LLANWERN EAST
WASTE
MANAGEMENT SITE
LANDFILL
CORUS WORKS
LLANWERN

APPENDIX 1
HYDROGEOLOGICAL RISK ASSESSMENT

Report Number 525.1/Appendix 2/0207

LLANWERN EAST WASTE MANAGEMENT SITE LANDFILL CORUS WORKS LLANWERN

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Report Number 525.1/Appendix 1/0207

Commissioned by

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1 INTRODUCTION

This hydrogeological risk assessment (HRA) forms part of the documentation supporting the closure of Llanwern Eastern Waste Management Site (LEWMS).

A detailed HRA was previously presented by Geotechnology in support of the PPC Application to continue waste disposal at the landfill (see Geotechnology report 294.1 December 2003). The simulations presented in the assessment were later revised and updated in response to issues raised in a Schedule 4 Notice from the Environment Agency (see Geotechnology reports 360.1 March 2005 and 360.2 April 2005). Therefore, the HRA presented in this closure report provides only a summary of these previous reports and the reader is referred to these earlier reports for further background information and detail. Reference is made in this report to appendices previously presented to avoid additional reprographics.

The Groundwater Regulations 1998 forbid the discharge of certain substances into groundwater and requires discharges of potentially polluting substances to be controlled to a degree that they will have an acceptably low environmental impact. This risk assessment evaluates the risk that the site presents to local ground and surface water. The assessment process is based upon a robust dataset comprising ground investigation data and ground, leachate and surface water chemistry results from the existing landfill. A conceptual model has been developed from the dataset and the fate of pollutants within this model has been examined numerically using the Environment Agency software LandSim2.

2 SITE DESCRIPTION

Llanwern Eastern Waste Management Site (LEWMS) is located at Ordnance Survey Grid Reference ST 397 864, as shown on Figure HRA1. It lies at the eastern edge of the Corus Llanwern Steelworks, and has accepted steelmaking and general wastes from the Llanwern site since the late 1960's. The waste management site is a landraise, with wastes being deposited initially into very shallow excavations (circa 1 metre) onto natural ground. Disposal has developed a raised landform that now reaches 15m above Ordnance Datum (AOD), or some 10m above surrounding ground level. The current topography of the site and the surrounding area is shown on Figure HRA2. This is based on a topographic survey completed by Geotechnology on 2 February 2007.

The site occupies an area of 197,835m^2 (19.78 Ha) which is fully occupied by deposited wastes. The landform of the site comprises a steep sided plateau, with only 1m of relief across the top of the landraise. LEWMS measures approximately 830m long by 300m wide with the long axis oriented north to south. In the northern half of the site, the boundary tapers to a point whilst the southern half of the site boundary is a uniform rectangle measuring 300m wide by 400m long.

To the east the landform slopes gently down to the plant boundary at Hundred Perches Reen, a slow flowing man-made ditch draining the surrounding levels. Mature vegetation has established itself along the eastern batter of the landfill, forming a tree and vegetation screen to the landraise. The western and southern boundaries of the site are steep waste slopes which drop from the waste plateau to site roads within the steel plant. These boundaries have leachate collection ditches running along 50% of their length set between the toe of the waste slope and the site roads. Surface water flows in the open collection ditches are directed into Drain 10 of the works effluent treatment system.

The north-eastern boundary of the site is marked by a shunting spur to the works railway system. Between the toe of the waste slope and the railway a ditch has been excavated to collect leachate moving through the slag starter layer beneath the waste. Leachate from this ditch is piped into Drain 9 of the works effluent treatment system.

With the exception of the eastern batter, each of the existing slopes comprise waste materials (principally steel slag) with a thin, impersistent covering of dredgings from the water courses around the plant. Vegetation is locally established on these flanks, comprising mainly invasive species such as Budlea and Thistle. The plateau area has also experienced colouration of the intermediate surface with these same species throughout, with the exception of the active disposal areas in the north of the site.

The land surrounding LEWMS is flat lying, and forms part of the Gwent levels. This is an area of reclaimed coastal marshland that extends through several counties surrounding the Severn Estuary. Though the site is 3.5km from the current estuary boundary this is the case only because of extensive land drainage and sea flood defences maintenance since Roman times.

Current levels typically comprise low grade arable and grazing land in a system of fields separated by drainage ditches or reens. The reens form an inter-bedded network of drainage ditches with levels controlled by a series of sluices at the sea defence to the south of the site. Surface water discharges at low tide and at periods of high water the sluices are closed to prevent seawater incursion into the reen system. The nominal elevation of the ground surface surrounding the site is 5m AOD with a reen water level of 2.3m AOD.

Examination of the Environmental Setting Plan reveals that the site lies in a remote area. There are five dwellings within 500m of the site, one warehouse and an industrial building (on the Llanwern site). Several public roads lie within 500m of the site as does the main South Wales to London railway line. All the land surrounding the perimeter of the eastern end of the Llanwern site is designated SSSI, part of the Gwent levels SSSI.

The principal watercourse close to the site is the Hundred Perches Reen which flows along the eastern boundary of the site. The relationship between the site and surrounding watercourses is shown on Figure HRA3.

