on an annual basis within three months of the end of each year.

This report is a review of the Hydrogeological Risk Assessment (HRA) for MHL that was submitted as part of the original Permit Application. This report is intended to discharge Permit condition 3.1.6 which states:

The operator shall submit to Natural Resources Wales a review of the Hydrogeological Risk Assessment:

- between nine and six months prior to the sixth anniversary of the granting of the permit, and
- between nine and six months prior to every subsequent six years after the sixth anniversary of the granting of the permit.

This report is the fourth review of the HRA as the Permit is almost twenty years old. The previous reviews have also been prepared by Geotechnology (see Geotechnology reports 711r1v1d0908, 1178r1v1d0912 and 1740r1v1d1217).

## 1.1 Review Objectives

In accordance with the EP Regulations and as set out in the Permit, the specific objectives of the HRA review is to:

**review the hydrogeological risk assessment included in the Application, together with any other parts of the Application that addressed the requirements of the EP Regulations. The review shall assess whether the activities of disposal or tipping for the purpose of disposal of waste authorised by the permit continue to meet the requirements of the EP Regulations.**

This review, therefore, includes an assessment of the conceptual hydrogeological model for MHL in light of any new observations and monitoring data, an update to the quantitative HRA and a review of associated risk-management provisions.

# 2 SITE LOCATION

This section is intended to provide an overview of the site location and the landfill activities undertaken.

## 2.1 Environmental Setting

MHL is located at National Grid Reference SS775184 as shown on Figure 1. The extent of the Permit boundary for MHL and its relationship with the adjacent MNHL and MCL is identified on Figure 2.

The site occupies a coastal location, adjacent to the dune system behind Margam Sands. The ground is generally flat with only 2 metres of relief between approximately 6m and 8m AOD, though the western edge rises to 14m AOD due to dune sands. The western edge of the permit area is the coastal dune field over its entire length and is roughly parallel to the beach which lies 75 metres further to the west. The southern edge of the permit area is a disused access track crossing from the coast road to the edge of the moors. This access track separates MNHL and MHL. The eastern edge follows the fence line at the western edge of Margam Moors. The northern edge of the site is defined by the landfill site yard.

MHL is in a remote location at the southern end of the Port Talbot Steel Plant. The site is surrounded by land entirely owned by Tata Steel. The adjacent Margam Moors as far as the railway line to the east is owned by Tata Steel as is the site of the existing MNHL and MCL as far south as the River Kenfig. There are no inhabited buildings within 1.9km. The landfill offices and yard are located within 100m to the northwest. There are no public roads within 1km of the site and the adjacent beach is also under the private ownership of Tata Steel. There are no services crossing the site. One public footpath crosses the moors close to the site although this is subject to a current application to divert its course away from the landfill.

## 2.2 Geology

As part of the original Permit Applications for MNHL and MHL, 18 boreholes and 24 trial pits were excavated around MNHL and MHL. This investigation showed that the entire area is underlain by an irregular sheet of wind-blown sand which extends from the ground surface down to an organic/alluvial clay layer. The sand deposit is typically several metres thick, though this locally increases due to dune topography. The dune sand is poorly graded due to wind deposition and has a very uniform grain size throughout. Locally, the wind-blown sand is overlain by made ground comprising steel making wastes. Small woodland patches along the base of the northeastern flank of the landfill appear to be dune migration barriers and mark the extent of the blown sand.

Underlying the wind-blown sand is an organic and alluvial clay layer up to 2.8m in thickness. The alluvial clay layer is continuous with the clays found at the surface on the adjacent Margam Moors, and therefore this layer represents the moorland surface prior to the deposition of the wind-blown sands. The clay layer is not completely flat and slopes consistently, falling from the south and west toward the north and east.

Throughout the area, the clay layer overlies an estuarine alluvium sequence, comprising principally dirty sands with shell fragments. Locally, finer lenses are seen and on occasions

the upper surface of the estuarine fines layer supports a thin organic layer. Within the estuarine deposits, gravels and even cobbles are noted occurring in bands.
To the south of the site, beneath MNHL, the clay layer is absent in places, although the precise line along which it terminates is not known. It is thought that its absence is somehow related to the presence of the River Kenfig, which in its meandering past has eroded the clay layer, resulting in the wind-blown sand lying directly over the estuarine alluvium.

The estuarine sands overlie glacial gravels at depth, which in turn are underlain by Coal Measures Bedrock.

## 2.3 Surface Water

The site is surrounded by a sand dune field and there are no surface water courses within the development area, or at its immediate perimeter. Surface water features in the vicinity of the site comprise the River Kenfig to the south, the Margam Moors ditch system to the north and the Bristol Channel to the west. A small number of isolated ponds can be seen on the low lying area to the north and south of the site.

The flat lying moors have been managed for centuries for agricultural production by draining the clay soils using a deep network of ditches. The configuration of ditches has been developed to address local ground conditions. The ditches are at their densest along the southern and western edge of the moors where there is a need to drain surface water originating in a pronounced springline. This springline is coincident with the extent of the upper sand layer. All the ditches feed into the Mother Ditch which flows northward to a single collection point. From here the entire flow of water is pumped into the works for use as process water. The pumping is carried out after the water discharges over a weir, and therefore pumping cannot affect water levels in the ditches.

The River Kenfig, approximately 2km southeast of MHL, drains a small catchment to the east of the site to the sea at Margam Beach. The river has a 95 percentile low flow of 950 litres/sec.

## 2.4 Groundwater

Groundwater is present in both the wind-blown sand and the estuarine sand and is separated by the clay aquitard. Groundwater is a perched layer in the wind-blown sand, sitting above the clay layer. In the underlying estuarine sands the groundwater is confined by the clay layer. Perched groundwater in the wind-blown sand is referred to as the shallow aquifer and the confined groundwater is referred to as the deep aquifer.

The base of the shallow aquifer is controlled by the topography of the underlying clay aquitard which generally dips from southwest to northeast and this is also the regional groundwater flow direction. Within the immediate area of MHL however, the topography of the underlying clay appears to fall to the northeast and southwest. As a consequence, MHL appears to straddle a groundwater divide caused by the underlying clay topography, although the position of the groundwater divide is not fixed (see groundwater contours in Appendix 1). MHL is positioned in an area where there may only be a small contribution from groundwater moving below MCL and MNHL. Again, this is most likely due to the fall in shallow groundwater following the topography of the upper clay surface. MHL appears to be to the west of a valley noted in the clay topography with MNHL to the East.

The groundwater gradient is very shallow and typically between 1:100 and 1:300. Because of the limited extent of the wind-blown sand over the extensive clay layer, a spring line has developed on the northeastern edge of the site. The spring line results in the soligenous fen ecology of the Margam Moors SSSI (Site of Special Scientific Interest). Deeper groundwater moves towards the northwest beneath the site.

Investigation boreholes have revealed that the clay layer that separates the two sand aquifers is absent in the vicinity of the Kenfig. A sequence of wind-blown sand over estuarine sands is therefore found here with a single water body. Water levels in the Kenfig and nearby boreholes are higher than the clay layer and springline at Margam Moor. The Kenfig therefore recharges both the lower and the upper aquifers in this area.

## 2.5 Meteorology

Meteorological data for MHL is recorded by two site weather stations. One is located on top of the weighbridge office and the other is located in the sub-contractors yard. A record of long-term rainfall is also routinely obtained from the Natural Resources Wales station located at Margam and at the Tata Steel Works site. The site typically receives approximately 1000mm rainfall per annum and the prevailing wind direction is southwesterly.

## 2.6 Ecological Areas of Interest

Three sites of ecological importance have been identified within the vicinity of MHL:

- Kenfig National Nature Reserve (KNNR)
- Margam Moors SSSI
- Margam Burrows

Margam Moors is managed by Tata Steel on behalf of Natural Resources Wales. Margam Burrows and KNNR is managed by Natural Resources Wales.

The northern boundary of Kenfig National Nature Reserve (KNNR) follows the path of Kenfig River approximately 1.5km to the south east. KNNR is a Site of Special Scientific Interest and a Special Area of Conservation (SAC). The designation is based on the dune habitats present and the flora and fauna supported within these areas. Several nationally scarce and rare species of plant have also been recorded. The exceptional wetness of the Kenfig dune system is of national significance and the hydrological regime appears perfectly natural. Although the KNNR groundwater system is thought to be mainly rain-fed, there is the possibility that groundwater inflow from underlying/neighbouring carbonate aquifers also plays a role.

Margam Moors is also a Site of Special Scientific Interest (SSSI). The mosaic of drainage ditches provides the main interest of the moors and it is principally for this feature that the site was designated SSSI.

Margam Burrows is possibly more isolated from human disturbance than any other dune area in South Wales and this key attribute greatly enhances its potential for ground-nesting birds. The area is known to support internationally important habitats, notably humid dune slacks.

# 3 OVERVIEW OF SITE ACTIVITY

Since the original HRA, the landfill has become operational and changes have occurred that influence the hydrogeological setting. An overview of these activities is provided in this section. The timeline of landfill construction and operation is summarised in Table 3-1.

**Table 3-1 Summary of landfilling activity to date at MHL**

| Activity | Start | Finish |
|---|---|---|
| Construction of MHL Cell 1 | 1 June 2004 | 19 October 2004 |
| Restoration of MCL | September 2004 | 8 June 2013 |
| Construction and operation of waste treatment centre | 5 December 2006 | Ongoing |
| Construction of MHL Cell 2 | October 2011 | Ongoing |
| Temporary storage of fire waste at MNHL | 25 June 2011 | 14 March 2014 |
| Transfer of Fforestfach fire waste to Cell 2 of MHL | March 2014 | March 2014 |
| Installation and operation of new leachate pumping system | 2018 | October 2019 |

## 3.1 Technical Precautions

MHL is designed upon the containment principle. Pollutants are kept within the wastes by surrounding the wastes with barriers that are virtually impermeable to water, liquids and gases. The landfill is being constructed as a series of cells with an Engineered Barrier System (EBS) consisting of Bentonite Enhanced Sand (BES) overlain by a High Density Polyethylene (HDPE) liner. Above the EBS is a leachate collection system. A cross section of the key landfill engineering systems is provided in Figure 3. Each cell is approximately 100m by 60m.

Since issue of the Permit, two cells have been constructed and at the time of writing sub-cell 2 is getting close to operational capacity and plans are being formulated for further sub-cells and the capping of cell 1. Each cell has been constructed in accordance with a strict Construction Quality Assurance (CQA) system. Only when NRW has confirmed acceptance of the CQA does landfilling commence. Information gathered as part of the CQA process was used in the previous HRA report to populate the quantitative groundwater model. Since the previous HRA, no further cells have been constructed.

## 3.2 Hazardous Waste Deposition

A summary of the waste types and tonnages deposited at the landfill as recorded by the landfill operator is regularly submitted to NRW in accordance with the Permit requirements. A graphical record of waste deposition to the end of 2021 is presented in Appendix 1, and below. In 2019, 207.95 tonnes of waste was deposited. In 2020, this dropped to 46.5 tonnes, the lowest annual total deposited. In 2021, 557 tonnes was landfilled.

As the cell is fully open to the elements, leachate is being produced and treated from rainfall falling over the entire cell footprint. This will continue unless measures are taken to reduce the area exposed to rainfall and infiltration.

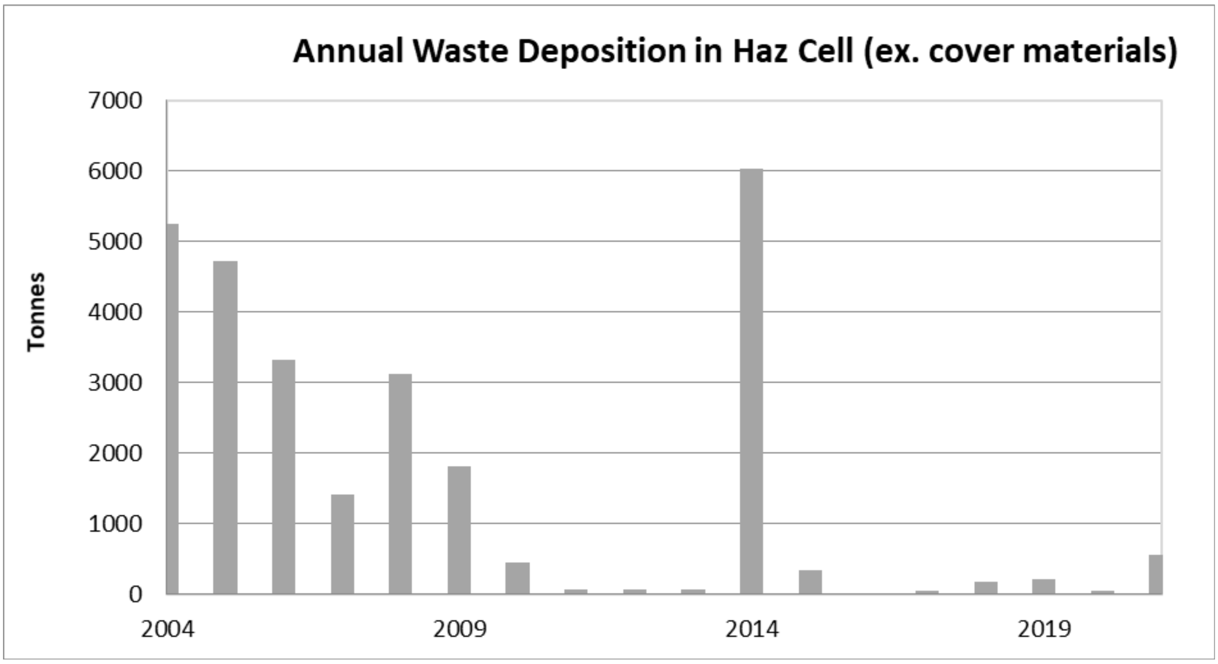



**Chart 3-1 Waste deposition at Hazardous Landfill**

### 3.2.1 Third Party Waste Storage

Tata Steel landfills are only permitted to accept wastes generated by the steelworks. However, in 2011 an exceptional emergency event occurred, following which Tata Steel was approached to assist by temporarily storing a third party waste.

On 16 June 2011 a major fire broke out in an industrial unit in Fforestfach, Swansea. The unit contained an estimated 5000t of tyre fluff from the treatment of shredded tyres. During the days immediately following the fire, the Fire Rescue Service (FRS) discovered that the fire could not be readily extinguished using conventional firefighting techniques. A crust was forming on the surface of the material, limiting the effectiveness of the cooling water so the mass kept burning. A multi-agency strategic co-ordinating group was set up to manage what was expected to be a protracted major incident. Using expertise from elsewhere in the country, a means of extinguishing the burning waste was developed. This involved mechanically quenching the burning mass by placing excavated loads into large water filled skips. This proved to be the only means of extinguishing the fire.

After quenching, large volumes of the extinguished material required immediate removal as there was no space at the fire site. As part of an appraisal of potential options for off-site management of the waste, Tata Steel was approached by Swansea City Council on 23 June 2011 with a view to exploring options for the temporary storage of waste at the Morfa site. Following this meeting and a site visit by the Tata Steel landfill operators (Darlow Lloyd and Sons) to Fforestfach, Tata Steel agreed to the use of Cell 2 of MNHL (subject to regulatory approval) for the temporary storage of the waste. NPTCBC (Planning Authority), the NRW (Waste Regulators) and waste specialists acting for the Strategic Co-ordinating Group (SCG) met prior to waste movement to discuss this option. Regulatory acceptance from both organisations was made subject to a number of strict controls and conditions. On 25 June 2011 Tata Steel started to accept waste into Cell 2 of MNHL. This process continued until 20 July 2011.

During March 2014, fire waste containing cement bound asbestos was moved from Cell 2 of MNHL into Cell 2 of MHL. The movement of the waste was, at times, observed by NRW and following completion of the works Geotechnology prepared a Validation Report documenting the works undertaken (see Geotechnology report 1327r1v1d0314).

## 3.3 Landfill Capacity

## 3.4 Topographic Survey

A topographic survey of the operational landfill cells was carried out on 8 January 2021 and a repeat survey on 14 January 2022. Following data acquisition, the digital data was imported into a digital terrain model for each of the cells to calculate the available void space.

Since 2013 the surveys have been completed using an unmanned aerial vehicle (UAV) with survey control established using dGPS land-based Hiper-SR equipment. The UAV data is then used together with ground control points to create a digital terrain model. This method of surveying collects data points at significantly closer intervals than methods previously used and is therefore able to create a more detailed topographic model, as shown in Figure 4.

## 3.5 Remaining Void Space

The currently available void space in the hazardous landfill cell is summarised in Table 3-2. This has been derived by comparing the waste surface surveyed on 14 January 2022 with the temporary top of waste surface for Hazardous Sub-Cells 1 & 2.

**Table 3-2 Current Cell Volume Capacity**

| Volumes ($m^3$) | Hazardous Sub Cell 1 | Hazardous Sub Cell 2 |
|---|---|---|
| Total | 24529.29 | 37401.04 |
| Used as of Jan 2021 | 25072.17 | 26129.28 |
| Available as of Jan 2022 | -542.88 | 11271.76 |
| % Available Space | Full | 30.14 |

Once the remainder of the hazardous landfill has been constructed a further 89060$m^3$ will become available.

## 3.6 Capping System

When disposal activities are complete, the entire site is to be covered with an engineered barrier in order to restrict the ingress of surface water into the waste. To date, no progressive restoration has been undertaken but plans are being made to cap Cell 1 shortly.

Ultimately, the cap will comprise several elements:

- An under cap gas drainage system (the intermediate cover layer)
- A blinding layer
- A FML (flexible membrane liner) moisture barrier

- A drainage geocomposite
- Restoration soils

In each cell, the finished waste mass is to be covered with an intermediate cover layer of selected slag fines to contain the wastes and control litter, dust, odour and vermin. When the entire cell is available for capping, this intermediate cover layer is to be proof rolled to provide a hard unyielding surface and also to assist the passage of landfill gas toward the gas vents. During this operation, any hollows or voids that develop are to be filled with slag and rolled until an acceptable surface is produced.

Covering the entire landfill, though constructed progressively, is to be a moisture barrier comprising a 1mm thick HDPE membrane placed onto the final cover (gas drainage layer). To protect the underside of the liner a 100mm blinding layer of slag or stone dust fines is to be used. The upper surface of the membrane should be protected with a geocomposite material that will serve as a protection fabric as well as a restoration soil drainage blanket. Restoration materials are to be placed above the drainage composite to provide a new ecosystem to off-set the losses caused by the landfill development.

## 3.7 Leachate Management

As shown in Figure 5, leachate collection facilities are provided above the geological barrier and artificially established barrier to allow leachate to flow quickly under gravity toward an engineered collection sump. Leachate levels are regularly monitored in the sump.

Until 2019, leachate was collected from the sump by vacuum pumps and tankered away from the landfill using $10m^3$ or $15m^3$ road-going tankers. These tankers took the leachate to the wastewater treatment facility at the steel works. This system has now been replaced by a fixed pumped system, discharging directly into the works via a holding / balancing tank facility.

The new system involves pumping leachate from all cells at MNHL and MHL (currently five cells). There are three individual leachate pipe runs, one for the two MNHL Biocell sumps, one for the two non-hazardous cell sumps at MNHL and one for the MHL cell sump. The pumping at each cell can be float controlled to ensure that leachate heads are within permitted limits.

The three individual pipe runs discharge initially into a holding/balancing tank located at the permitted Waste Transfer Station area near to the DLS offices. The balance tank is also float controlled and combines all leachates for further pumping into the end discharge sump within the main works, located at Morfa Coke Ovens, Gas Holder Deep Sump. Flowmeters are located at each sump location, and at the balance tank, to record individual and cumulative leachate outflows. The use of flowmeters will provide a check on the potential for leakage from any of the three pipes entering the balance tank.

The installation of the leachate pipework system was carried out in accordance with the principles of the Construction Quality Assurance (CQA) Plan and Specification (Geotechnology report 1486r1v2d0917). Validation was documented in Geotechnology report 1486r2v1d0719.