3 GEOLOGY

Geotechnology has developed a conceptual geological and hydrogeological model based upon published information and site investigation data (see Appendix HRA1). The flow of water through the ground is a direct result of the geometry of the strata beneath and around the site and the physical properties of each stratum. Clearly, a thorough understanding of the geology is fundamental to the risk assessment process.

Available information on the site comprises a published Geological Survey Plan which is included for reference in Appendix HRA1. A series of six trial pits and six boreholes have been positioned around the site to provide a detailed understanding of the geometry and properties of the strata beneath the site. A plan of the locations of each of the trial pits and boreholes is provided on Figure HRA4.

The entire site is underlain by a very uniform sequence of marine (estuarine) clays, freshwater peat, gravels and Mercia mudstone bedrock. A series of geological cross-sections are provided on Figure HRA5 showing an interpretation of the ground conditions between boreholes and trial pits beneath the site. The very regular sequence of strata encountered in each borehole and trial pit indicates that there can be a high degree of confidence on the interpolation made to develop the model. In each of the boreholes and trial pits the sequence summarised in Table HRA 3-1 was encountered.

Table HRA 3-1 Lithological sequence beneath landfill

Lithology	Thickness / m
Made Ground (Fill)	1.90 - 4.50
Upper Clay	1.85 - 2.60
Peat	1.40 - 2.55
Lower Clay	1.35 - 3.50
Gravel	0.45 - 2.00
Bedrock	>10

With a ground surface elevation typically of 5 to 7m the upper clay lay just above Ordnance Datum (i.e. mean sea level). All other strata, including the peat horizon lies below mean sea level.

3.1 Geological History

The Severn Estuary Levels are all those lands nearly at sea level on the edge of the inner Bristol Channel and the Severn Estuary as far upstream as Gloucester. They comprise some 850 square kilometres, straddling the former counties of Gloucestershire, Avon, Gwent and Somerset. The landscape as we see it today is characterised by flat meadows and scattered arable fields, defined by water-filled ditches and crossed by tranquil streams and willow-lined lanes.

In their natural state, before people from the Romans onward built enclosing sea-banks to protect the land and fundamentally change its use and character, the Levels were vast expanses of marsh which grew up along the coast through the deposition of chiefly tidal mud. The marshes were dissected by branching networks of tidal creeks. This process has operated over the last 8,000 years in response to a fluctuating rise of sea level totalling 25-30 metres. That rise is continuing today, and apparently accelerating, at the rate of a few millimetres annually. During several short periods when sea level stopped rising and may even have fallen slightly, the tide flowed only into the larger creeks that passed fresh water across the Levels, and peat marshes spread almost everywhere between. This was especially the case between about 6,000 and 2,500 years ago.

The geological deposit - known as the Wentlooge Formation - that was formed beneath the Levels is a series of alternating layers or beds of mainly blue-green silt and brown-black peat that total l0-15 metres thick in most places. The deposit represents tidal mudflats and different types of tidal-freshwater marsh. Locally, the beds are interrupted by silted-up tidal creeks, called palaeochannels. Because of coastal erosion, the layers are visible at countless places on the shores of the Levels, but ditch-cleaning, boreholes, and development activities show that they also range far inland beneath the surface of the Levels.

The Wentlooge Formation (i.e. the Upper Clay, Lower Clay and the Peat) has been deposited over a flat rock surface of Mercia Mudstone (or Keuper Marl as it is commonly known). The flat ground reflects the flat lying Wentlooge Formation but some 1km to the north, the ground surface rises to a series of low hills at the village of Bishton. The available geological plan reveals that the hills comprise Blue Lias, a sequence of limestone with calcareous clay bands. Above the lias, near the hilltops is a sequence of clays with limestone bands. This more erosive resistant sequence has formed the higher ground around which the Wentlooge Formation clays and peats have been deposited.

4 HYDROGEOLOGY

The hydrogeology of the site has been studied using data from ground investigations, topographic surveys, meteorological records and surface water flow records.

Ground investigation boreholes and trial pits excavated around the site have been used to obtain basic groundwater data, including groundwater levels and strata permeabilities. Samples recovered during the investigation have been subjected to laboratory testing to determine the chemistry of encountered water bodies and the permeability and mineralogical composition of clay layers.

When drilling from surface, ground water is initially encountered at shallow depths (typically 1 to 2 metres) at an elevation of between 3.9m AOD and 4.6m AOD. The water lies within the highly permeable fill materials, which comprise principally steel making slag. Permeabilities in this material were measured in five separate test locations with an average permeability of 3.1 x 10-4 ms^{-1}.

The water body in the fill materials was seen to be perched on the Upper Clay layer. Due to the very fine grained nature of the clay it was impractical to attempt field permeability tests so undisturbed samples were subjected to laboratory permeability determination. Three tests from different boreholes revealed permeabilities of 3.9 x 10-10, 4.2 x 10-10 and 9.2 x 10-10 ms^{-1}, indicating a stratum of consistently very uniform low permeability.

An examination of the cross sections shown on Figure HRA5 shows that the fill materials have been placed into a shallow excavation in the clay. This is consistent with historical information which indicates that the site was previously used for water settlement lagoons. The lagoons were dug and embankments constructed around them to contain the water. When the lagoons were decommissioned, they were backfilled with steel slag wastes and thus the water body in the made ground is contained by the clay materials.

Beneath the upper clay layer peat was encountered in each of the boreholes during the ground investigation and on every occasion was described as damp, with no discernable water strikes. A single well was placed into the peat to evaluate long term moisture response and permeability, and a further two wells were placed with screens through the peat and the upper and lower clay horizons. The results of permeability field tests indicate that the peat is of relatively low permeability, ranging from 7.2 x 10^{-6} ms to 4.83 x 10^{-7} with an average of 2. x 10-6 ms^{-1}. Groundwater recovered slowly into the boreholes after drilling allowing water samples to be recovered from the peat horizon.

In every borehole a second, lower clay layer was encountered beneath the peat horizon. The clay was subjected to simple classification tests to compare its physical composition to that of the upper clay layer. This revealed that the two clay layers are almost identical in composition, grading and strength and therefore the likelihood is that the permeability of the lower clay layer will also be very similar to the upper clay.

Beneath the lower clay Mercia mudstone bedrock was encountered in each of the boreholes. In each case it was overlain by a thin layer of sub-rounded gravels with localised clays and silts forming the matrix. Recharge to the gravel layer is almost certainly due to the underlying bedrock aquifer, nevertheless permeability tests were undertaken which revealed permeabilities averaging 3.6 x 10-5 ms^{-1}. The underlying bedrock was investigated by three deep boreholes (16m) drilled by rotary methods. Surprisingly, permeability tests revealed a stratum permeability ranging from 1.5 x 10^{-6} to 2.9 x 10^{-4}, with an average of 1.3 x 10^{-4} ms^{-1}. Geotechnology consider that this is most likely due to fracture flow or secondary

permeability rather than primary permeability related to porosity, which is known to be low in the Mercia mudstone.

The second principal water body beneath the site was encountered in the Mercia mudstone bedrock. Water levels rose rapidly upon intersecting the bedrock or the directly overlying gravels during drilling to an elevation of 2.9m AOD in Borehole 1 (north of the site) to 2.64m in Borehole 6 and 2.63m in Borehole 4 (south of the site).

4.1 Groundwater Flow

Groundwater flow in the shallow fill has been examined by contouring the piezometric surface, as shown on Figure HRA6. The levels, based upon 6 boreholes and 5 trial pits, reduce in elevation from east to west, and from centre to north and south. This is not unexpected. A surface water drain, transmitting water from nearby parts of the plant follows the western edge of the landfill at a level controlled by a weir at Drain 10. This water, destined for the works effluent treatment plant acts as a fixed head in the fill materials, controlling the rise of groundwater above this level. This mechanism provides an opportunity for groundwater lowering by reducing the fixed head.

On the southern and northern corners of the site ditches have been excavated to collect groundwater. From these ditches it is piped into effluent drains 9 and 10 for treatment. These ditches also act as fixed heads controlling groundwater levels in the near surface fill.

With heads controlled on the western, southern and northern edges of the site, and no formal control system on the eastern boundary groundwater levels are elevated in the east. This is not problematic for surface water as the elevation of the water surface (4.6m AOD) is less than the elevation of the clay layer between the landraise and Hundred Perches Reen (5.3m AOD). There is also a low permeability bund constructed along the eastern boundary that was used to contain the original water settlement ponds. Consequently, a steady state flow system is established from east to west due to the combination of infiltration recharge through the wastes and the head maintenance at the ditches.

The water flowing in the fill is recharged by infiltration through the waste mass. This is considered to be leachate formed as a result of precipitation, infiltration and subsequent mounding within the waste mass. With the head distribution and flow pattern shown on Figure HRA6 there is no lateral recharge and therefore the fill through which the leachate flows could reasonably be considered to be the leachate drainage blanket. This analogy is considered in further detail in the LandSim modelling section.

Groundwater flow in the Mercia mudstone aquifer has been established by drilling three piezometers into the rock and measuring the piezometric head. The groundwater levels are sub-artesian, and are confined by the lower clay layer. Upon piercing the lower clay and the clayey basal layer groundwater was seen to rise to 2.9m AOD in the north of the site to 2.6m AOD in the south. Consequently, a very shallow groundwater gradient from north to south has been detected, as shown on Figure HRA6.

Groundwater flow and movement between the leachate body and the Mercia mudstone aquifer is poorly understood. The presence of layers of contrasting permeability is likely to have resulted in a degree of groundwater stratification.

Whilst understanding this in greater detail is a worthy longer term objective, the conceptual model developed at this stage conservatively assumes that any flow of contaminants through the upper clay layer will enter flowing groundwater beneath to be entrained to flow to the receptor. The presence of a second low permeability horizon close to rockhead makes this a particularly conservative solution.

4.2 Effects of Landfill Capping

As part of the closure measures, the landfill is to be capped to minimise infiltration. Capping will comprise covering the carefully profiled wastes with an intermediate cover/support layer, a gas drainage blanket, a moisture barrier (fml), a soil underdrainage blanket and restoration soil. The restoration soils will be seeded to establish a grass sward which will be maintained by mowing to prevent the development of invasive species such as those currently present on the intermediate layer.

The profiled capping system offers several mechanisms which affect the production of leachate and the flow of surface run-off. Rainfall at the ground surface will in part run over the surface of the restored cap giving rise to run-off. That which doesn't run-off will either soak into the cap, becoming infiltration, or will be lost through evapo-transpiration. Infiltrating water will either be stored as soil moisture, or will pass through to the agricultural under-drain from where it will either be removed laterally through the drainage layer or will pass through defects in the capping membrane. A water balance to illustrate this is provided in Table HRA 4-1.