## 3.8 Restoration of adjacent Morfa Closed Landfill (MCL)

Phased restoration of unlined MCL was completed in 2013 having started in 2004. The restoration involved placement of geomembranes which, in combination, provide gas and surface water management as well as providing barriers to precipitation ingress and gas egress. The sympathetic restoration also involves the placement of sand on top of the geomembranes, creating dune morphology like the surrounding land.

As part of the re-profiling to achieve stable restoration surfaces, the opportunity was taken to recover materials for use in the steel making process. During this aspect of the works, wastes were temporarily exposed to weathering and leaching prior to them being reprofiled and capped.

## 3.9 Construction and Landfilling at adjacent Non Hazardous Landfill

Two biodegradable cells (Biocells A and B) and two non-hazardous waste cells (Cells 1 and 2) have been constructed at the adjacent MNHL. During 2021, the biodegradable waste cell was extended into Cell 1, creating additional biodegradable waste capacity.

# 4 MONITORING PLAN

To demonstrate that the site is functioning as designed, a rigorous monitoring programme is in place in accordance with the requirements of the Permit. The programme is managed by Tata Steel. The Plan covers ground and surface water monitoring, dust and noise emission, landfill gas production and stability. Control levels have been previously identified at which the landfill would be considered to be behaving differently from expected. If these control levels were to be breached, investigation and remediation will be actioned. If compliance limits are exceeded, the site is outside the scope of the Permit and the operators must take whatever action is necessary to keep the site within the terms of the Permit.

Continued environmental protection and the re-evaluation of the original HRA are intimately linked to the high quality monitoring programme. The detail of the routine monitoring has been reported elsewhere as part of the annual Permit reporting requirements.

## 4.1 Monitoring Network

Routine hydrogeological monitoring at MNHL has occurred since 2004. During this time the monitoring network has expanded and changed. The full monitoring network AT Morfa Landfill is shown in Figure 6. The specific monitoring network for MHL is shown in Figure 7.

The monitoring network and the equipment used to take on-site measurements are routinely checked and calibrated where necessary. One of the key improvements to the monitoring network is the installation of dedicated inertial or submersible pumps at each position for the collection of samples. These enable samples to be collected more efficiently and avoid the potential for cross contamination between sample points. Unfortunately, the locked borehole headworks are sometimes vandalised, particularly in the remote parts of the site, and the equipment stolen.

In February 2022, replacement boreholes were installed at BH28 due to a blockage within the original well preventing routine sample collection.

## 4.2 Laboratory Analysis

Severn Trent Laboratories (STL) was the laboratory used at the start of the monitoring programme in February 2005. In July 2006, STL was replaced by Testing Solutions for all water analysis by Tata Steel. Testing Solutions is based at the Engineering Centre for Manufacturing and Materials (ECM) in Margam, adjacent to the steelworks. Testing Solutions, (now known as TDC) has been responsible for all water and leachate analysis since July 2006. All aspects of the analytical programme are directly managed by the Tata Steel Environment Department.

# 5 OVERVIEW OF LEACHATE LEVEL AND CHEMISTRY

## 5.1 Current Leachate Chemistry

### 5.1.1 Leachate Level

Based on monitoring undertaken by the landfill operator, the variation of leachate head is illustrated in Appendix 2 and Chart 5-1. In accordance with the Permit conditions, the head of leachate has not exceeded one metre above the base of leachate monitoring point (L17) apart from a few weeks at the start of 2016 and in August 2018. At GA30, leachate has never been found to be present.

During 2021, leachate levels did come close to the Permit limit and there does appear to be an increasing baseline. This should be carefully evaluated within the context of the new leachate management system to ensure that heavy, intense and prolonged rainfall events do not result in elevated leachate levels. The data potentially suggest that some of the waste has reached its field capacity which may mean that leachate levels rapidly respond to antecedent rainfall.

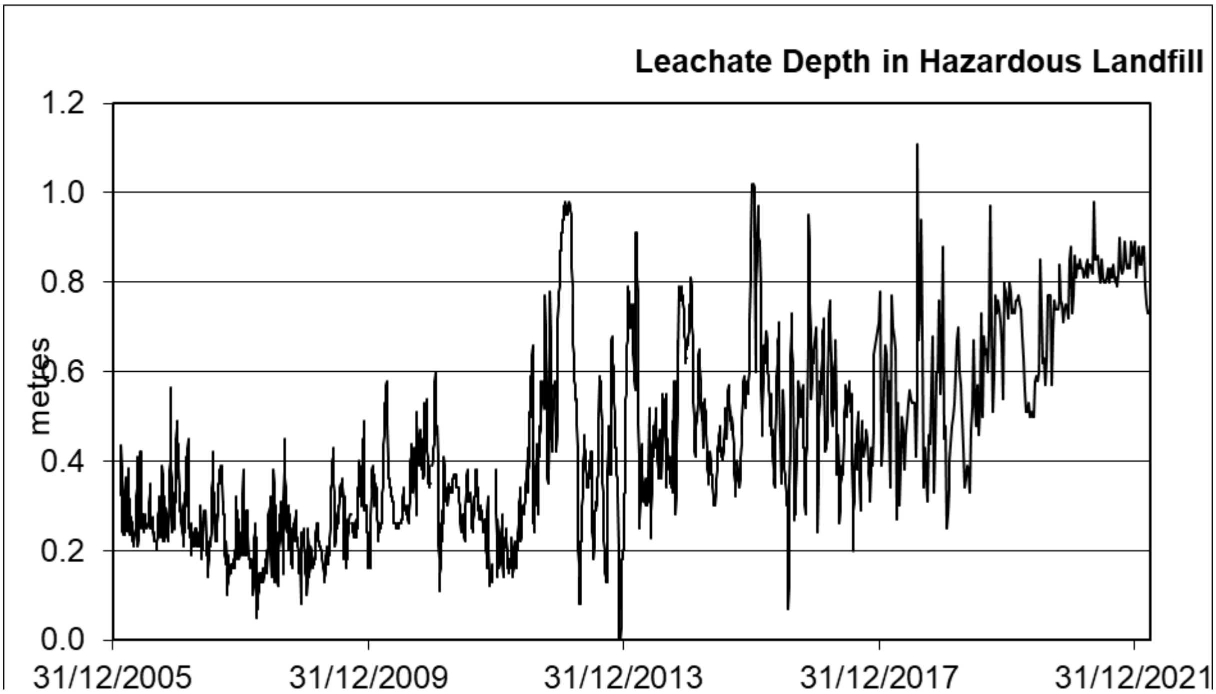



**Chart 5-1 Leachate levels in Hazardous Landfill (recorded at sump L17)**

## 5.2 Leachate Chemistry

The temporal variation of leachate chemistry is graphically illustrated in Appendix 3.

As the waste landfilled at MHL does not contain a large degradable component, the evolution of the leachate is not following the same path which is well documented for municipal solid wastes. Rather, the leachate chemistry is being controlled by mostly inorganic processes.

Leachate chemistry is currently characterised by elevated pH (pH 12 – 13) and moderate electrical conductivity (~4000 micros/cm). Over the past five years the concentration of several parameters has typically declined, although mineralisation has increased during 2020 and 2021, as shown in the graphs in Appendix 3 which displays data gathered up to April 2022. This appears to be as a consequence of increased alkalinity. This may reflect the ratio between slag cover materials and some of the industrial wastes covered.

Under the highly alkaline conditions, trace metals (including hazardous substances cadmium and mercury) are typically present at low levels or below the level of detection. During 2020, trace metals were once again at low concentrations with cadmium and mercury not being detected. In 2021, Cadmium was detected at up to 8.4 microg/l, mercury was not detected, lead was up to 29.3 microg/l.

Due to the nature of the waste streams, very low levels of hydrocarbons, volatile organic compounds (VOC's) and semi VOC's have been detected to date. During 2021 these compounds were not detected.

## 5.3 Assessment against Control Levels and LandSim Criteria

The modest mineralised content of the leachate is reflected in the summary provided in Table 6-1. This shows selected key parameters to be well within the modelled levels from the previous HRA.

**Table 5-1 Evaluation of Leachate Chemistry**

| | **Ammonia** | **Arsenic** | **Chloride** |
|---|---|---|---|
| | **mg/l** | **mg/l** | **mg/l** |
| **LandSim PDF*** | Triangular (0.05, 10, 50) | Triangular (0.005, 0.3, 3) | Log Triangular (1000, 10000, 61000) |
| **Leachate chemistry 2018** | | | |
| Maximum 2018 Leachate chemistry (L17) | <0.05 | 0.0007 | 72.8 |
| **Leachate chemistry 2019** | | | |
| Maximum 2019 Leachate chemistry (L17) | 0.25 | 0.0586 | 79.1 |
| **Leachate chemistry 2020** | | | |
| Maximum 2020 Leachate chemistry (L17) | 0.62 | 0.0006 | 87.1 |
| **Leachate chemistry 2021** | | | |
| Maximum 2021 Leachate chemistry (L17) | 1.09 | 0.494 | 112 |
| **Leachate chemistry up to April 2022** | | | |
| Maximum 2022 Leachate chemistry (L17) | 1.24 | <0.075 | 165.5 |
| *PDF – Probability Density Function used to describe statistical distribution of parameter. Triangular and Log Triangular are the PDFs used in most recent HRA. Values in parenthesis are minimum, most likely and maximum values used in LandSim model | | | |

## 5.4 Contingency Actions Taken

No specific contingency actions were required but Tata Steel has continued to improve operation and management of leachate levels.

# 6 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual hydrogeological model for the landfill site developed as part of the original Permit Application was based on the ground investigations related to the installation of the extensive monitoring network. Since this time, the monitoring network has changed very little. However, more monitoring data is now available, particularly for the shallow aquifer. In this section the conceptual model is reviewed and updated.

## 6.1 Strata Geometry

Several phases of site investigation and groundwater monitoring well installation have occurred as follows:

- April 1995 – Installation of boreholes with piezometers by Posford Duvivier. Piezometers targeted the shallow and deep aquifer. The positions installed were BH1, 2, 3, 4, 5, 6
- April and May 2000 - Excavation of 14 trial pits using a backhoe excavator and six boreholes using cable tool drilling. 19mm steel piezometers were installed in two trial pits and are referred to as TPG and TPV. Each of the boreholes were fitted with piezometers targeting the shallow and deep aquifer. The boreholes installed were BH11, 12, 13, 14, 15 and 16
- January/February 2005 – ground water/gas wells installed using cable percussive drilling. At monitoring locations BH 15, 16, 17, 18, 19, 20, 25, 26 and 27, piezometers were installed in the upper and lower aquifers for groundwater monitoring purposes. At BH7 and GWT2a, piezometers were only installed in the upper aquifer for groundwater monitoring purposes. Boreholes GA7, 8, 9, 10, 11, 12, 15 and 16 were drilled for the installation of landfill gas monitoring wells and only partly penetrated the upper aquifer
- April 2005 - twenty four 19mm steel piezometers were manually driven into the shallow aquifer at depths of up to 3m below ground level. These piezometers are referred to as P1 – P24
- July 2007 - Cable tool drilling BH28 and BH29 which were instrumented with 50mm ID wells sampling the shallow and deep aquifer
- December 2008 – Cable tool drilling BH30 and GWT3a which were instrumented with 50mm ID wells sampling the shallow aquifer
- February 2022 - Installation of replacement well at BH28

All monitoring positions have been topographically surveyed to Ordnance datum using a differential GPS.

Relative to the data at the time of the Permit Application, the supplementary boreholes installed in 2005 confirmed the known sequence of strata beneath the site. Those that pierced the clay aquitard between the two aquifers demonstrated that the clay thickness shows little variation across the site and does not appear to be subject to localised variability. An interesting refinement to the conceptual understanding of the clay aquitard was noted following the investigations completed in 2005. Previously, it was thought that the upper surface of the clay aquitard was planar and dipping gently to the north but these investigations revealed that whilst it does gently dip to the north, it is in fact slightly undulating. The principal feature of importance was the discovery of a broad shallow valley or trough running centrally through the site from south to north. Sufficient density of ground investigation data allowed this feature to be identified and it explained a phenomenon noted for some time but never adequately understood.

## 6.2 Groundwater Flow

Within the vicinity of MHL, groundwater appears to move towards the northeast and southwest in the shallow aquifer, as shown by the contour plans provided in Appendix 1. This is most likely related to the topographic position of the site. Although MHL and MNHL/MCL appear to be separated by the shallow trough in the clay topography the groundwater contours suggest that there could still be small contributions to groundwater at MHL from MCL.

Groundwater within the deep aquifer also appears to move to the northwest and southeast, with passage to the northwest potentially the dominant flow direction. Groundwater flow within the deep aquifer around MHL is strongly influenced by the levels found at BH12.

## 6.3 Groundwater Chemistry

The water quality monitoring continues to indicate that groundwater within the vicinity of MHL is impacted to a variable extent, particularly in the shallow aquifer around BH12. For most parameters, the concentration in groundwater is higher than that observed in leachate sump L17. This is because the area surrounding the landfill, particularly to the south, contains legacy slag deposits and access roadways are constructed of slag and these aggregate materials are open to leaching and weathering. Groundwater may also be influenced by seepage from MCL.

Similar variations are also observed in other monitoring positions around the landfill cell (BH25 – BH29), although the trend is not as distinct, and the temporal variations are different. Given the proximity of some of the positions to the sea there may also be a saline/ tidal influence on groundwater quality and water level. This would appear to be particularly the case at BH27 and BH28, both of which are located on the western seaward side of the landfill. At BH27 for instance, both sodium and chloride are at higher concentration than at some of the other groundwater monitoring wells and leachate. There is also a potential 'cyclical' pattern where pH falls from ~pH 9 to pH 7 during a 12 month period before returning to ~pH 9. This may be due to localised changes in drainage patterns and tidal influences.

The monitoring programme has included the analysis of an extensive list of volatile and semi volatile organic compounds in leachate and groundwater. No VOCs or SVOCs have been detected in the groundwater samples analysed by the Tata Steel laboratories since 2009.

The key point to note is that the data continues to indicate that MHL is not having a discernible impact on groundwater and that groundwater sometimes contains higher concentrations of several parameters when compared with leachate.

## 6.4 Receptors

Controlled water receptor identification in the vicinity of the site is relatively straightforward. The groundwater beneath the site flows in a shallow sand aquifer toward Margam Moors and Margam Sands. There are no private or public abstractions of groundwater between the landfill and the receptors, so the springline on the moor and the beach represents the closest receptor where groundwater meets the biosphere. All of the land between the development and the receptors is under the control of the applicant and therefore future abstraction consents from the thin shallow aquifer are unlikely to be sought.

The receptor for hazardous substances is the groundwater directly beneath the site. As this cannot be monitored directly, the compliance point for the groundwater receptor will be a down-gradient monitoring borehole located adjacent to the site.

The compliance point for non-hazardous pollutants is the springline on the Moors, where groundwater breaks through to surface. Within the LandSim model this is referred to as the off-site compliance point with contaminant concentrations at this point reported as groundwater concentrations.

## 6.5 Model Update

A pictorial presentation of the current conceptual hydrogeological model is provided in Figure 8. The model illustrates the position of MHL above a groundwater divide that is considered to be influenced by the topographic position of the landfill related to the surface topography of the underlying clay aquitard. As a consequence, groundwater is able to move in an approximate radial pattern. On the western side of MHL, there may be a contribution from groundwater that has passed below MCL. This could also include deep groundwater from the east.

# 7 HYDROGEOLOGICAL RISK ASSESSMENT

In this section, the existing quantitative model used to evaluate the risks to the water environment is evaluated within the context of the data gathered since it was last reviewed. The aim of the model review is to ensure that the HRA is not divorced from the reality of the landfill facility. This link is made explicit by the reliance of the original Permit HRA on the essential and technical precautions at the landfill. With regard to the construction of the landfill lining systems and leachate quality, fundamental assumptions were made in the original HRA.

## 7.1 Numerical Modelling

A comprehensive evaluation of engineering changes upon receptor impact was undertaken using the LandSim 2 model at the time of the PPC Application (see Geotechnology report 245). Many iterative changes were made during the design process to determine the optimum landfill design to ensure environmental protection. LandSim 2 was the quantitative computer software chosen to simulate the performance of MHL as the model was developed to meet the NRW's need for a consistent approach to modelling the groundwater emissions from landfill sites. The conceptual hydrogeological model of this site, described in the previous section was approximated in developing the model.

Groundwater conditions beneath the site were represented in the LandSim 2 model by specifying the upper aquifer as the receiving aquifer. Leakage from the upper aquifer to lower aquifer was not modelled as it was considered likely that with the depression of the piezometric surface in the upper aquifer, caused by loss of infiltration, recharge would result in groundwater levels being close to equilibrium. Therefore, the upper aquifer was considered to be hydraulically confined and the escape of pollutants into the lower aquifer was considered inconsequential.

In the original PPC Application four models with unique titles were presented:

- Three simulations to demonstrate the performance of the chosen design over the short, medium and long term.
- One simulation to examine the performance of the Landfill Regulations default Engineering Standard for comparative purposes.

Following issue of the Permit, the next time that the original HRA LandSim model was updated was during 2005 in response to Permit Improvement Conditions (IC) 3, 4 and 5 (see Geotechnology report 403.2/0/1205). The ICs required the establishment of groundwater trigger levels for all groundwater monitoring boreholes, which necessitated a review of the conceptual model and quantitative simulations. Following refinement of the conceptual hydrogeological model, LandSim 2.5 was used to simulate the performance of the landfill as this was the model available at the time.

As LandSim 2.5 is still the validated model for assessing the long-term risks to groundwater from landfills, this HRA review has continued to use this model for all numerical modelling.

## 7.2 Model Parametrisation

Appendix 4 presents a summary and review of the LandSim input parameters used in the previous HRA. Key aspects are discussed further below.

### 7.2.1 Leachate Inventory

Table 7-2 provides a summary of leachate chemistry to date. Comparison of this data with the Probability Density Function (PDF) used to describe the leachate inventory in the previous HRA model indicates that the observed leachate quality falls within the modelled PDF. This suggests that there is no reason to alter the leachate inventory on the model.

**Table 7-1 Comparison of leachate chemistry with LandSim Inputs**

| | Ammonia | Arsenic | Chloride |
|---|---|---|---|
| | mg/l | mg/l | mg/l |
| **2017 HRA Leachate Inventory Probability Density Function** | | | |
| **Minimum Value** | 0.05 | 0.005 | 1000 |
| **Most Likely Value** | 10 | 0.3 | 10000 |
| **Maximum Value** | 50<br>(150) | 3<br>(30) | 61000 (100000) |
| **PDF Used** | Triangular | Triangular | Log Triangular |
| **Actual leachate quality** | | | |
| **Max values between Q2 2017 (previous HRA review) and Q2 2022 (current HRA review)** | 1.24 | 0.494 | 1824 |

### 7.2.2 Landfill Drainage System

In the previous HRA review the PDF describing leachate levels was modified to a triangular PDF with a minimum value of 0.1m, most likely value of 0.6m and maximum value of 1m. This would still appear to be applicable as the new leachate extraction system is maintaining leachate levels below 1m.

### 7.2.3 Engineered Barrier

Since the previous HRA, there has not been a need to construct any new cells. On this basis, the data included in the previous model has been retained.

### 7.2.4 Geological Units and Aquifer Properties

There is no new evidence available to suggest that the properties given to the geological units below the landfill within the LandSim 2.5 base model require modification. Therefore, no changes have been made at this time.

## 7.3 Predicted Emissions to Groundwater

### 7.3.1 Updated Numerical Model

Very little has changed since the previous HRA review in 2017. On this basis, the numerical model has not warranted update and so the latest Landsim model remains:

- MHL HRA REVIEW NOV 2017

i) Hazardous Substances

Hazardous substances have been screened out of the assessment, as they are currently either undetectable or present at such low concentrations that they do not pose a risk to the environment. This means that the landfill should continue to meet one of the requirements of the Environmental Permitting Regulations, provided the landfill continues to be designed and operated in accordance with the current practices.