Table HRA 4-1 Water balance for landfill cap

Year	Effective Rainfall	Exposed waste on landfill area	Restored Landfill Area	Leachate	Infiltration through cap	Surface water
	m	m^2	m^2	m^3	m^3	m^3
2007	0.981	198700	0	194924.7	0	0
2008	0.981	149025	49675	147168.15	974.6235	47756.55
2009	0.981	99350	99350	99411.597	1949.247	95513.1
2010	0.981	49675	149025	51655.046	2923.8705	143269.7
2011	0.981	0	198700	3898.494	3898.494	191026.2

Recent research into the effectiveness of fml capping barriers has shown that a 1mm HDPE fml, installed with appropriate CQA, should reduce infiltration into the waste mass by 98.2%. Thus only 1.8% of the effective rainfall will infiltrate into the waste mass. Under such circumstances leachate heads are expected to fall in response to the vertically eliminated recharge.

The capping system will cover the entire area with the membranes terminating in a piped drain at the toe of the slopes. Runoff and drainage blanket water will be directed into the pipework which will collect and transmit the water through a series of drainage pipes into Drain 10. The water will be circulated into the works effluent treatment system.

Existing waste slopes will also be capped using the same system. An anchor trench system located on the berm will fix the membranes to the slope and a similar toe drain detail will allow the collection of surface water and drainage blanket water. The collected water will

also drain into Drain 10, and pan into the works effluent treatment system. The eastern slope however will not be capped below the berm level. Vegetation has become well established on this slope which is shallower than those on the west and south. Rather than disturb what is now mature vegetation the slope will remain intact, and the somewhat greater degree of infiltration will be accepted as a better option than disrupting the slope.

5 RISK ASSESSMENT

Undertaking a hydrogeological risk assessment first requires the conceptual model of the geology and hydro-geology to be developed from ground investigation data. Whilst there is limited ground investigation data available for this site, the extraordinary uniformity between boreholes surrounding the site gives a very high degree of confidence in the interpolation. The conceptual hydrogeological model presented in Figure HRA7 is therefore considered to represent site conditions very closely. This conceptual model has therefore provided a medium through which the fate of pollutants has been examined. Through a process of iteration and sensitivity analysis the likelihood of receptor impact has been evaluated.

This hydrogeological risk assessment considers the risk to receptors from pollutants escaping from the landfill (the source) in to the ground beneath in accordance with the processes indicated in the conceptual model. Landfill leachate is considered the source. For the consideration of List 1 pollutants within the leachate, the groundwater beneath the site is the receptor, with the unsaturated zone representing the pathway. For List 2 pollutants the receptor is considered to be a distant environmental receptor with off-site groundwater being the pathway through which the receptor may be exposed. The risk of the receptor being exposed to the source is quantified using the numerical model LandSim2 which has been developed by the Environment Agency for this specific task.

Many iterative LandSim models have been made and it is not practical to provide copies of each simulation. This report therefore provides a summary of the performance prediction of the proposed capping design in the short, medium and long term. Further detail is provided in the earlier Geotechnology reports (294.1, 360.1 and 360.2).

5.1 Developing the Numerical Risk Assessment Model

LandSim2 v2.5 has been chosen to simulate the performance of the landfill. This numerical model has been developed to meet the Environment Agency's need for a consistent approach to modelling potential groundwater emissions from landfill sites. Whilst the model provides a consistent mechanism to undertake Monte Carlo simulations of the landfill hydraulics and contaminant fate there are underlying assumptions within the model that have to be fulfilled for the model to reasonably simulate future landfill performance.

The conceptual hydrogeological illustrated in Figure HRA7 has to be approximated in developing the model. LandSim treats existing hydrogeology in a simple way, assuming that the landfill is developed over an aquifer in which flow is in one direction, with flow volumes determined by head differences and distance (hydraulic gradient) and permeability. The model is sufficiently sophisticated to recognise variability within the input parameters and a range of values can be input for each variable, to better represent actual conditions.

5.2 Ground Conditions

The disposal site was developed on an area of land used initially for water settlement lagoons. A bund was constructed along the eastern edge of what is now the site boundary and a shallow excavation made to form the large ponds. These were subsequently filled with granular slag dominated wastes to form the current landform. The wastes currently cover the entire landfill area to a depth of approximately 10m.

LEWMS has been situated on a natural geological barrier consisting of low permeability clay of greater than 2m thickness. Laboratory testing has shown the clay to have a very narrow

distribution of permeability, indicating a layer of uniform and predictable performance. Ground investigation works have shown the clay to be of uniform thickness across the entire site. To model this using LandSim, the natural geological barrier has been considered to be the engineered barrier. A clay mono-liner has been chosen, with thickness and permeability parameters obtained from the ground investigation and laboratory testing. Geotechnology recognise that the clay layer is not a formally constructed CQA supervised liner, but the uniformity of test results indicates that there should be a high degree of confidence in the clay performance. The upper clay and overlying slag layer has therefore been incorporated into the model as a single clay EBS with a total thickness of 2.35m based on ground observations.