The occurrence of hazardous substances is dictated by the properties of the waste streams. If these change, the leachate chemistry should be scrutinised. Consideration should also be given to potential emerging contaminants as scientific knowledge improves.

ii) Non-Hazardous Pollutants

The full model and results are provided in electronic format in Appendix 5. A summary of the maximum predicted concentrations at the 95th percentile confidence limit are summarised in Table 7-2.

Comparison of the predicted concentrations with the freshwater EQS included in Table 7-2 and the shallow and deep groundwater chemistry detected around the landfill in Charts 7-1 and 7-2 indicates that the predicted concentrations will not cause pollution and may not be clearly discernible given background groundwater chemistry.

**Table 7-2 Maximum Concentration Predicted at Compliance Point**

| | **Emissions to Groundwater at Compliance Point** | | |
|---|---|---|---|
| | **Predicted LandSim Emissions (2012 HRA)** | **Predicted LandSim Emissions (2017 HRA)** | **EQS** |
| | **mg/l** | **mg/l** | **mg/l** |
| Ammonia | 0.03 | 0.03 | 0.3 / 0.6 |
| Arsenic | 0.002 | 0.002 | 0.05 |
| Chloride | 31 | 28.5 | 250 |
| All data presented at 95$^{th}$ percentile. | | | |

All models are simplified representations of reality and should be viewed as aids to the decision-making process. Decisions as to whether the site complies with the Regulations and must combine several lines of evidence including professional judgement, the model results and an understanding of the assumptions within each model.

Despite including several conservative assumptions, comparison of the model results with groundwater chemistry and EQS indicate that the predicted emissions at the Margam Moors springline will be imperceptible for all but the most mobile species. In understanding the predicted emission limits, it is useful to consider the assumptions built into the modelling.

Two of the most important assumptions are:

- assuming that the leachate chemistry is worse than is currently encountered.
- ignoring all retardation processes within the EBS and underlying geology

When taking these factors into consideration, it is evident that the landfill will not leach non-hazardous substances that cause pollution, provided the waste properties remain similar to

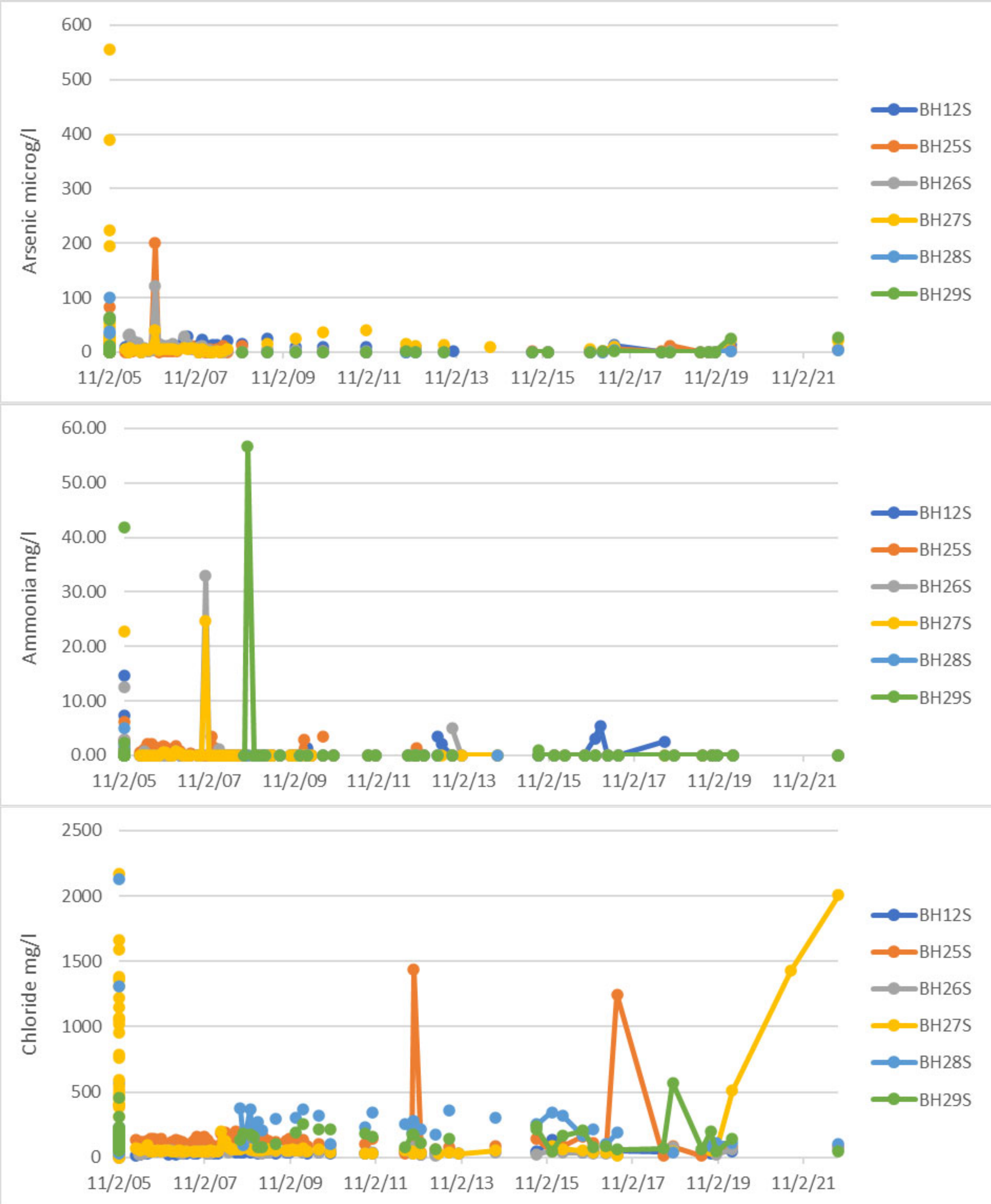



**Chart 7-1 Shallow groundwater chemistry around MHL**

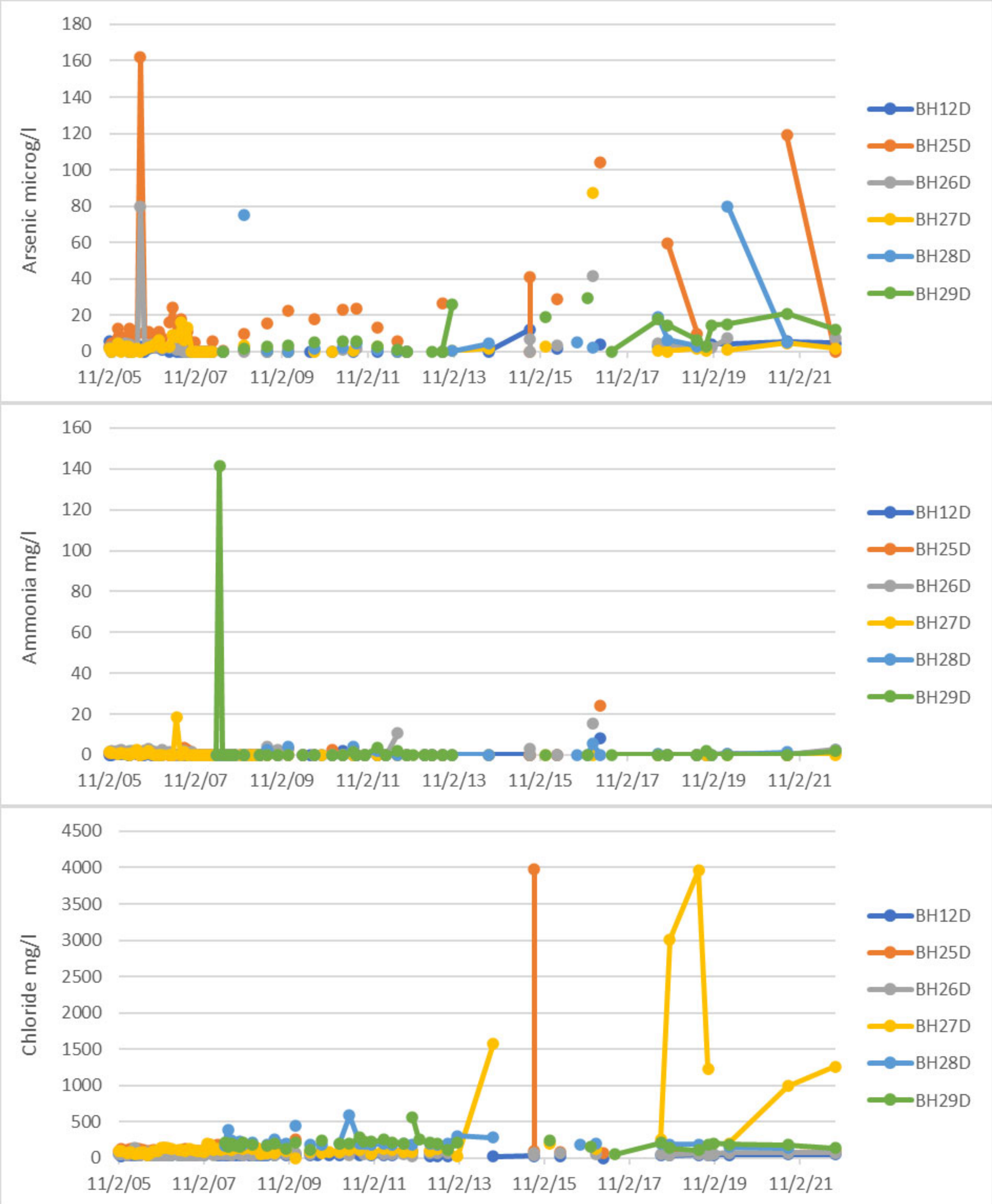



**Chart 7-2 Deep groundwater chemistry around MHL**

those observed and the landfill continues to be constructed and operated in accordance with the design requirements.

## 7.4 Emissions to Surface Water

Provided the landfill is constructed and operated in accordance with the design, the landfill is not predicted to directly impact surface water at any stage.

## 7.5 Environmental Protection

The updated LandSim model provides evidence that MHL continues to meet the requirements of the Environmental Permitting Regulations.

## 7.6 Review of Technical Precautions

Risks to controlled water at MHL are being controlled and monitored through careful waste management and prudent landfill operation. Key to the continued success of minimising and controlling the risks to the environment is the continued construction of cells under CQA supervision, active leachate extraction and implementation of an effective monitoring programme. As cells become no longer operational, progressive restoration should be taking place, as this limits the amount of leachate requiring management and reduces the potential flux of contaminants.

## 7.7 Operational Management

Construction Quality Assurance (CQA) information gathered to date has enabled the LandSim 2.5 model to take account of as built engineering properties. The thickness of the BES and its hydraulic conductivity have at least matched the design requirements and in the majority of cases, significantly exceeded the requirements. As a consequence, the risks posed to the environment are reduced. Further, monitoring of the landfill operation has indicated that management controls are robust and highly effective. Most notably, the leachate level can now be tightly controlled by the new leachate extraction system. The consequence of such controlled leachate levels is highly significant as it reduces the driving head for leakage, enables leaching and flushing of the waste during the landfill management phase and therefore directly minimises the potential long-term risks posed to the groundwater environment.

## 7.8 Requisite Surveillance

The monitoring programme as set out in the recent Permit Variation is providing data with which to evaluate the risks to the controlled water environment. There does not appear to be any reason, at this stage, to alter the current monitoring programme.

## 7.9 Review of Control and Compliance Levels

Compliance and control levels are set and agreed with NRW for leachate, groundwater and surface water. The findings of the HRA suggest that the current leachate control levels are set at levels protective of the environment.

# 8 LANDFILL CLOSURE AND COMPLETION CRITERIA

## 8.1 Landfill Closure and Surrender

Landfill closure is an on-going process between the time when the site is 'closed' and ceases accepting waste for disposal and 'definitive closure' when the NRW agrees that the site may enter the aftercare phase.

Definitive closure of the landfill will be granted by NRW following review of the reports requested in the Closure Notice and a final on-site inspection. Following definitive closure, the Aftercare Monitoring period will last until the authorisation is successfully surrendered. During this period, the agreed Aftercare Monitoring Plan will be followed and the operator shall continue monitoring and maintaining the landfill for as long as NRW considers the landfill poses a hazard to the environment. The landfill can only be surrendered when NRW does not consider the landfill to pose a hazard to the environment. The aftercare period will likely last for a number of years.

The ultimate surrender application will need to contain a site report describing the condition of the site relative to the condition of the site as described in the original site application. The application will also need to contain a description of any steps that have been taken to avoid any pollution risk on the site resulting from the operation of the installation, or to return the site to a satisfactory state.

## 8.2 Completion Criteria

Completion of the landfill is defined as the point at which the landfill has stabilised physically, chemically and biologically to such a degree that the undisturbed contents of the site are unlikely to cause pollution of the environment or harm to human health. At completion, post monitoring procedures are no longer required and the licensing permit can be surrendered. Completion can only occur if certain criteria are met during the post closure monitoring.

For MHL, the completion criteria will need to take consideration of the groundwater impacts caused by unlined MCL and the antecedent groundwater quality and receptor water quality at the time of closure. The current conservative predictions from the LandSim 2.5 software suggest that (i) MHL will not discharge detectable levels of Hazardous substances to groundwater and (ii) the emission of non-hazardous pollutants will not cause pollution.

# 9 SUMMARY

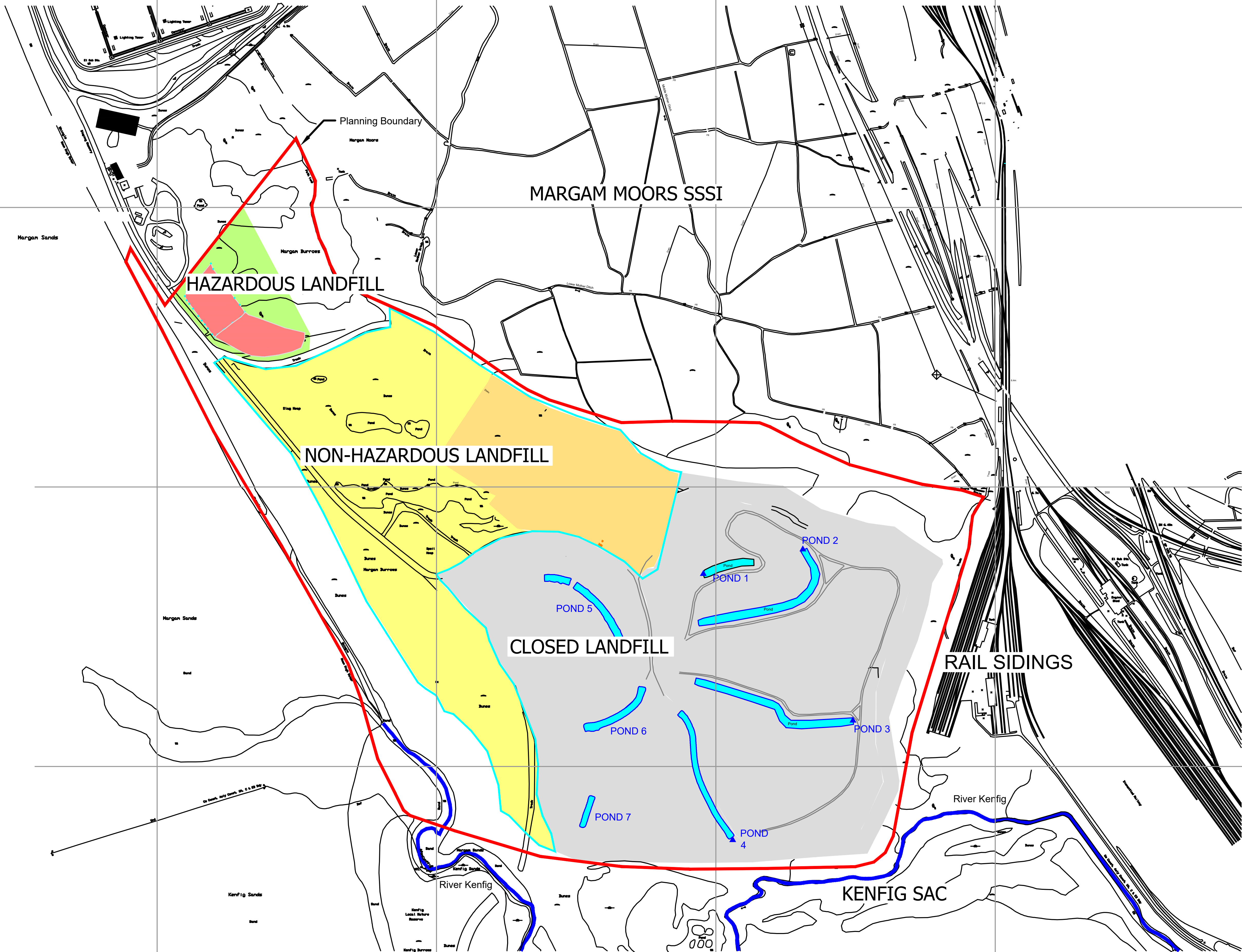
As MHL is constructed, a high quality CQA programme and environmental monitoring programme is being implemented. As a consequence, this enables the potential risks posed to groundwater and the original HRA to be continually updated based on as-built design details and monitoring data.

The risk posed to groundwater by the landfill is being controlled by the leaching properties of the waste and the operational control of leachate levels in all landfill cells. The assessment of the risks using LandSim and judgement of the predicted emissions indicates that the requirements of the Regulations are being satisfied. Based on the monitoring data collected to date, there is no evidence to suggest that the landfill is not behaving as initially predicted and the identified receptors remain protected from potential impacts related to MHL. At MHL there will always be significant difficulty in determining influences on groundwater as both the shallow and deep aquifers have been impacted by seepage from upgradient MCL and potentially other sources.

As cells cease to operate, progressive restoration should be taking place as this limits the amount of leachate requiring management, potentially reduces the mineralised content requiring treatment and reduces the potential flux of contaminants.