Groundwater conditions beneath this site have been represented in the LandSim model by specifying the Mercia mudstone aquifer as the receiving aquifer. Leakage from the leachate saturated wastes through the Upper Clay layer has been modelled by assuming that the peat layer beneath is unsaturated. This maximises the head difference between the leachate and the ground beneath, and accordingly the model will tend to over-estimate leakage through the clay layer.

The peat layer between the Upper and Lower Clay layers is of relatively low permeability. This is typical of organic materials under high effective stresses. To in-build further conservatism the peat is considered to be a thin unsaturated layer above a vertical saturated pathway comprising the Lower Clay beneath. During the ground investigations, water strikes were not observed in the boreholes that intersected the peat. However, subsequent monitoring has shown that water is present within the peat, although it is not considered to be an aquifer capable of transmitting groundwater from the site to distant receptors.

Beneath the peat, the lower clay layer forms an effective aquitard over the underlying Mercia Mudstone aquifer. This is modelled in LandSim as a vertical saturated pathway transmitting contaminants down into the underlying groundwater. As the clay layer is confining the aquifer, the head difference across the Lower Clay layer is less than that modelled. Again, the model will provide an over-estimate of flow and the passage of contaminants.

A limitation in the use of LandSim is its treatment of aquifer flow toward the nominated receptor. The model assumes a single gradient flowing to the east and conventionally the landfill would be simulated by rotating its geometry to comply with the model. As the groundwater gradients beneath LEWMS slope to the south, the landfill has been modelled as a single cell with a groundwater gradient measured from Figure HRA6.

5.3 Drainage System

Apart from the creation of the impoundment embankments, it is unclear whether the site has been developed over a prepared subgrade comprising permeable materials, or whether disposal activities commenced by end tipping into the water settling lagoons. The engineering control and design of the landfill base is therefore unclear.

Geotechnology consider it likely that a starter layer was initially placed to stabilise the wet sediments on the floor of the disused settling ponds. The investigation has revealed a consistent layer of fill of uniform permeability across the site. The LandSim model assumes no formal drainage layer, rather the model has been built with a blanket drainage system. Leachate head is therefore controlled by waste permeability which has been specified from the ground investigation results. The waste permeability data are entirely consistent with a waste stream dominated by granular steel slag.

5.4 Meteorological Data

Rainfall data has been obtained from the Meteorological Office for a ten year return period, and is provided in Appendix HRA2. A uniform probability density function (PDF) has been used to describe the infiltration to the waste prior to the final capping with the minimum set at 744 and the maximum at 1218mm. A single value of 110mm has been used to describe the infiltration to the capped grassland based on the Meteorological Office Rainfall and Evaporation Calculation System (MORECS).

5.4.1 Species Concentrations in Leachate

Leachate concentration monitoring data is available for a range of pollutant species and a summary of this data can be found in Appendix HRA3. From this information, six key pollutant species were identified, each with different fate and transport properties. These pollutants have been chosen to model the performance of the landfill, the effectiveness of its capping system and it's impact on the surrounding environment. List I and List II substances have been selected, as summarised in Table HRA 5-1.

Table HRA 5-1 Leachate Source Concentration

Parameter	Data Range	Probability Density Function (PDF)
Ammonia	10 – 20 - 40	Log Triangular
Cadmium	0.00017 – 0.00085	Uniform
Calcium	460 – 920 – 1840	Log Triangular
Chloride	900 – 1800 - 3600	Log Triangular
Zinc	0.01 – 0.021 – 0.042	Log Triangular
TPH	0.3 – 0.61 – 1.22	Log Triangular

For all parameters apart from List I Cadmium (Cd), the maximum value obtained from the monitoring information have been used as the 'most likely' value in the contaminant PDF. The 'minimum' contaminant PDF value has been set at 50% of the most likely value and the 'maximum' value set at twice the most likely value. For the List I substance Cd, additional conservatism has been incorporated by adopting a uniform PDF and using the maximum observed leachate concentration as the minimum value and five times this value as the maximum.

5.5 Leachate Head

Leachate head has been specified as a single value of 1.2 m for the blanket drainage system within LandSim. The head distribution on the clay surface is known at six locations, and it has been possible to quantify for this data the average head on the clay.

6 RECEPTOR CHARACTERISTICS

Groundwater beneath the site flows slowly southward toward the Severn Estuary some 3.5km to the south of the site. There are no private or public abstractions of groundwater between the landfill and the receptor, so therefore the estuary represents the closest receptor where groundwater meets the biosphere. The geological history described earlier indicates that the development of the Wentlooge Formation of clay, peat and clay is recognised throughout the Severn area and is very consistent. This is certainly corroborated by the ground investigation information. It is very unlikely therefore given that the land between the landfill and the estuary is part of the levels, that the aquifer approaches sufficiently close to the surface to leak water into the biosphere.

The Groundwater Regulations (1998) forbid the discharge of certain (List 1) substances to groundwater. Therefore, the receptor in terms of List 1 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 List 2 substances will also be the down-gradient boreholes.

Environmental Acceptance Levels (EALs) for each receptor have been determined from comparison of the most stringent available Environmental Quality Standards (EQSs) for estuarine water, groundwater and drinking water with current background water quality. This comparison reveals that current groundwater quality is inferior to several EQSs. In this circumstance, EALs should be established that prevent further groundwater pollution, as described in Environment Agency guidance LFTGN01. In this instance, Geotechnology have therefore set EALs at either the most stringent EQS or 25% higher than the maximum observed groundwater quality to allow for seasonal variation. The EALs determined using this methodology are presented in the last column of Table HRA 6-1.