## Figure 1  Site Location Plan


Reproduced from the Ordnance Survey Land Ranger Map
with the permission of The Controller of Her Majesty's Stationery Office




Drawing Number 2239/2

Legend

- Undeveloped Part of MHL
- Developed Part of MHL
- Developed Part of MNHL (2 bio cells & 2 non-haz cells)
- Undeveloped Part of MNHL
- Restored Extent of MCL

Notes

| Rev | Date | Status/Ammendments |
|---|---|---|
| | | |
| | | |

CLIENT
Tata Steel Ltd

PROJECT
Morfa Hazardous Landfill
Review of Hydrogeological Risk Assessment

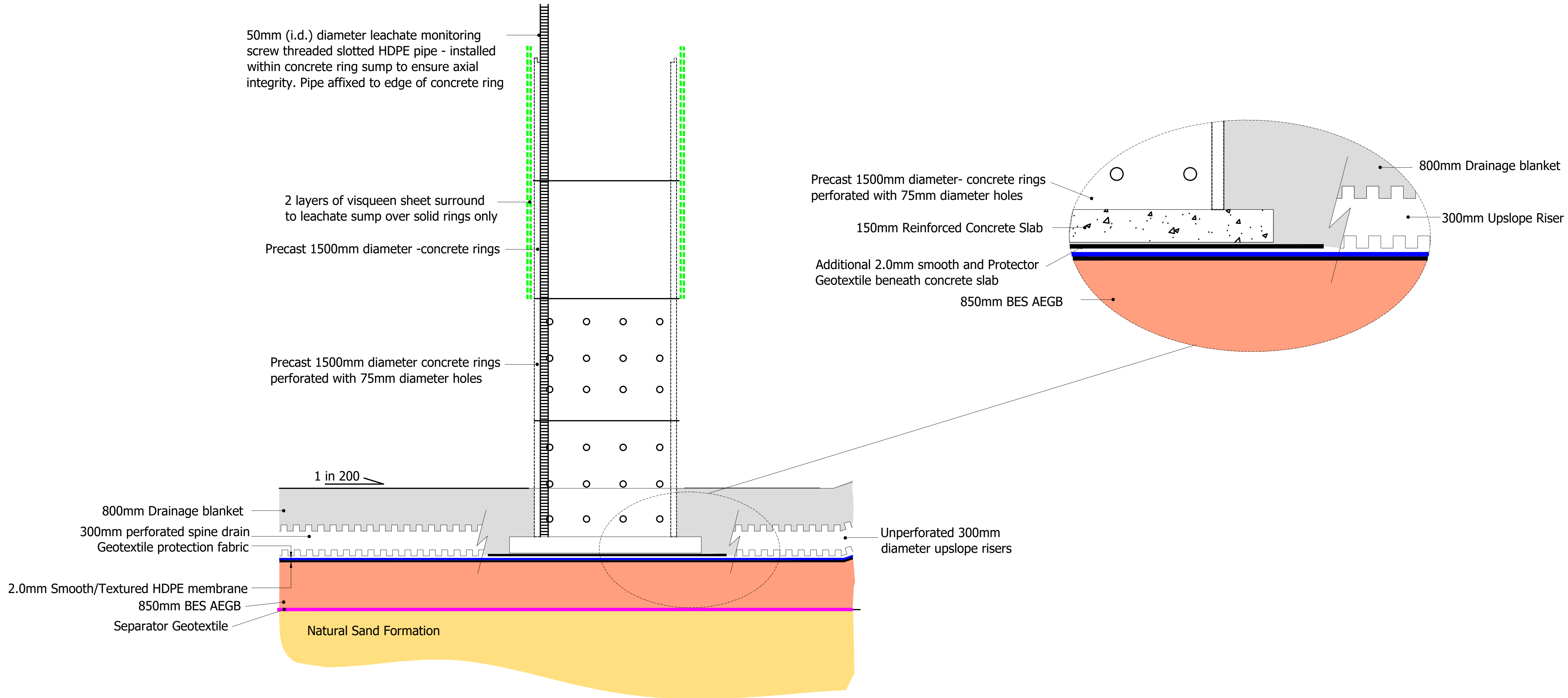
TITLE
Environmental Permit Boundaries

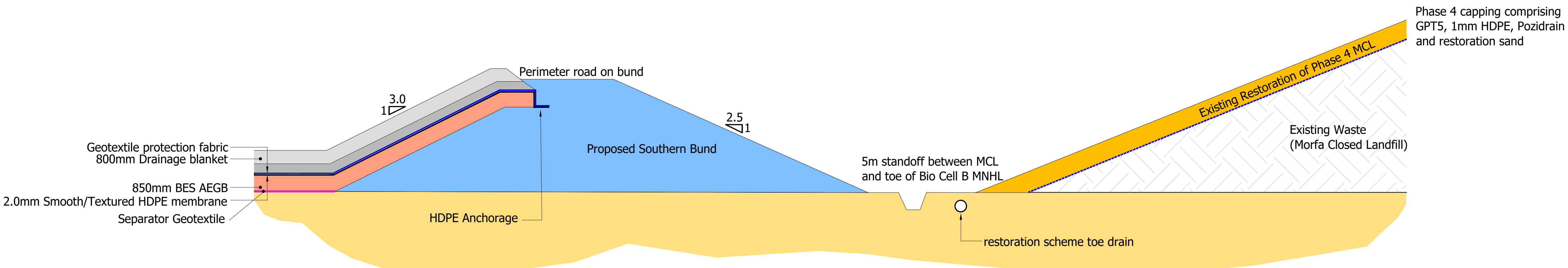
| DRAWING NUMBER | | | REVISION |
|---|---|---|---|
| 2239/2 | | | 0 |
| DATE | DRAWN | CHECKED | SCALE AT A3 |
| 06.22 | KJT | | NTS |

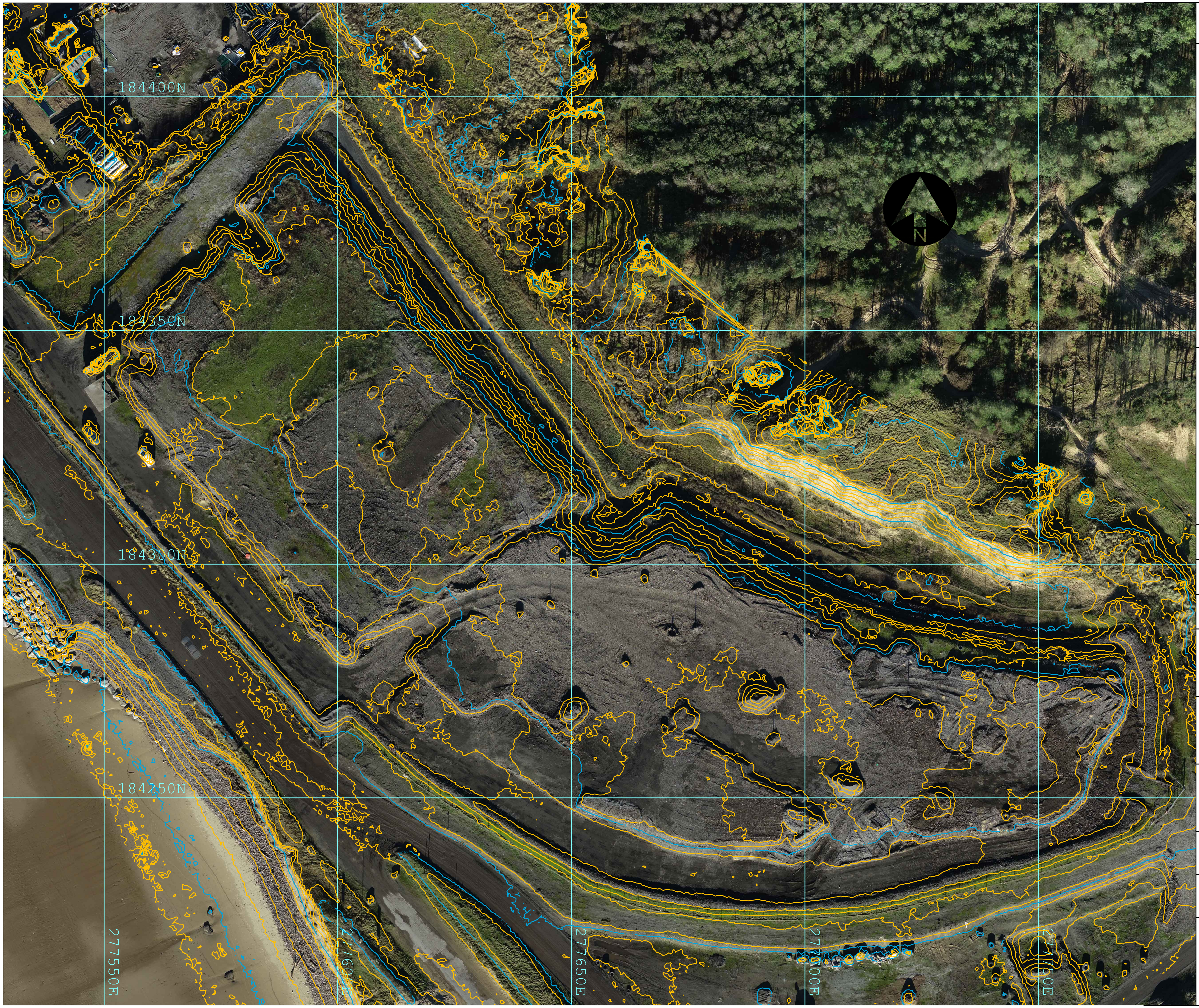

Geotechnology Limited
Ty Coed, Cefn-yr-Allt,
Aberdulais, Neath
SA10 8HE
01639 775293
www.geotechnology.net


GEO TECHNOLOGY

## Figure 3  Cross Sections of Key Landfill Engineering Systems






Drawing Number 2239/4

Legend

Prominent Contour (2.5m)

Normal Contour (0.5m)

Notes

Digital survey model generated using Pix4D image processing software.

Imagery acquired by DJI Phantom 4 pro RTK photogrammetry survey on 14 January 2022.

Survey control installed using Topcon Hiper SR dGPS Network Rover.

OS Grid spacing at 50m

| Rev | Date | Status/Ammendments |
|---|---|---|
| | | |
| | | |

CLIENT

Tata Steel (UK) Limited

PROJECT

Morfa Hazardous Landfill
Review of Hydrogeological
Risk Assessment

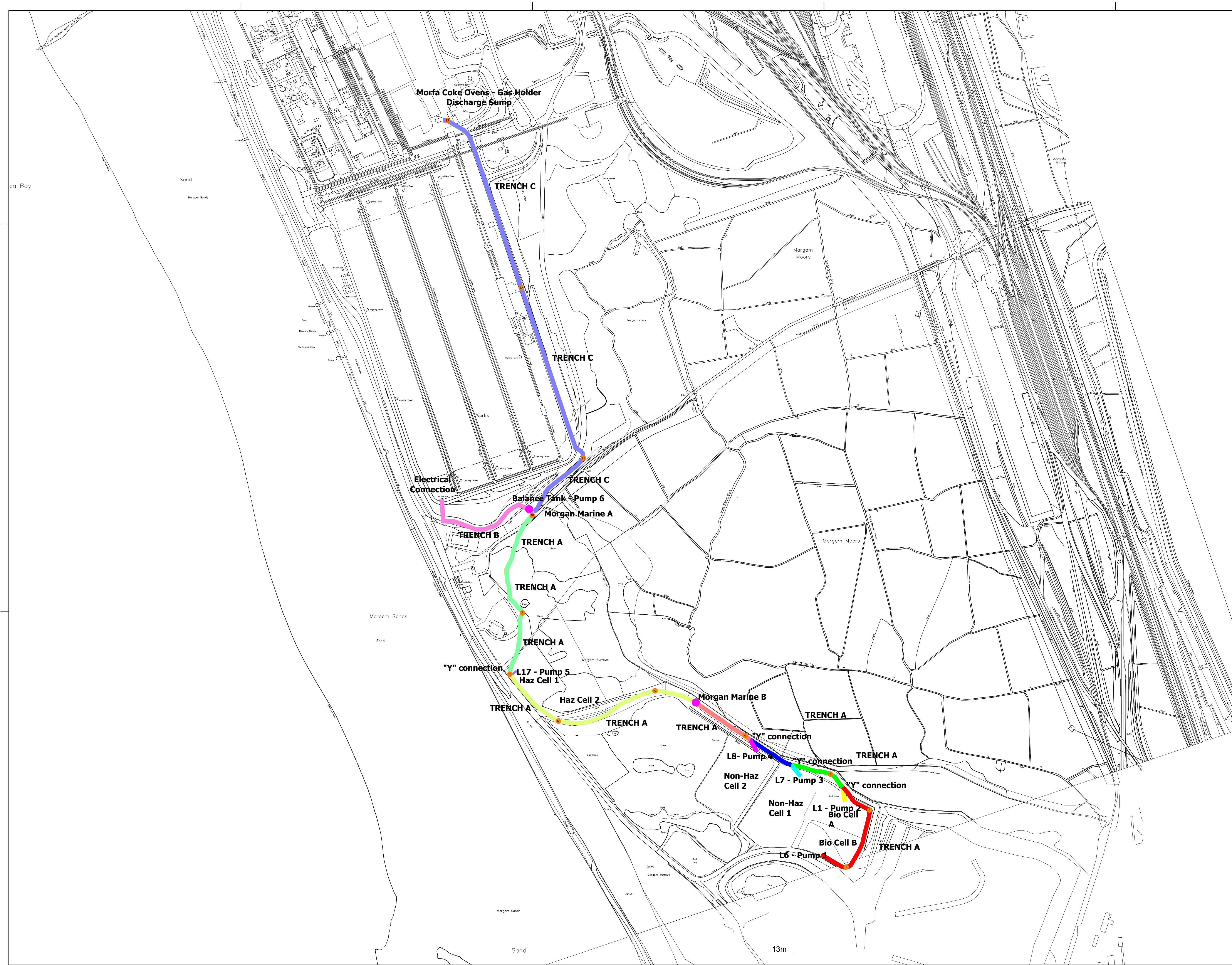
TITLE

Topographic Plan of Landfill

| DRAWING NUMBER | | | REVISION |
|---|---|---|---|
| 2239/4 | | | 0 |
| DATE | DRAWN | CHECKED | SCALE AT A3 |
| 06.22 | KJT | | 1:750 |

Geotechnology Limited
Ty Coed, Cefn-yr-Allt,
Aberdulais, Neath
SA10 8HE
01639 775293
www.geotechnology.net

GEO TECHNOLOGY




Drawing Number 2239/5

**Legend**

- L6 Sump Number
- Survey Check Point (see Table 7-1)
- Location of Electrical Control Panel - Morgan Marine A or B
- Chainage A
- Chainage B
- Chainage C
- Chainage D
- Chainage E
- Chainage F
- Chainage G
- Chainage H
- Chainage I
- Chainage J
- Chainage K
- Chainage L

**NOTE**

| Rev | Date | Status/Ammendments |
|---|---|---|

CLIENT: TATA STEEL (UK) Ltd.

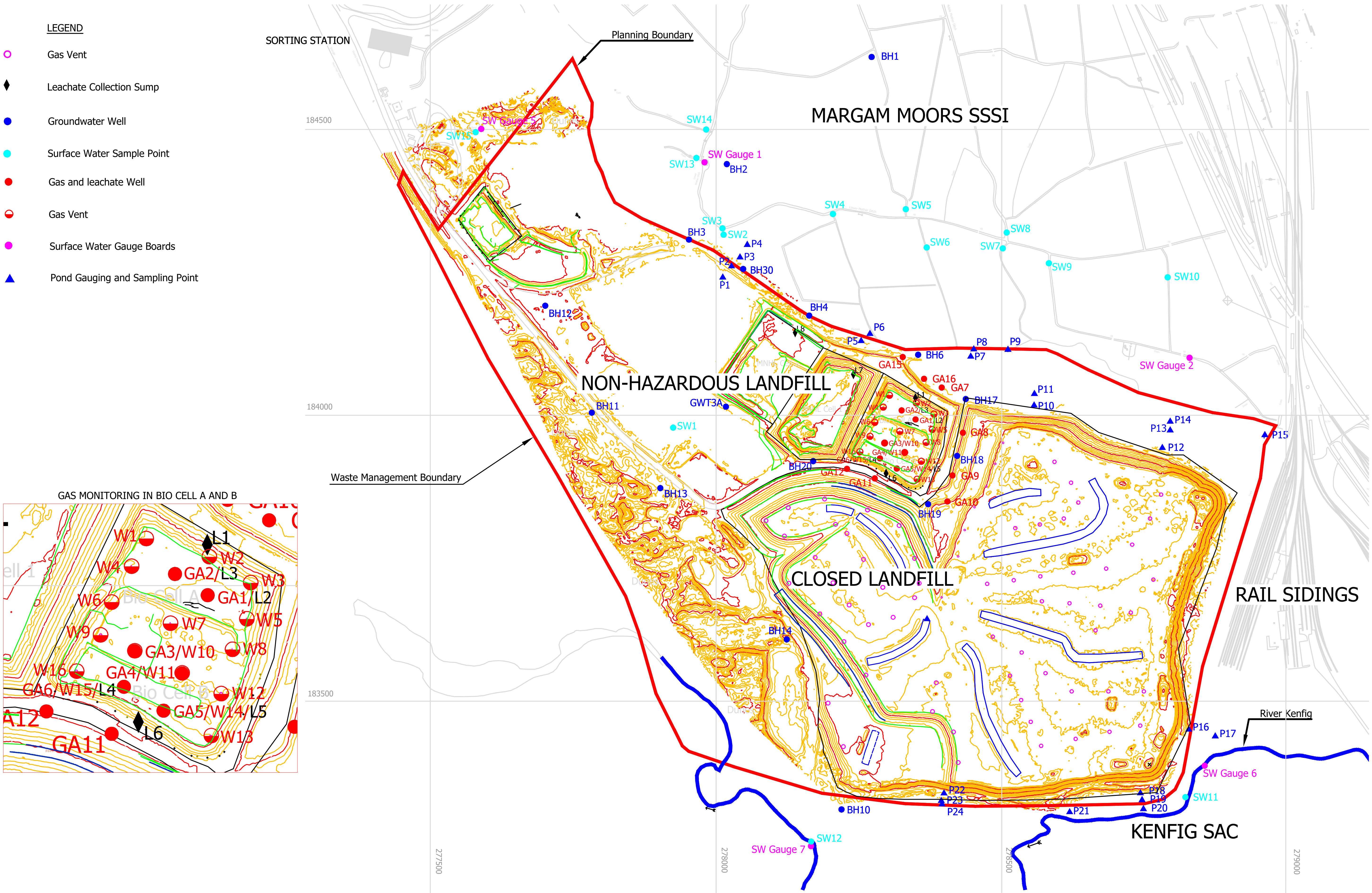
PROJECT: Morfa Hazardous Landfill Review of Hydrogeological Risk Assessment

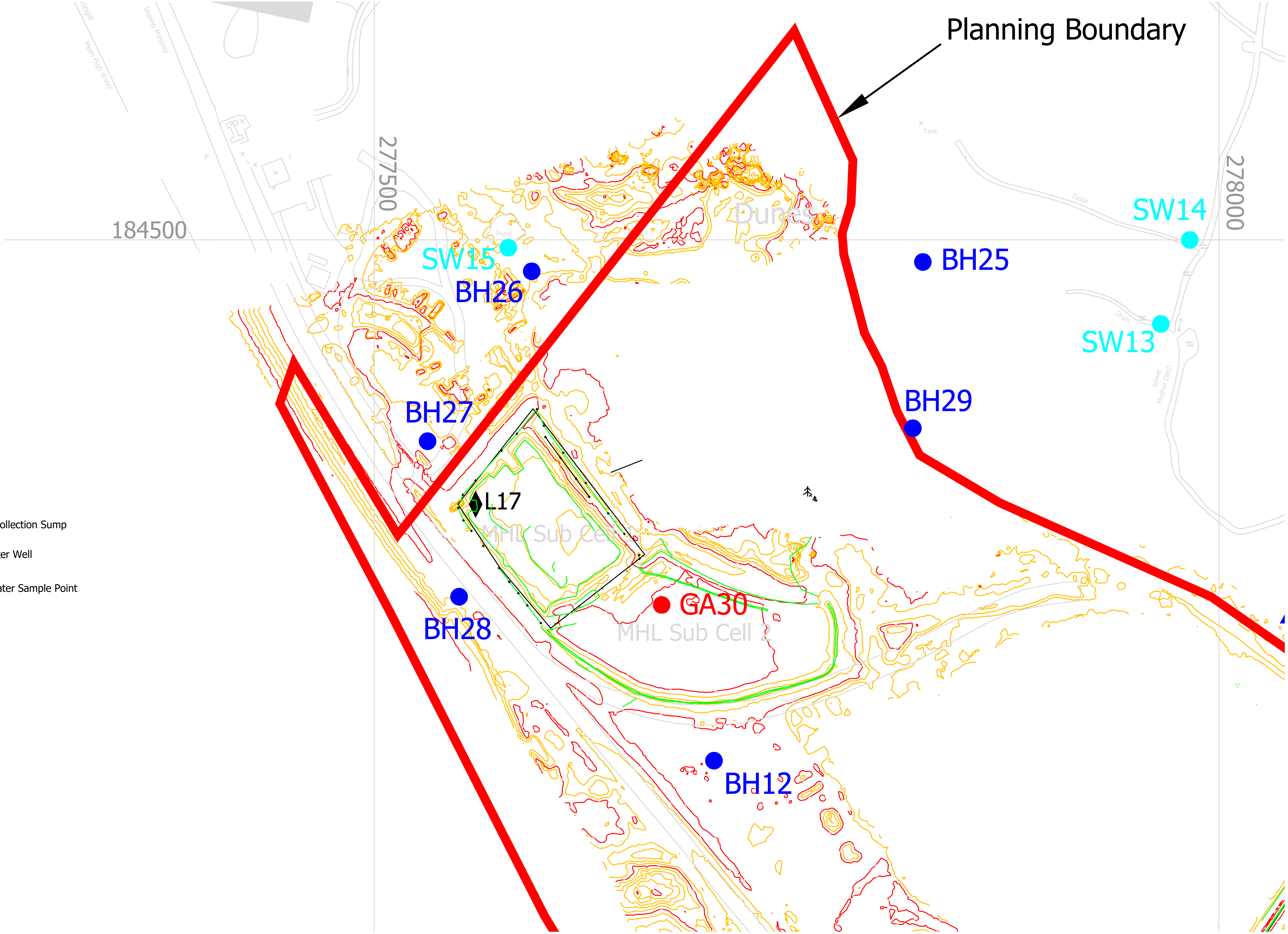
TITLE: LEACHATE PIPE ROUTE

| DRAWING NUMBER | REVISION |
|---|---|
| 2239/5 | 0 |

| SCALE AT A1 | DATE | DRAWN | CHECKED |
|---|---|---|---|
| 1:4000 | 06.22 | AJ/KT | |

Geotechnology
Ty Coed, Cefn-yr-Allt,
Aberdulais, Neath
SA10 8HE
01639 775293
www.geotechnology.net