Table HRA 6-1 Proposed EAL's for Llanwern

Determinand mg/l	Maximum Value Leachate Chemistry	Maximum Value Groundwater Concentration	UK DWS	EQS	MRV for clean water	EAL proposed for Llanwern
Ammonia	20	5.9	0.5 as ammonium	0.015 as ammonia freshwater		7.37 [1]
Cadmium	0.00017	<0.005	0.005	0.0025 saltwater	0.0001	0.0001 [2]
Calcium	920	73	250	-		250 [3]
Chloride	1800	1600	250	250 freshwater		2000 [4]
Zinc	0.021	0.022		5		0.0275 [1]
TPH	0.610	<0.01	0.01		0.001	0.001 [2]

1 EAL for determinand selected as background concentration +25% to take account of natural background concentration, where this exceeds water quality standards.
2 EAL set at minimum reporting value
3 EAL set at most rigorous EQS/DWS
4 EAL exceeds leachate concentration and is therefore not proposed for compliance monitoring purposes.
5 Ammonium will be the dominant N species within groundwater at the pH observed.
6 Freshwater EQS
DWS – Drinking Water Standard. EQS - Environmental Quality Standard. Values taken from LFTGN01 (Environment Agency, 2003). All values in mg/l.

7 PATHWAY CHARACTERISTICS

Between the base of the waste mass and the groundwater surface is an unsaturated zone which includes the upper clay layer. This constitutes the pathway for List 1 substances. List 2 substances have to travel from the landfill to the nearest identified receptor, which is the Severn Estuary directly down-gradient of the site. The pathway for List 2 substances is therefore a combination of advective flow through the unsaturated zone, saturated vertical percolation through the lower clay layer and then aquifer flow through the Mercia mudstone.

7.1 Contaminant Retardation and Biodegradation

Along each pathway, contaminant transport will be subject to natural attenuation processes that will serve to retard and attenuate contaminant dispersion. Processes operating along the flow paths will be dependent on local conditions and contaminant properties, but will include adsorption, absorption, dilution, oxidation and reduction, volatalisation, precipitation and cation exchange. Within LandSim, these processes have been accommodated by defining partition coefficients for each contaminant. For hydrocarbons, the partition coefficient has been calculated based on defined organic carbon content. As LandSim will only consider partitioning between the aqueous and solid phase the approach represented by the model is likely to be far more conservative than actual conditions along the flow paths due to the presence of thick continuous sequences of clay and peat. Further, the model adopts a linear isotherm, which means that the partition coefficient remains constant at all concentrations.

7.2 Unsaturated Zone

The conceptual pathway between the underside of the clay liner and the aquifer is illustrated schematically on Figure HRA7. Directly beneath the Upper Clay is a peat layer which is of low permeability (3 x 10-6ms^{-1}) and is described during drilling as damp. With sufficient recovery time it would appear that the layer is saturated. However, in order to conservatively model the flow of leachate through the Upper Clay, a head of zero has been assigned to the underside of the layer. This in effect means that a thin unsaturated zone is modelled at the underside of the clay. Nominally this has been given a 10cm thickness. Thus the model considers the peat to be only 10cm thick, and unsaturated. Permeability parameters for the peat have been assigned to this layer, though it plays little part in the attenuation or diffusion of pollutants.

7.3 Vertical Saturated Pathway

The Lower Clay layer shown on Figure HRA7 is considered to be the vertical saturated pathway. The thickness of the lower clay averages 2.82m in the six boreholes that each encountered it. It was seen to vary slightly in thickness, from 1.35m to 3.5m, though the average has been adopted for these simulations. Laboratory testing has revealed that the clay is indistinguishable in physical characteristics to the upper clay and accordingly it has been modelled with the same average permeability.

7.4 Aquifer Pathway

The distance to the biosphere receptor varies from 3500m at the closest edge of the landfill cell to 4160m at the furthest edge. The longitudinal dispersivity has been as 10% of the aquifer pathway length and the transverse dispersivity as 10% of this. The aquifer mixing zone has been limited to 20m. The porosity of the Mercia mudstone has been modelled at 20%, due principally to the secondary (fracture flow) porosity. Contaminant transport within the aquifer portion is not retarded, adding further conservatism to the assessment.

The groundwater gradient is well understood as secondary (fracture flow) porosity of the groundwater. Within the LandSim model a value of 0.005 has been adopted. The available hydraulic conductivity of the aquifer is also well understood and a single hydraulic conductivity value of 0.000113 m/s has been specified in the LandSim model.

8 PERFORMANCE EVALUATION

The LandSim2 model of the current site has been created to statistically predict the impact of landfill pollutants on the nearest environmental receptors. It is a design tool that has allowed the performance of the chosen capping system to be evaluated, and also to be compared with the performance of other potential systems. Accordingly, the model has been run very many times to test the sensitivity of the predicted impact to design changes. Thus the landfill cap has been largely "designed" by understanding and quantifying the impact upon the receptors by each element of the design. The model has been previously presented (see Geotechnology reports 360.1 March 2005).