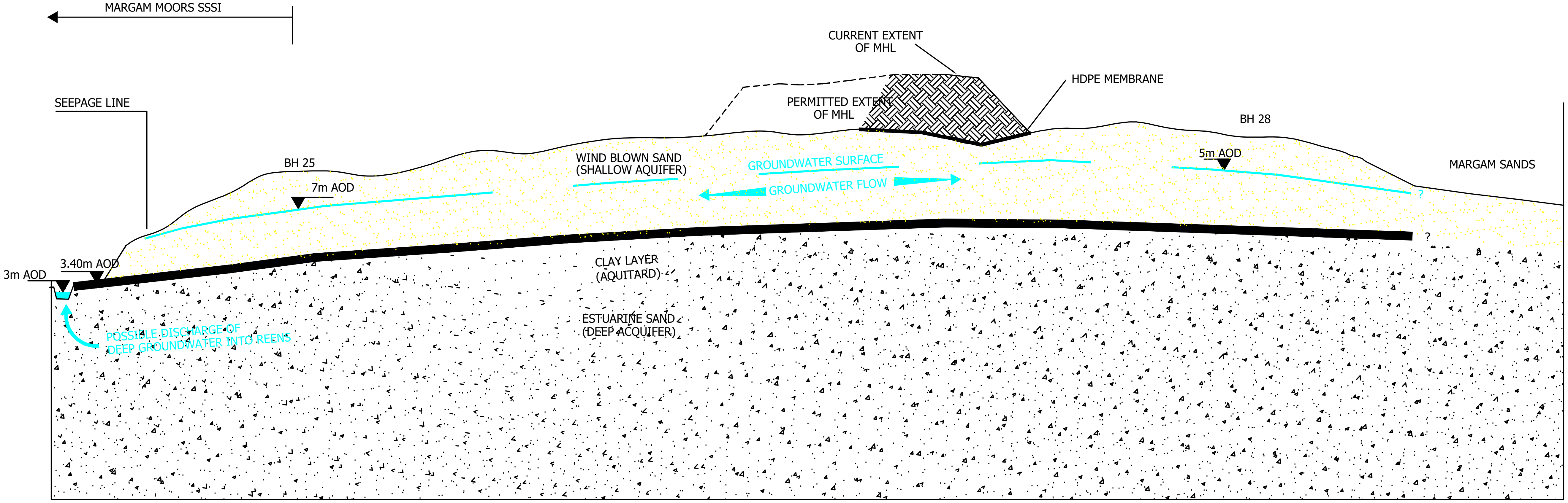

LEGEND
Gas Vent
Leachate Collection Sump
Groundwater Well
Surface Water Sample Point
Gas and leachate Well
Gas Vent
Surface Water Gauge Boards
Pond Gauging and Sampling Point
SORTING STATION
Planning Boundary
MARGAM MOORS SSSI
NON-HAZARDOUS LANDFILL
CLOSED LANDFILL
RAIL SIDINGS
KENFIG SAC
River Kenfig
Waste Management Boundary
GAS MONITORING IN BIO CELL A AND B
184500
184000
183500
277500
278000
278500
279000
BH1
BH2
BH3
BH4
BH6
BH10
BH11
BH12
BH13
BH14
BH17
BH18
BH19
BH20
BH30
GWT3A
SW1
SW2
SW3
SW4
SW5
SW6
SW7
SW8
SW9
SW10
SW11
SW12
SW13
SW14
SW15
SW Gauge 1
SW Gauge 2
SW Gauge 6
SW Gauge 7
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
P16
P17
P18
P19
P20
P21
P22
P23
P24
GA7
GA8
GA9
GA10
GA11
GA12
GA15
GA16
W1
W2
W3
W4
W5
W6
W7
W8
W9
W12
W13
W16
GA1/L2
GA2/L3
GA3/W10
GA4/W11
GA5/W14/L5
GA6/W15/L4
L1
L6
Bio Cell A
Bio Cell B




LEGEND

- Gas Well
- Leachate Collection Sump
- Groundwater Well
- Surface Water Sample Point

## Figure 8  Current Conceptual Hydrogeological Model

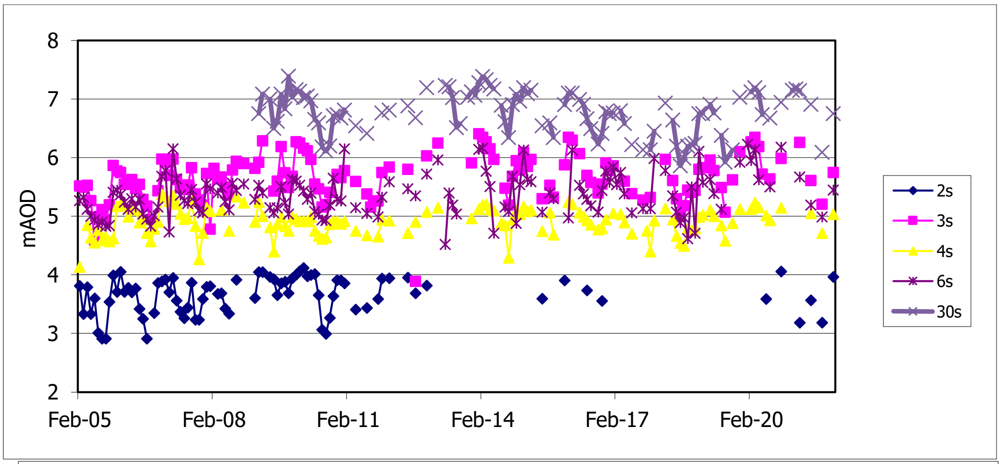


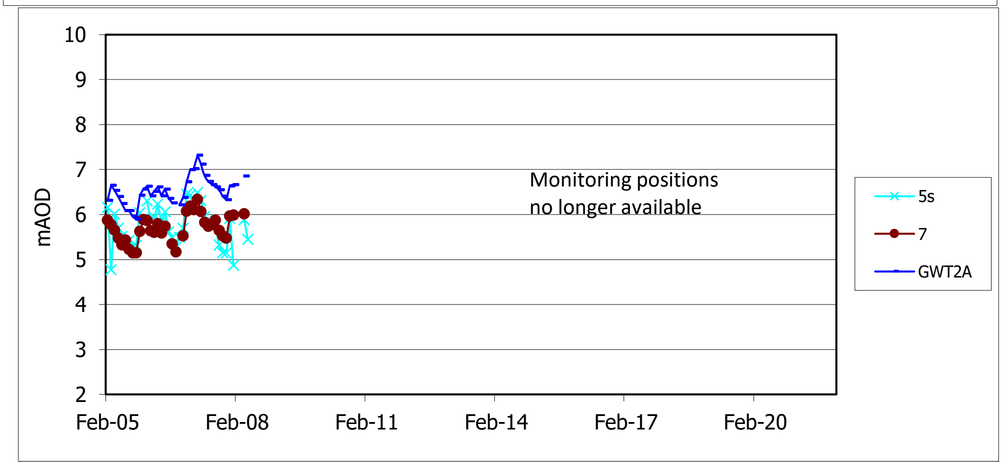
**MORFA HAZARDOUS LANDFILL**
**PORT TALBOT**

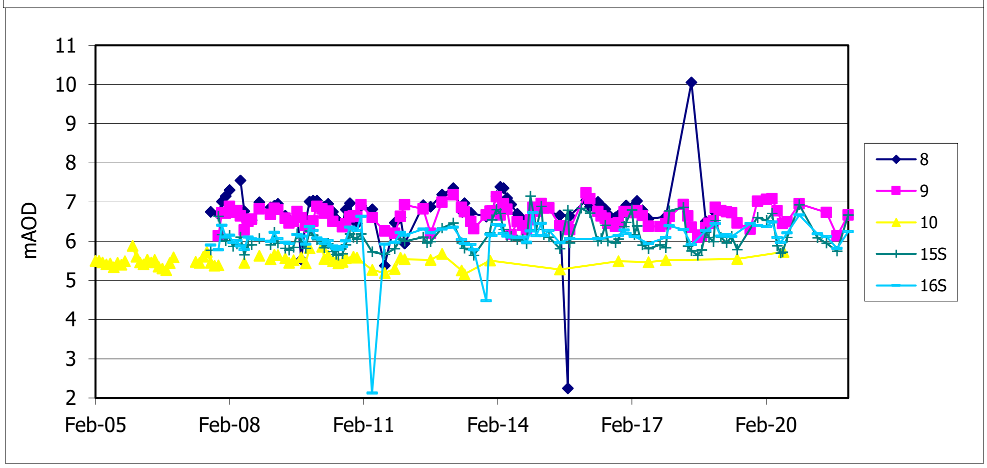
**ENVIRONMENTAL PERMIT BW2692IM**

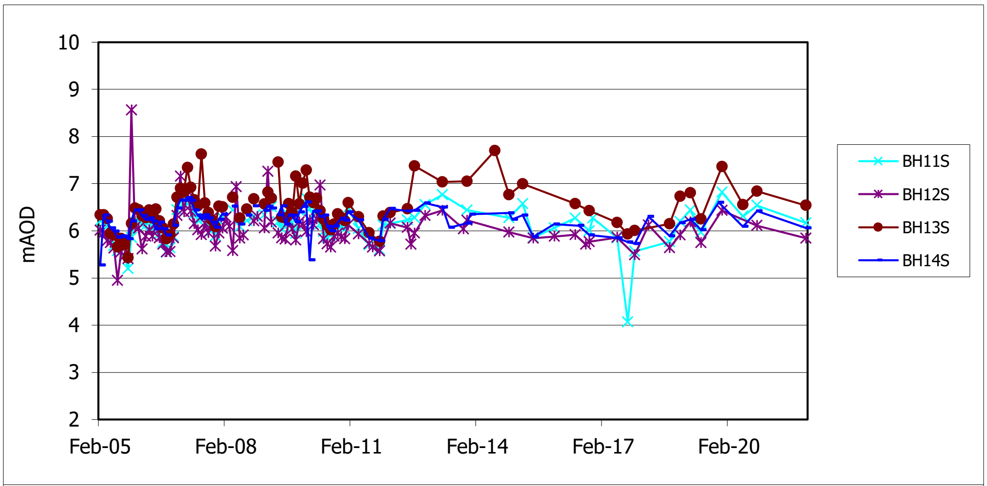
**Review of Hydrogeological Risk Assessment**

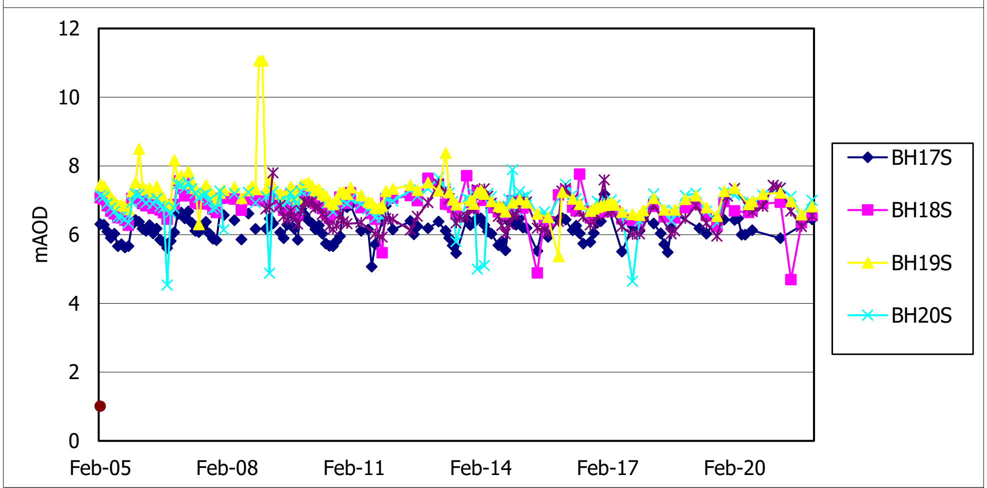
**Appendix 1**
**Groundwater Levels and Contour Plans**
*Report Number 2239r1v1d0622*

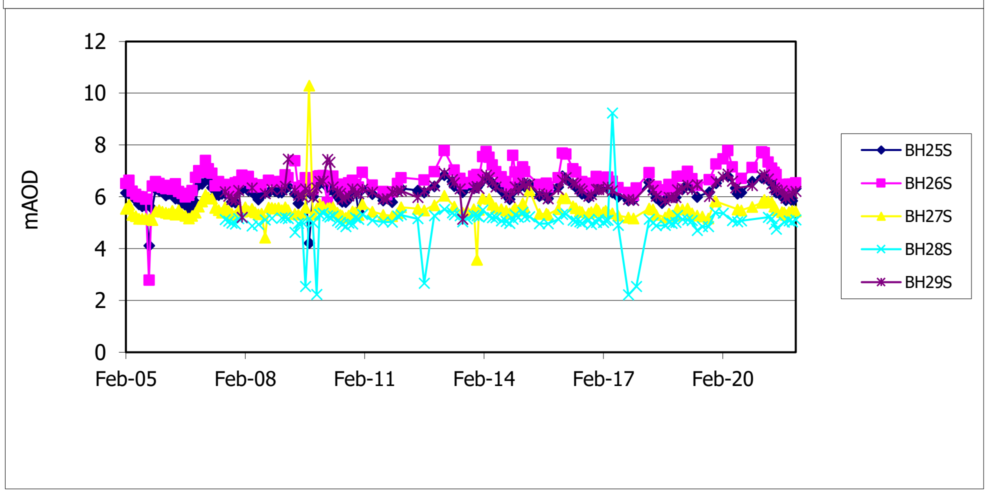

mAOD
8
7
6
5
4
3
2
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
2s
3s
4s
6s
30s

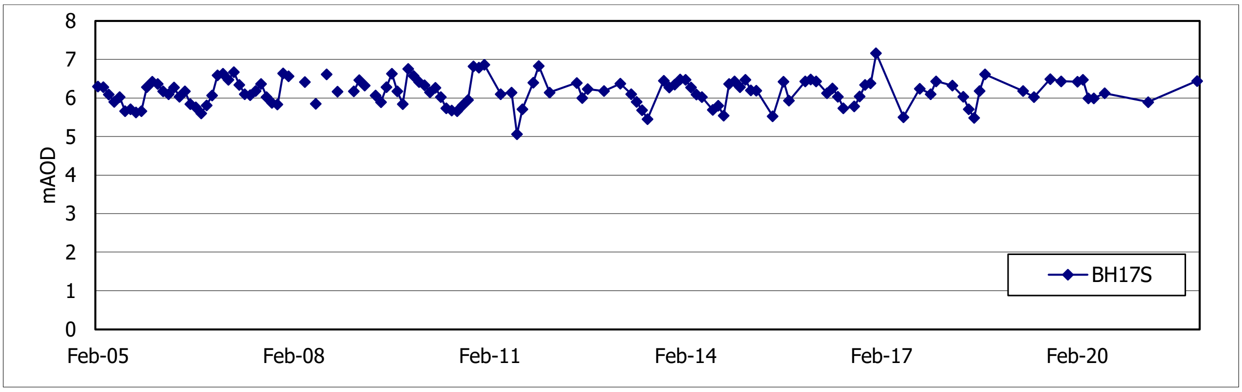

mAOD
10
9
8
7
6
5
4
3
2
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
Monitoring positions
no longer available
5s
7
GWT2A

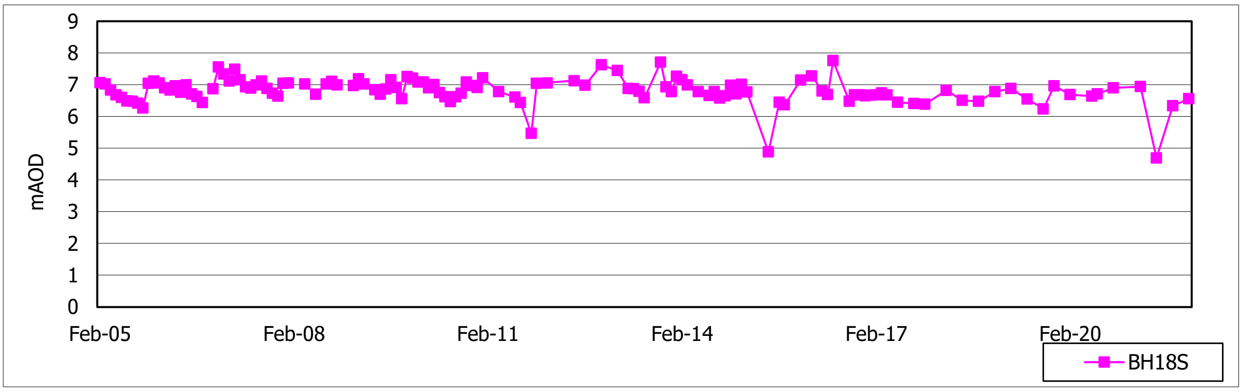

mAOD
11
10
9
8
7
6
5
4
3
2
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
8
9
10
15S
16S

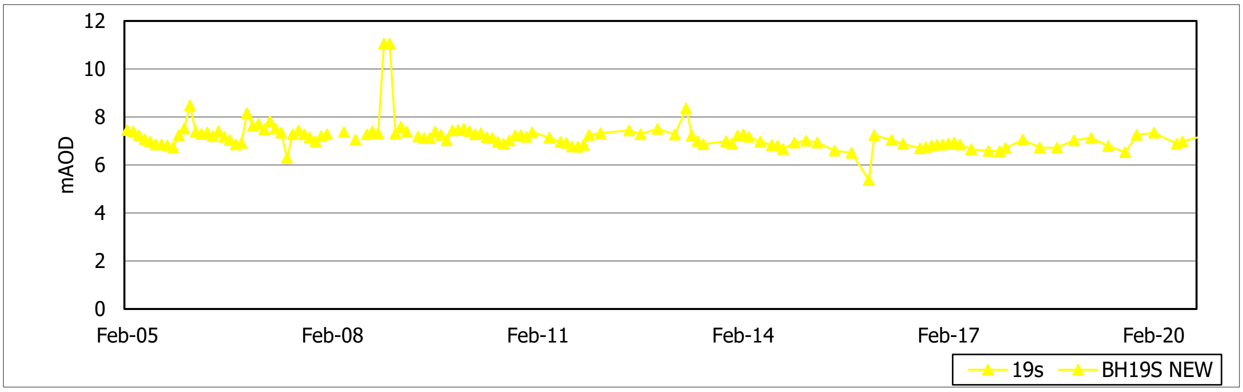

mAOD
10
9
8
7
6
5
4
3
2
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH11S
BH12S
BH13S
BH14S

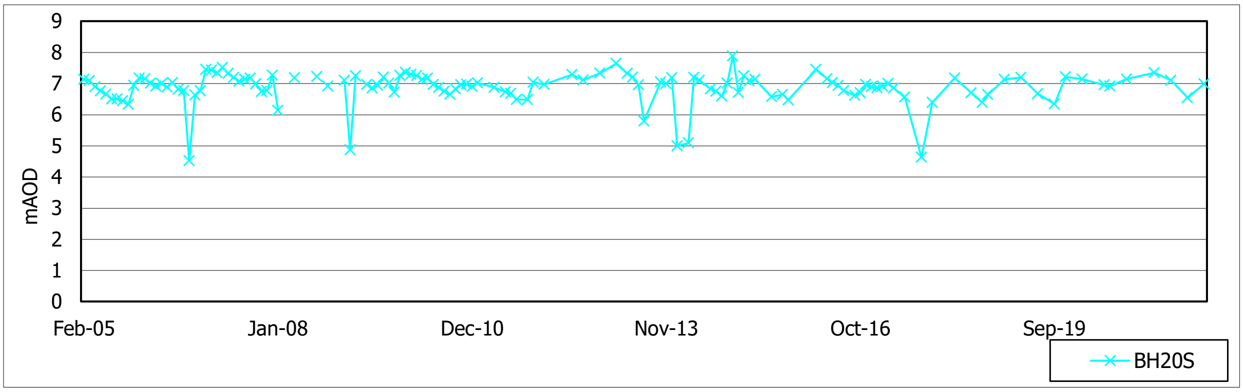

mAOD
12
10
8
6
4
2
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH17S
BH18S
BH19S
BH20S

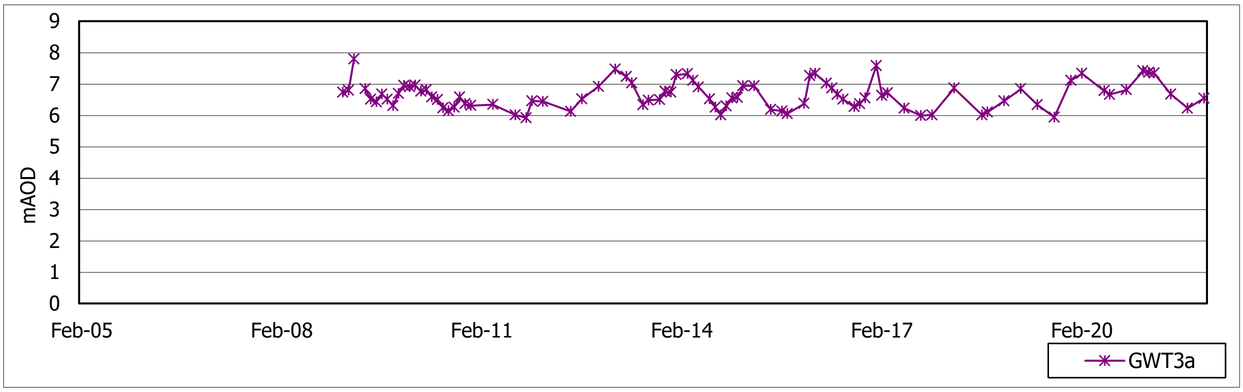

mAOD
12
10
8
6
4
2
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH25S
BH26S
BH27S
BH28S
BH29S

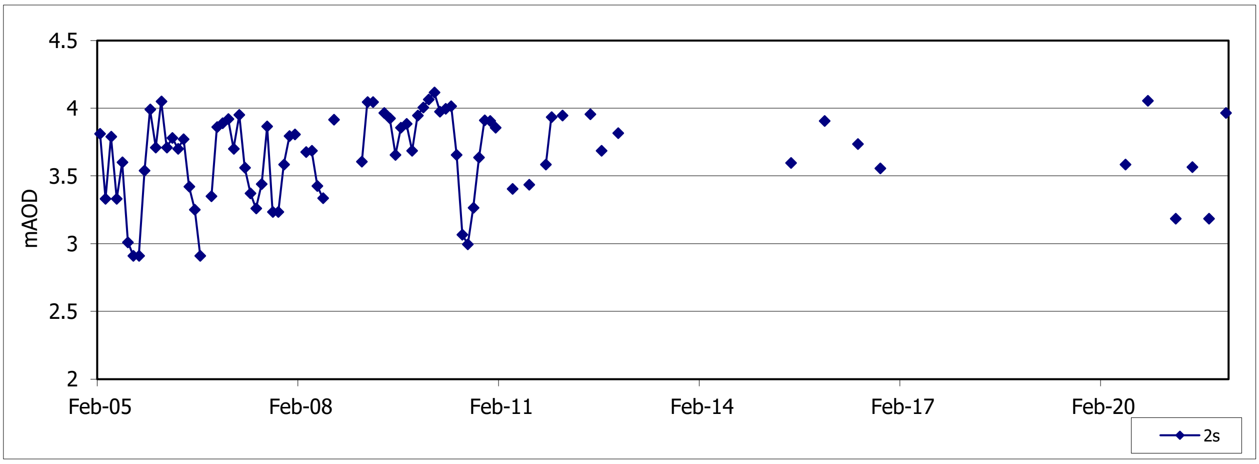

mAOD
8
7
6
5
4
3
2
1
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH17S

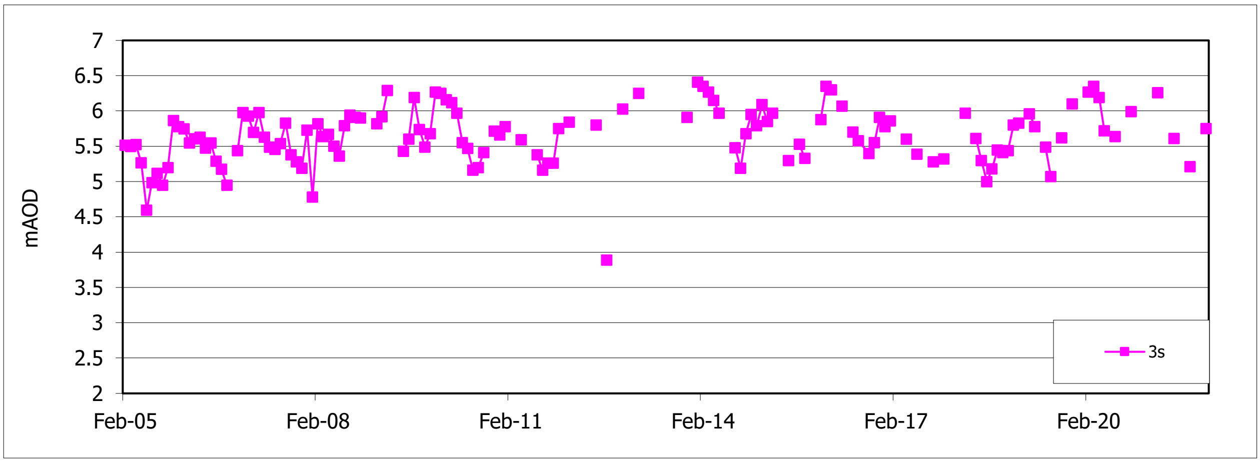

mAOD
9
8
7
6
5
4
3
2
1
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH18S

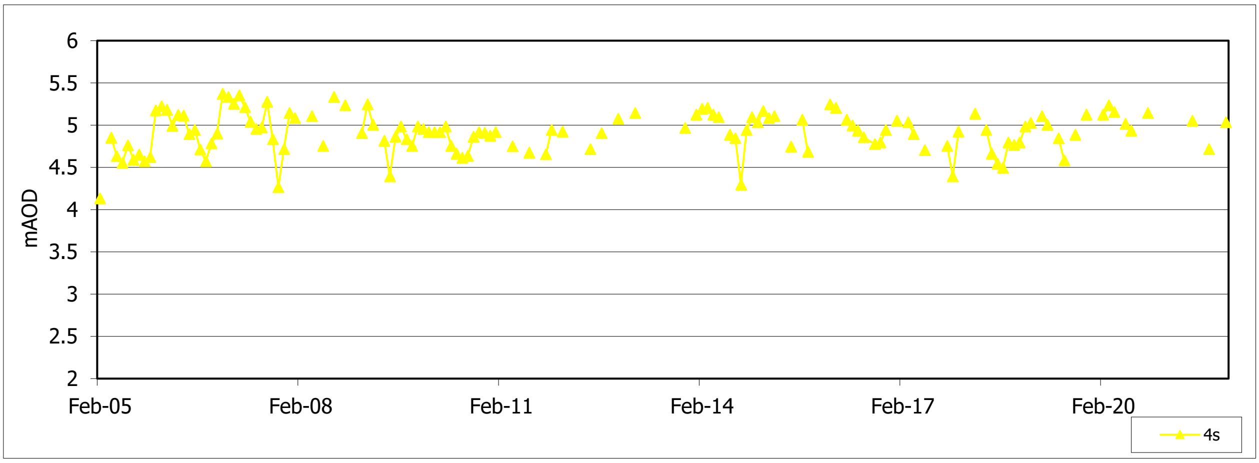

mAOD
12
10
8
6
4
2
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
19s
BH19S NEW