8.1 Receptor Concentrations

The Landfill Regulations require that the fate of pollutants arising at the facility is studied for the entire lifecycle of it's operation. Thus, the risk assessment has been considered over the time period until completion criteria can be met. The actual time for waste stabilisation and degradation to an "inert" mass cannot be accurately predicted, as this site accepts an unusual waste stream. Accordingly, the LandSim model has been run to consider the short, medium and long term, with simulations extending as far as 20000 years. Over this timescale the degradation (not failure) of engineering systems has been modelled, with reduced efficiency in the drainage blanket, and increased leakage through the capping and lining system.

Using the methodology prescribed in Environment Agency Horizontal Guidance Note H1 the anticipated maximum pollutant concentrations at the closest environmental receptor have been compared with Environmental Assessment Levels derived from data included in Guidance Note H1. Table HRA 8-1 reveals that for all of the timescales considered, each of the pollutants are no greater in concentration than the EAL.

Table HRA 8-1 Maximum Predicted Concentration relative to EAL

	EAL	30yrs	100yrs	300yrs	1000yrs	20000yrs
Ammonia	7.37	5.9	5.9	5.9	5.9	5.9
Cadmium	0.0001	0	0	0	1.3E-17	8.7E-5
Calcium	250	73	73	73	73	125
Chloride	2000	1600	1601	1639	1629	1600
Zinc	0.0275	0.022	0.022	0.022	0.022	0.022
TPH	0.001	0	0	0	0	0

In preparing Table HRA 8-1 the 95 percentile concentration has been quoted. The concentrations presented for all substances apart from Cd are those predicted at the off-site compliance point. For Cd, the concentrations presented are those predicted at the base of the unsaturated zone.

The LandSim Model has identified that at no time do List 1 substances reach groundwater below the facility. Therefore the site poses no threat to groundwater quality from List 1 substances through-out the facilities full life cycle and complies with the requirements of the Groundwater Directive. With respect to List 2 substances, all predicted concentrations at the compliance point are below the established EAL, indicating that there is no significant deterioration in groundwater quality.

The risk assessment has identified that once capped, all site management procedures could cease and the site would not pose an unacceptable pollution risk. As a result, the hydrogeological completion criteria are considered to be met at the end of the sites post closure after care period, which is likely to be approximately 60 years.

It is estimated that the surrender time of the installation will be in excess of 60 years, post closure. This will however be determined by analysis of the acquired monitoring during the remaining operational period and also the post closure monitoring.

8.2 Effects of Additional Waste Deposition

The effects of additional waste deposition at the site can not be evaluated using the LandSim software. However, there are several lines of evidence which demonstrate that the potential risks to groundwater will not change with additional waste deposition.

- The LandSim predictions are based on the existing site which currently comprises approximately 2.5 Mt. Geotechnology estimate that a further 4000t is required to complete the landform. Therefore, the additional waste will occupy just 0.16% of the final waste mass.

- The additional waste will comprise of inert and non-hazardous waste. The material will largely comprise of soil and stone, mixed construction and demolition waste, supplemented by small amounts of slowly biodegradable materials (general office paper and card waste). Consequently, the additional waste will not alter the source term used to evaluate the current site within the LandSim model.

Based on these two key factors, Geotechnology consider that the overall conclusions reached above and therefore the overall site risk profile will not be changed by short-term additional waste deposition.