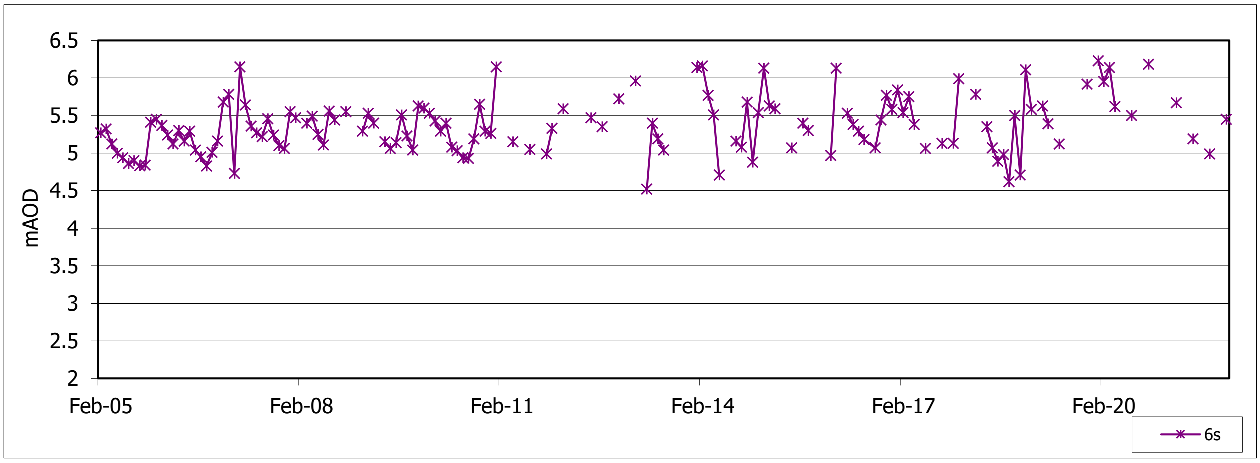

9
8
7
6
5
4
3
2
1
0
mAOD
Feb-05
Jan-08
Dec-10
Nov-13
Oct-16
Sep-19
BH20S

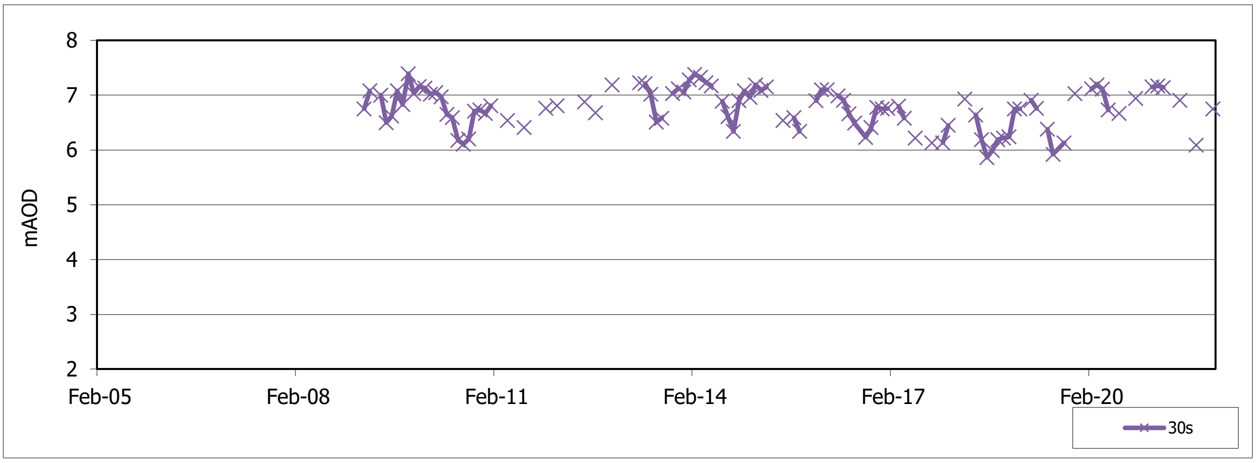

9
8
7
6
5
4
3
2
1
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
GWT3a

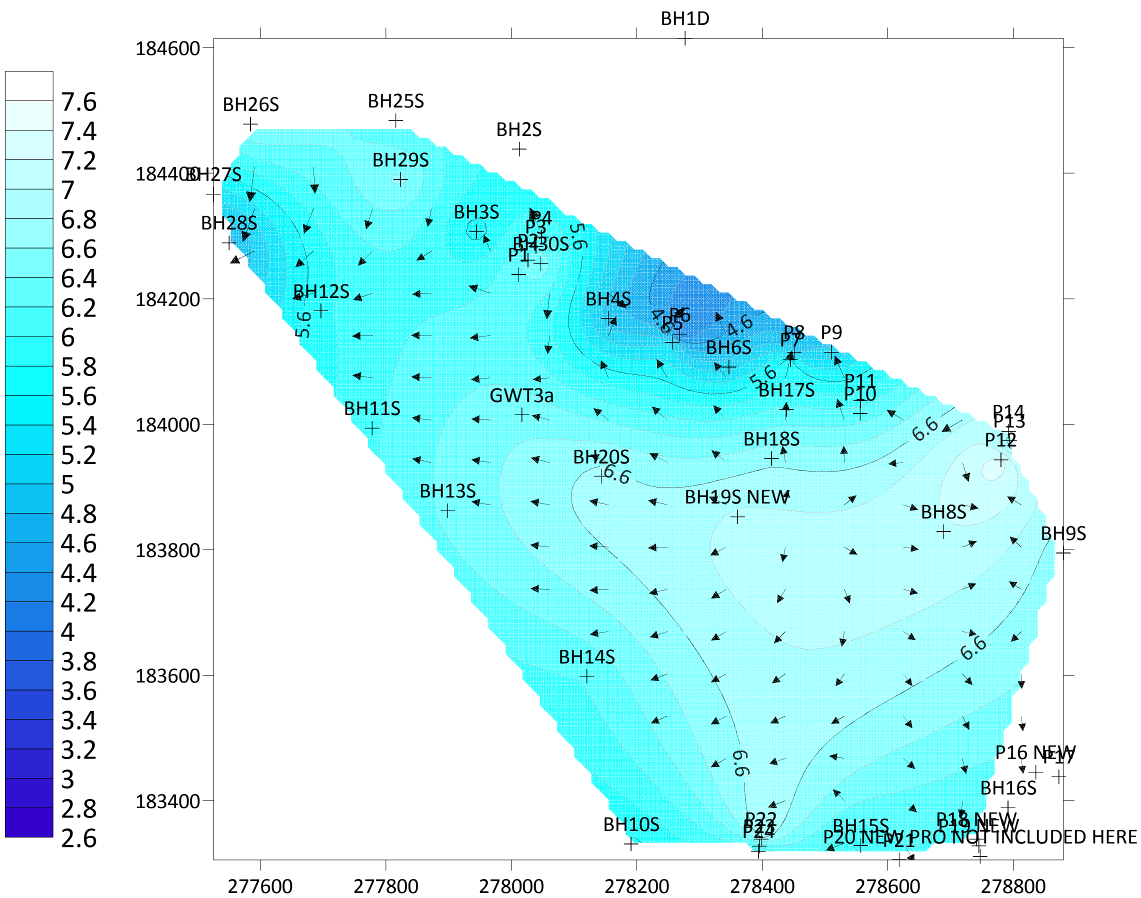

4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
2s


7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
3s


6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
4s

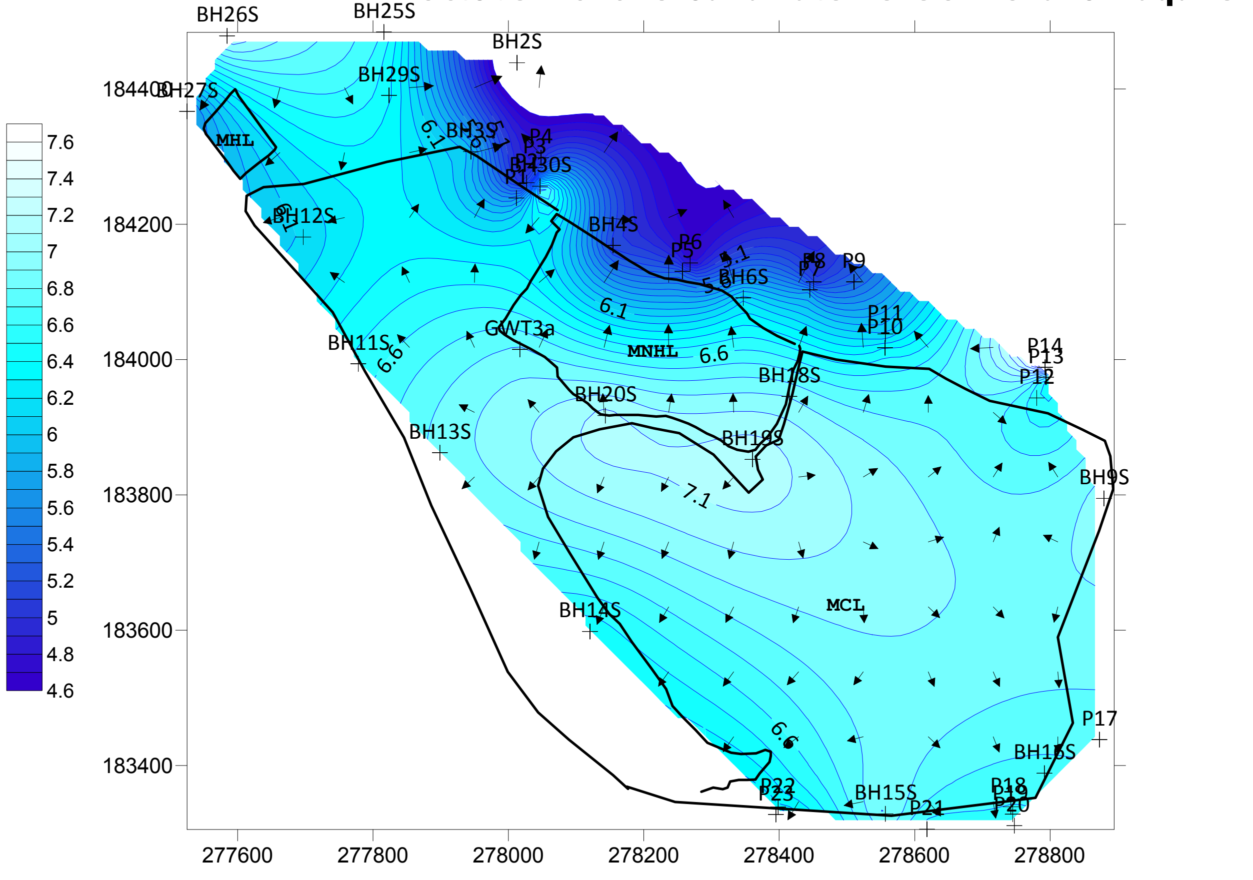

6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
6s

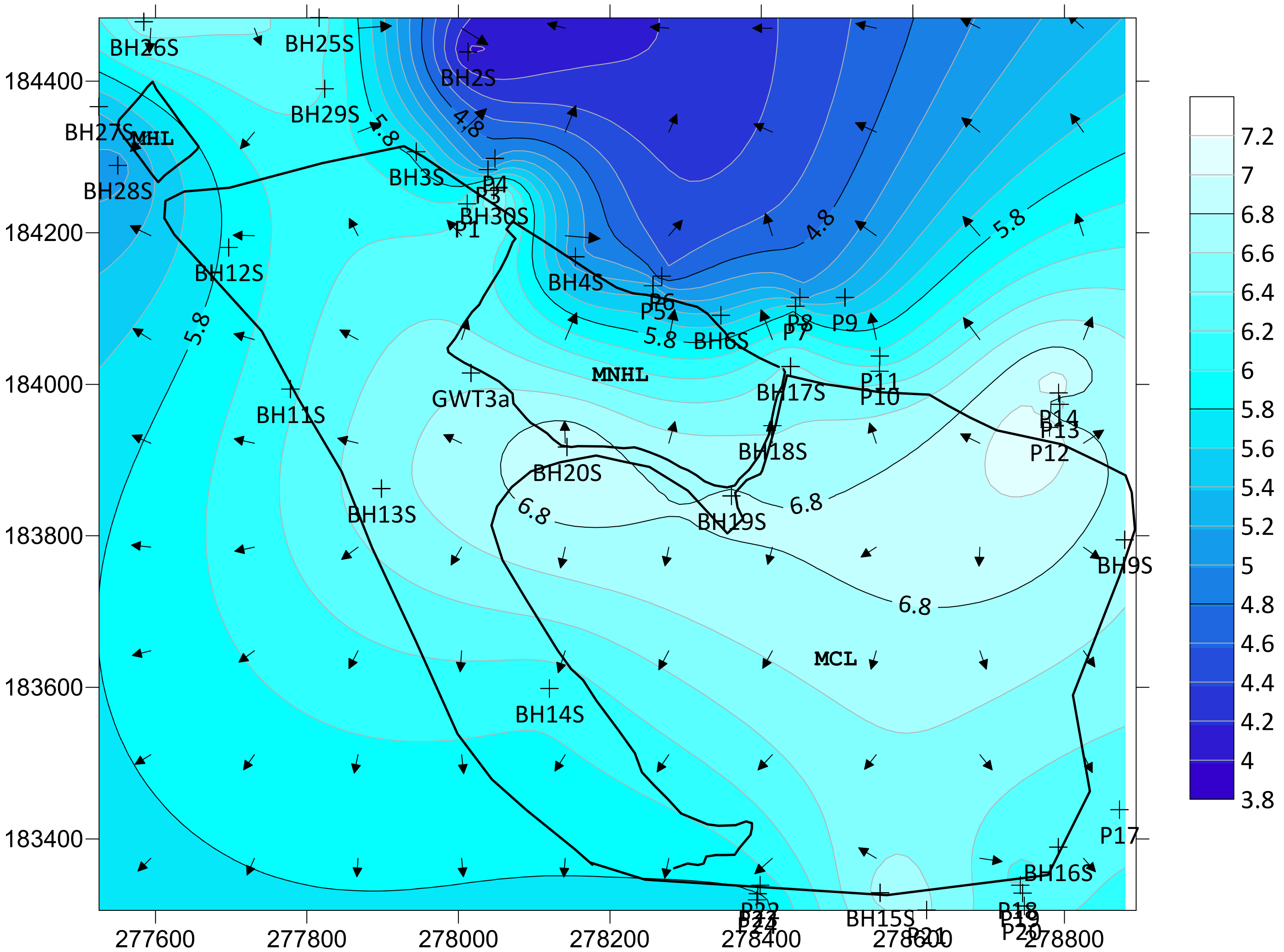

8
7
6
5
4
3
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
30s




**Shallow Groundwater Contours, June 2019**

**October 2020. Groundwater levels in shallow aquifer**






**December 2021. Groundwater levels in shallow aquifer**

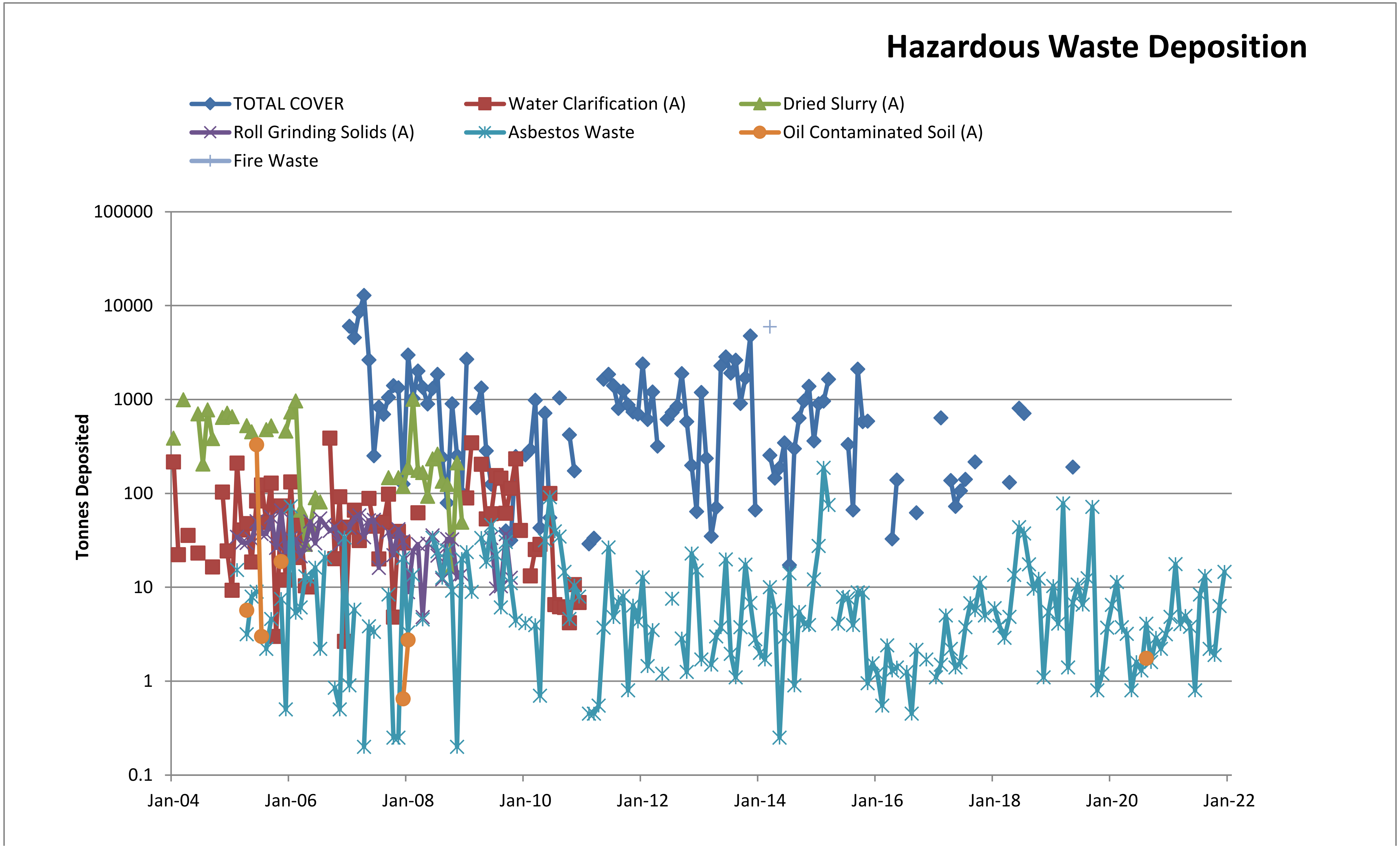
**MORFA HAZARDOUS LANDFILL**
**PORT TALBOT**

**ENVIRONMENTAL PERMIT BW2692IM**

# Review of Hydrogeological Risk Assessment

## Appendix 2
## Graphical Record of Waste Types Landfilled

*Report Number 2239r1v1d0622*

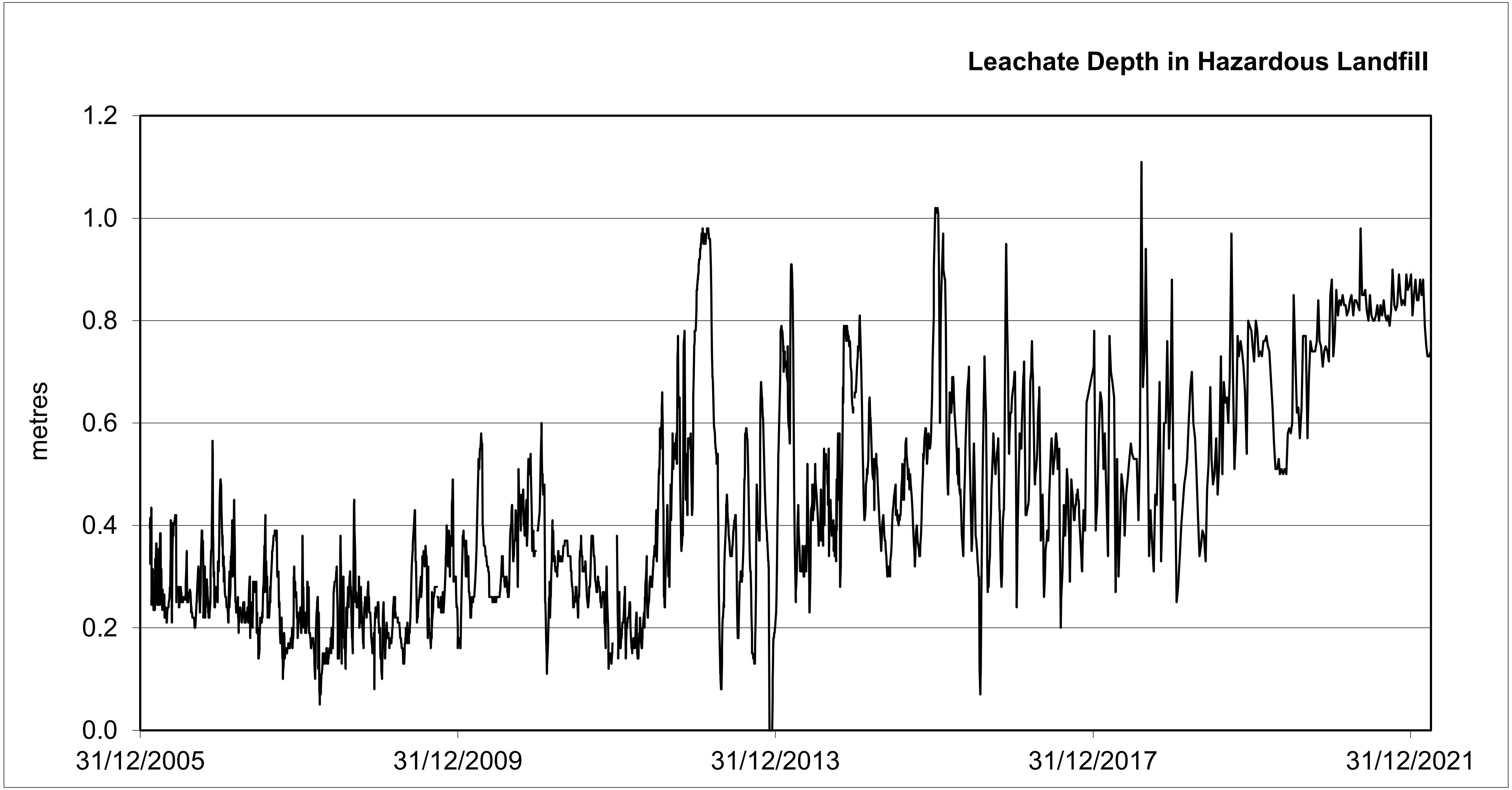

Hazardous Waste Deposition
TOTAL COVER
Water Clarification (A)
Dried Slurry (A)
Roll Grinding Solids (A)
Asbestos Waste
Oil Contaminated Soil (A)
Fire Waste
Tonnes Deposited
100000
10000
1000
100
10
1
0.1
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22

**MORFA HAZARDOUS LANDFILL**
**PORT TALBOT**

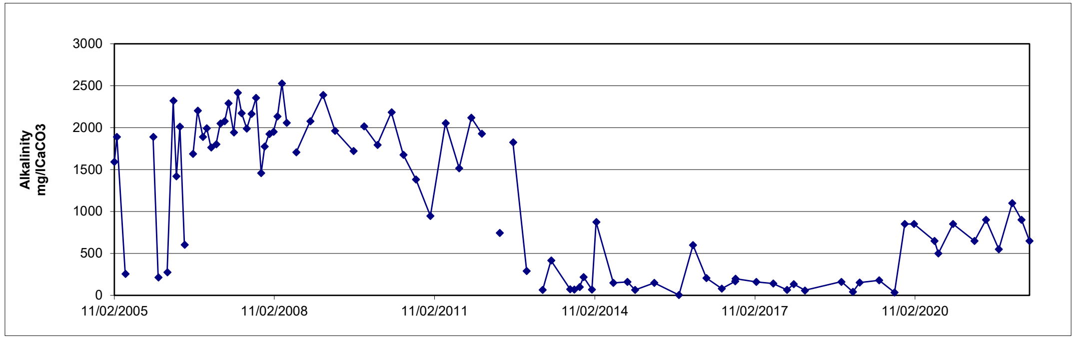
**ENVIRONMENTAL PERMIT BW2692IM**

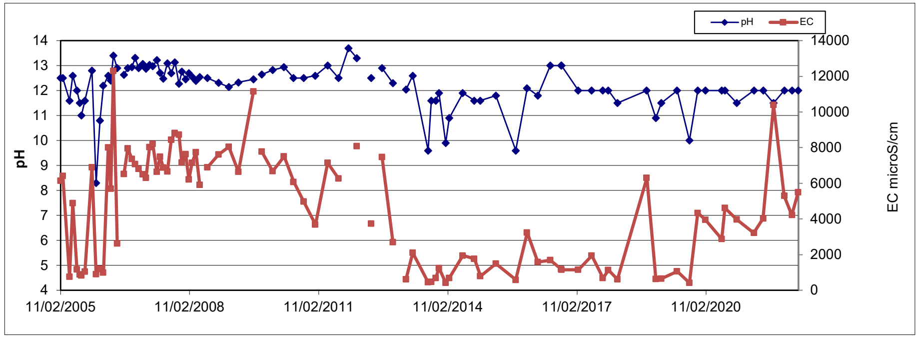
**Review of Hydrogeological Risk Assessment**

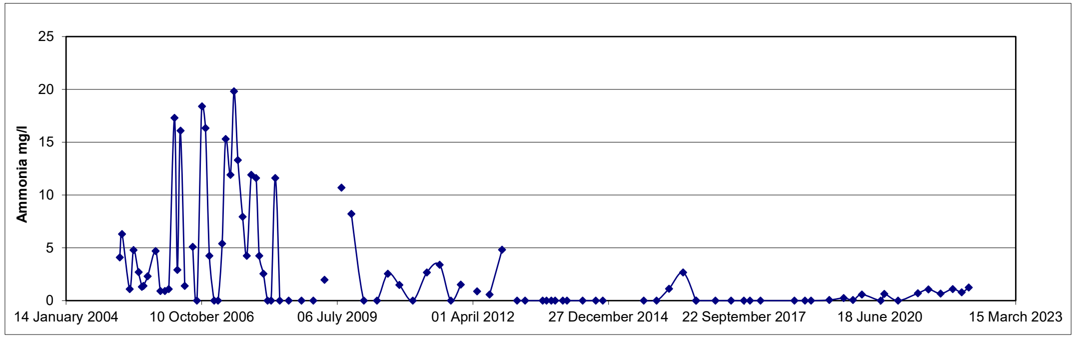
**Appendix 3**
**Leachate Depth and Chemistry in Sump**
*Report Number 2239r1v1d0622*

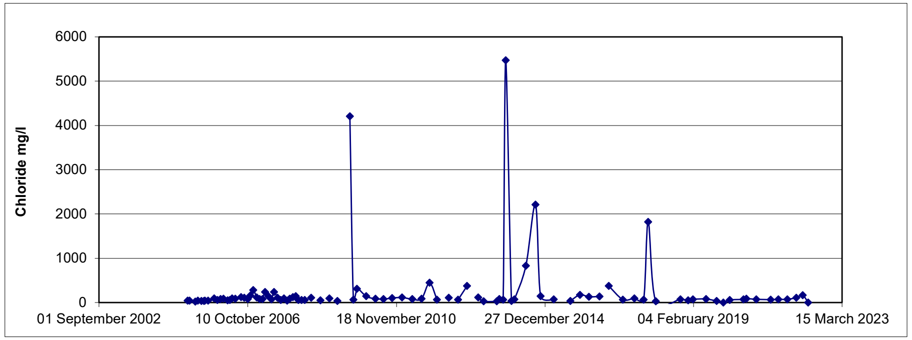


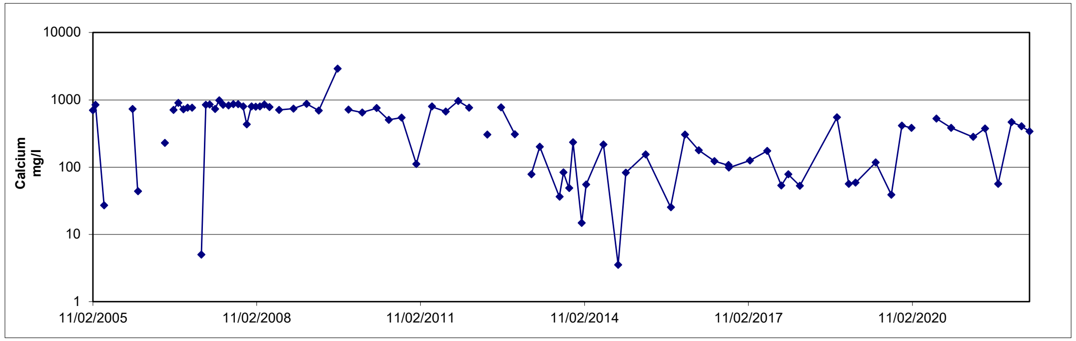
Leachate Depth in Hazardous Landfill
metres
1.2
1.0
0.8
0.6
0.4
0.2
0.0
31/12/2005
31/12/2009
31/12/2013
31/12/2017
31/12/2021

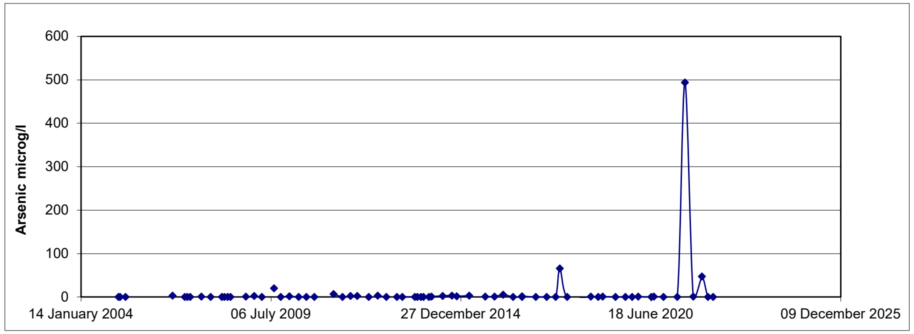

Alkalinity mg/lCaCO3
3000
2500
2000
1500
1000
500
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

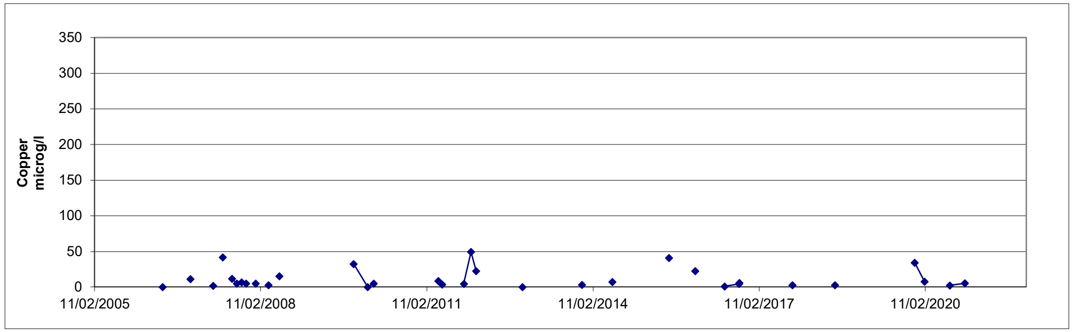

pH
EC
14
13
12
11
10
9
8
7
6
5
4
14000
12000
10000
8000
6000
4000
2000
0
EC microS/cm
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

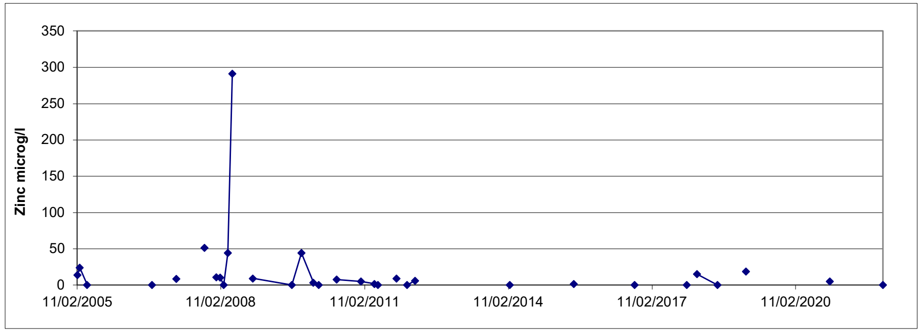

Ammonia mg/l
25
20
15
10
5
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

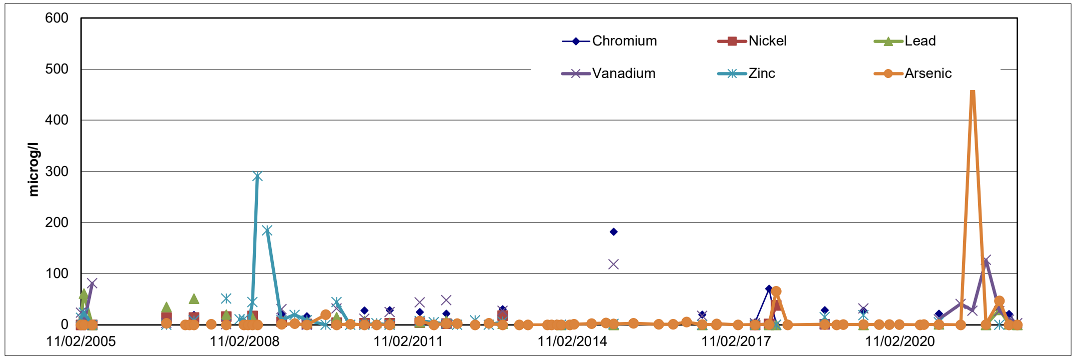

Chloride mg/l
6000
5000
4000
3000
2000
1000
0
01 September 2002
10 October 2006
18 November 2010
27 December 2014
04 February 2019
15 March 2023

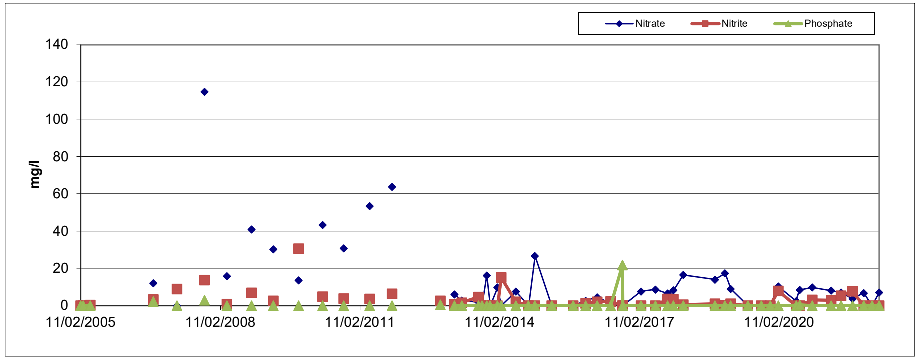

Calcium mg/l
10000
1000
100
10
1
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

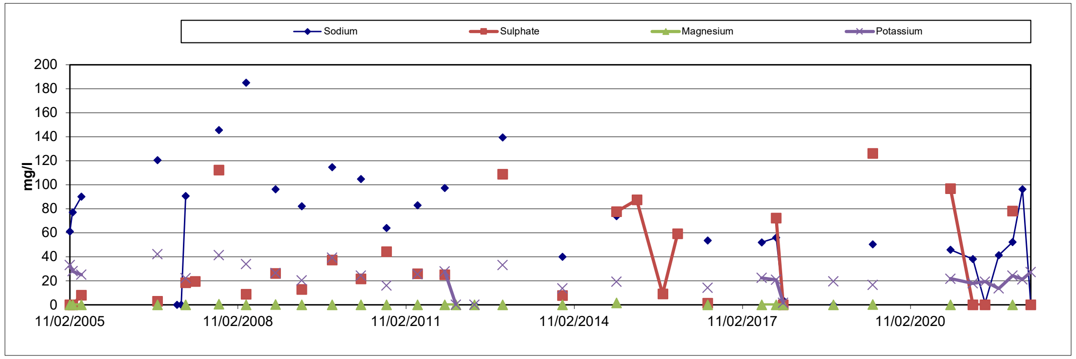

Arsenic microg/l
600
500
400
300
200
100
0
14 January 2004
06 July 2009
27 December 2014
18 June 2020
09 December 2025

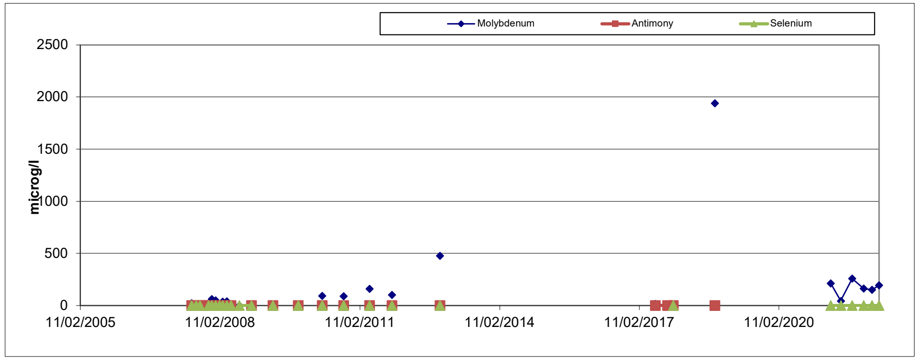

Copper microg/l
350
300
250
200
150
100
50
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Zinc microg/l
350
300
250
200
150
100
50
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


microg/l
Chromium
Nickel
Lead
Vanadium
Zinc
Arsenic
600
500
400
300
200
100
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Nitrate
Nitrite
Phosphate
mg/l
140
120
100
80
60
40
20
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Sodium
Sulphate
Magnesium
Potassium
mg/l
200
180
160
140
120
100
80
60
40
20
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Molybdenum
Antimony
Selenium
microg/l
2500
2000
1500
1000
500
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

**MORFA HAZARDOUS LANDFILL**
**PORT TALBOT**

**ENVIRONMENTAL PERMIT BW2692IM**

**Review of Hydrogeological Risk Assessment**

# Appendix 4
# Review of LandSim 2.5 Input Parameters

*Report Number 2239r1v1d0622*

**LandSim Information**

| Project Information | Base Model Information | | | | Modification to Base Model (HRA Review 2 2012) | Justification | Modification to Base Model (HRA Review 2017) | Justification | Modification to Base Model (HRA Review 2022) | Justification |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Customer** | Corus UK Ltd | | | Tata Steel UK Ltd | | No change | | No change | |
| | **Project** | Morfa Hazardous Landfill | | | No change | | No change | | No change | |
| | **Geotechnology job number** | 403 | | | 1178 | | 1740 | | 2239 | |
| | Notes | Full simulation including declining source term with retardation. Simulation carried out to evaluate emission of pollutants using LandSim 2.5 in the recommended way. The original HRA simulations included several runs of LandSim 2 in order to determine emission time history. Management control is taken conservatively as 60yrs post-closure, representing the financial provision made available. This simulation is carried out after construction of the first Cells with the benefit of a 12 month monitoring period for gw and leachate. The construction records have allowed the design to be quantified accurately and the monitoring data has allowed a better understanding of leachate chemistry. This simulation takes a conservative approach in order to specify the source term, with 1.5 times the max recorded concentrations as a max and the recorded max as a most likely. The loss of management control is specified conservatively as 60yrs post closure (63 yrs after closure) as this represents the available Financial Provision. | | | Full simulation including declining source term without retardation. Simulation carried out to evaluate emission of pollutants using LandSim 2.5 in the recommended way as part of four year HRA Review. This simulation is carried out after construction of Cell 1 and Cell 2. The construction records have allowed the design to be quantified accurately and the monitoring data has allowed a better understanding of leachate chemistry. This simulation uses actual leachate chemistry. The loss of management control is specified conservatively as 60yrs post closure (63 yrs after closure) as this represents the available Financial Provision. | | No change | | No change | |
| **Timescale** | 30/100/300/1000 | | | | No change | | No change | | No change | |
| **Phase** | | | | | | | | | | |
| | Name | Morfa Harzardous Landfill | | | No change | | No change | | No change | |
| | | | y | | | | | | | |
| | Location | 900 | 1000 | | No change | | No change | | No change | |
| | Length | 60 | 100 | | No change | | No change | | No change | |
| | Time Offset | 0 | | | No change | | No change | | No change | |
| | Duration of Management Control | 63 | | | No change | | No change | | No change | |
| **Receptor** | | | | | | | | | | |
| | Name | spring | | | | | | | | |
| | | x | y | | | | | | | |
| | Location | 1040 | 1000 | | No change | | No change | | No change | |
| **Preferences** | | | | | | | | | | |
| **Use Expected Values Only** | No | | | | No change | | | | | |
| | Mineral Liner | Unsaturated Pathway | Vertical Pathway | Aquifer Pathway | | | | | | |
| **Unretarded Contaminant Transport** | N | No | No | No | Unretarded | | No change | | No change | |
| **Biodegradation** | No | No | No | No | No change | | No change | | No change | |
| **Maximum number of trials** | 1001 | | | | No change | | No change | | No change | |

| LandSim Information | Base Model Information | | Modification to Base Model (HRA Review 2 2012) | Justification | Modification to Base Model (HRA Review 3 2017) | Justification | Modification to Base Model (HRA Review 2022) | Justification |
|---|---|---|---|---|---|---|---|---|
| Infiltration | Infiltration Open to Waste (mm/yr) | Triangular (744, 981, 1218) | No change | | Triangular PDF (1000, 1200, 1600) | Based on rainfall records | No change | |
| | Cap Design Infiltration (mm/yr) | Triangular (15, 20, 25) | No change | | Triangular (20, 24, 32) | Based on 0.02 of infiltration | No change | |
| | End of Filling (years from start of waste disposal) | 4 | No change | | No change | | No change | |
| | PE Cap | Yes | No change | | No change | | No change | |
| | Infiltration to Grassland (mm/yr) | Single (200) | No change | | No change | | No change | |
| | Start of cap degradation (years from end of waste disposal) | 250 | No change | | No change | | No change | |
| | End of cap degradation (years from end of waste disposal) | 1000 | No change | | No change | | No change | |

| LandSim Information | Base Model Information | | | Modification to Base Model (HRA Review 2 2012) | Justification | Modification to Base Model (HRA Review 3 2017) | Justification | Modification to Base Model (HRA Review 4 2022) | Justification |
|---|---|---|---|---|---|---|---|---|---|
| Cell Geometry | Cell Width at Base(m) | 100 | | No change | | No change | | No change | |
| | Cell Length at base (m) | 60 | | No change | | No change | | No change | |
| | Number of cells all the same | 1 | | No change | | No change | | No change | |
| | Each cell (Ha) | Base Area 0.6 | Top area 0.62 | No change | | No change | | No change | |
| | Landfill area (Ha) | Base Area 0.6 | Top area 0.62 | No change | | No change | | No change | |
| | Final Waste Thickness (m) | Single (8) | | No change | | No change | | No change | |
| | Waste Porosity (Fraction) | Single (0.35) | | No change | | No change | | No change | |
| | Waste density (kg/l) | Single (1.8) | | No change | | No change | | No change | |
| | Waste Field Capacity (fraction) | Single (0.1) | | No change | | No change | | No change | |
| | Head of leachate when surface water breakout occurs (m) | Single (4) | | No change | | No change | | No change | |

**Model:** **mnhlcell1Dec2005.sim**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Use Declining Source Term | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Species | Ammoniacal_N | Arsenic | Cadmium | Chloride | Copper | Zinc | Alkalinity |
| | Species concentration in leachate (mg/l) | Triangular (27.1, 44.7, 67) | Triangular (0.337, 0.576, 0.864) | Triangular (0.0016, 0.0053, 0.008) | Triangular (1180, 1770, 2655) | Triangular (0.016, 0.054, 0.081) | Triangular (0.054, 0.128, 0.192) | Triangular (1590, 2260, 2835) |
| | Kappa value constant m (mg/l) | 0 | 0.0415 | 0.0823 | 0.0298 | 0.0664 | 0.0403 | 0 |
| | Kappa value constant c (mg/l) | 0.59 | -0.086 | 0.1589 | 0.2919 | -0.048 | 0.0561 | 0.04 |
| | Data are spot measurements of leachate quality | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Substance to be treated as list 1 | No | No | Yes | No | No | No | No |

**Model:** **mnhlSept2009.sim**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Use Declining Source Term | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Species | Ammonia | Arsenic | Cadmium | Chloride | Copper | Zinc | Alkalinity |
| | | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l CaCO3 |
| Species concentration in leachate (mg/l) | Minimum | 4.69 | 1.13E-02 | 6.89E-04 | 98.10 | 0.04 | 0.04 | 1781.33 |
| | Most Likely | 141.00 | 0.20 | 1.00E-03 | 392.00 | 1.43 | 1.00 | 2525.00 |
| | Maximum | 211.50 | 0.30 | 1.50E-03 | 588.00 | 2.15 | 1.49 | 3787.50 |
| | Kappa value constant m (mg/l) | 0 | 0.0415 | 0.0823 | 0.0298 | 0.0664 | 0.0403 | 0 |
| | Kappa value constant c (mg/l) | 0.59 | -0.086 | 0.1589 | 0.2919 | -0.048 | 0.0561 | 0.04 |
| | Data are spot measurements of leachate quality | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Substance to be treated as list 1 | No | No | Yes | No | No | No | No |
| | PDF | Triangular | Triangular | Triangular | Triangular | Triangular | Triangular | Log Triangular |
| | DATA SOURCE | BH29D | BH25S | BH26S | BH28D | bh28s | BH28L | L17 |

**Model:** **MHL HRA REVIEW 2 AUG 2012**

| | Ammonia | Arsenic | Chloride |
|---|---|---|---|
| | mg/l | mg/l | mg/l |
| Minimum Value | 0.05 | 0.005 | 1000 |
| Most Likely Value | 10 | 0.3 | 10000 |
| Maximum Value | 50 | 3 | 61000 |
| PDF Used | Triangular | Triangular | Log Triangular |

| HRA Review 2017 |
|---|
| No change to leachate inventory |

| HRA Review 2022 |
|---|
| No change to leachate inventory |

| **LandSim Information** | **Base Model Information** | | | | **Modification to Base Model (HRA Review 2 2012)** | **Justification** | **Modification to Base Model (HRA Review 3 2017)** | **Justification** | **Modification to Base Model (HRA Review 4 2022)** | **Justification** |
|---|---|---|---|---|---|---|---|---|---|---|
| Drainage System | Specified Head | Yes | | | Yes | | No change | | No change | |
| | Head on EBS (m) | Single (1.0) | | | TRIANGULAR(0.1,0.3,0.6) | Leachate monitoring results adopted | Triangular (0.3, 0.6, 1.0) | Based on leachate monitoring | No change | |
| Engineered Barrier | Composite EBS | Yes | | | Yes | | No change | | No change | |
| | Properties | | | | | | | | | |
| | Construction includes a CQA system | Yes | | | Yes | | No change | | No change | |
| | Defects/hectare as waste is placed (triangular distribution) | Min | Most likely | Max | | | | | | |
| | Pinholes (0.1-5mm2) | 0 | | 25 | No change | | No change | | No change | |
| | Holes (5-100mm2) | 0 | | 5 | | | No change | | No change | |
| | Tears (100-10,000mm2) | 0 | 0.1 | 2 | | | No change | | No change | |
| | | | | | | | | | | |
| | Onset of FML degradation (years since filling commenced) | 150 | | | No change | | No change | | No change | |
| | Time for area of defects to double (years) | 100 | | | No change | | No change | | No change | |
| | | | | | | | | | | |
| | Clay or BES Substrate | | | | | | | | | |
| | Design thickness of mineral liner (m) | Single (0.85) | | | No change | | No change | | No change | |
| | Moisture content (fraction) | Uniform (0.06, 0.1) | | | No change | | No change | | No change | |
| | Hydraulic Conductivity (m/s) | Normal (7.76E-11, 1.7E-11) | | | TRIANGULAR(~Min = 1.1e-011, Most likely = 6.5e-011,Max = 9.5e-011) | Modification based on measured hydraulic conductivity values from CQA monitoring of landfill construction to date. See Geotechnology report 712. | No change | | No change | |
| | Longitudinal Dispersivity (m) | Single (0.1) | | | | | No change | | No change | |

| LandSim Information | Base Model Information | | Modification to Base Model (HRA Review 2 2012) | Justification | Modification to Base Model (HRA Review 3 2017) | Justification | Modification to Base Model (HRA Review 4 2022) | Justification |
|---|---|---|---|---|---|---|---|---|
| Unsaturated Pathway | Geological unit | Wind Blown Sand | No change | | No change | | No change | |
| | Flow model | Porous medium | No change | | No change | | No change | |
| | Pathway length (m) | Triangular (2.6, 3.41, 4.1) | No change | | No change | | No change | |
| | Moisture Content (fraction) | Uniform (0.1, 0.12) | No change | | No change | | No change | |
| | Conductivity (m/s) | Uniform (2.4E-5, 0.0017) | No change | | No change | | No change | |
| | | | | | | | | |
| Vertical Flow | Included in simulation | No | No change | | No change | | No change | |
| | | | | | | | | |
| Aquifer Flow | Geological Unit | Wind Blown Sand | No change | | No change | | No change | |
| | Pathway width (m) | Single (110) | No change | | No change | | No change | |
| | Mixing zone thickness(m) | Single (2.5) | No change | | No change | | No change | |
| | Conductivity (m/s) | Uniform (2.4E-5, 0.0017) | No change | | No change | | No change | |
| | Regional Gradient (-) | Single (0.01) | No change | | No change | | No change | |
| | Pathway porosity (fraction) | Single (0.3) | No change | | No change | | No change | |
| | Dispersion | | | | | | | |
| | Longitudinal dispersivity (m) | Uniform (11,17) | No change | | No change | | No change | |
| | Transverse dispersivity (m) | Uniform (0.33,0.51) | No change | | No change | | No change | |

**MORFA HAZARDOUS LANDFILL**
**PORT TALBOT**

**ENVIRONMENTAL PERMIT BW2692IM**

**Review of Hydrogeological Risk Assessment**

**Appendix 5**
**Digital Copy of LandSim 2.5 Model and Results**
*Report Number 2239r1v1d0622*

Geotechnical &
Environmental Services

Ty Coed
Cefn-yr-Allt
Aberdulais
Neath SA10 8HE

**T** 01639 775293
**F** 01639 779173

enquiries@geotechnology.net
www.geotechnology.net