LLANWERN EAST WASTE MANAGEMENT SITE LANDFILL CORUS WORKS LLANWERN

APPENDIX HRA1
BOREHOLE AND
TRIAL PIT LOGS

Report Number 525.1/Appendix 1/0207

LLANWERN EAST WASTE MANAGEMENT SITE LANDFILL CORUS WORKS LLANWERN

APPENDIX HRA2
METEOROLOGICAL DATA

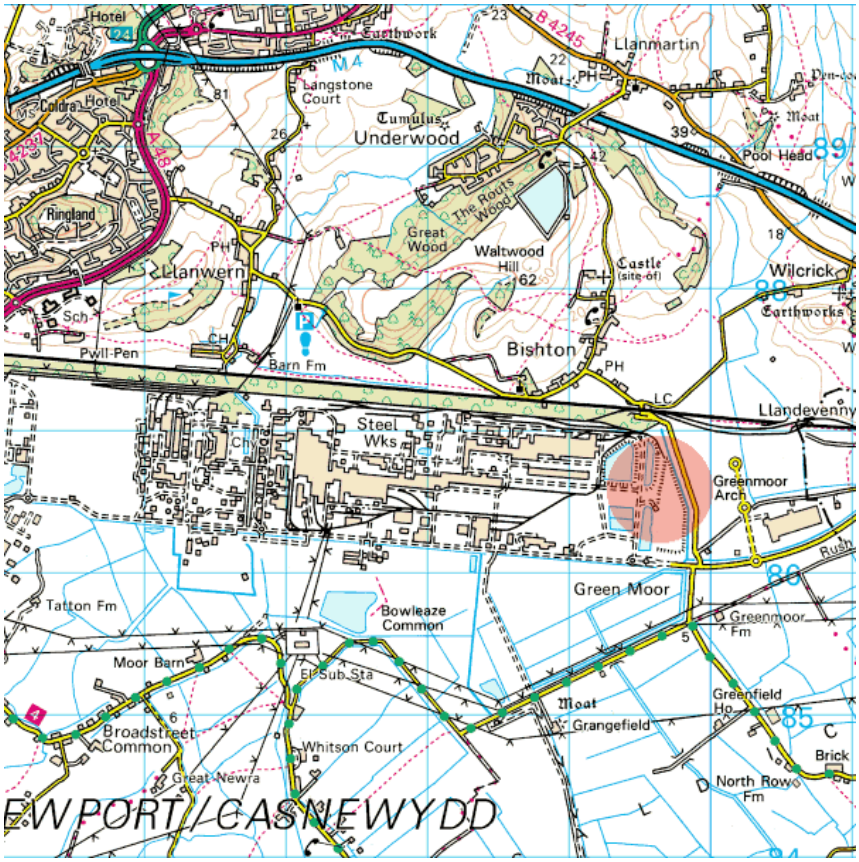
Report Number 525.1/Appendix 1/0207

LLANWERN EAST
WASTE
MANAGEMENT SITE
LANDFILL
CORUS WORKS
LLANWERN

APPENDIX HRA3 LEACHATE, GROUNDWATER AND SURFACE WATER CHEMISTRY

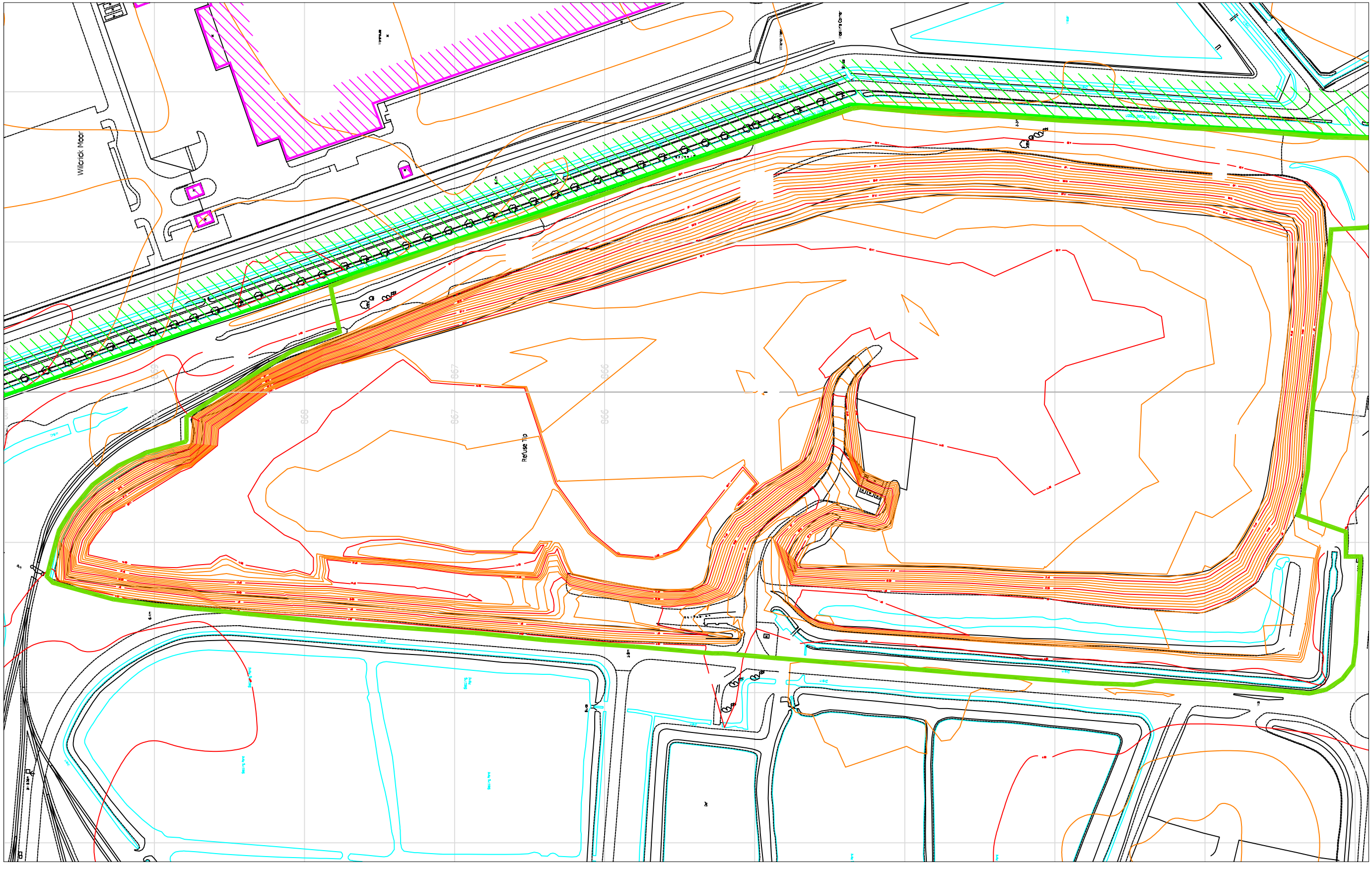
Report Number 525.1/Appendix 1/0207

Figure 1 Site Location Plan



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Figure HRA2 Topographic Plan



Revision 1

525.1/0/0207 Figure HRA2

Scale: 1:2500

Figure HRA3 Hydrology



Figure HRA4 Ground Investigation Plan

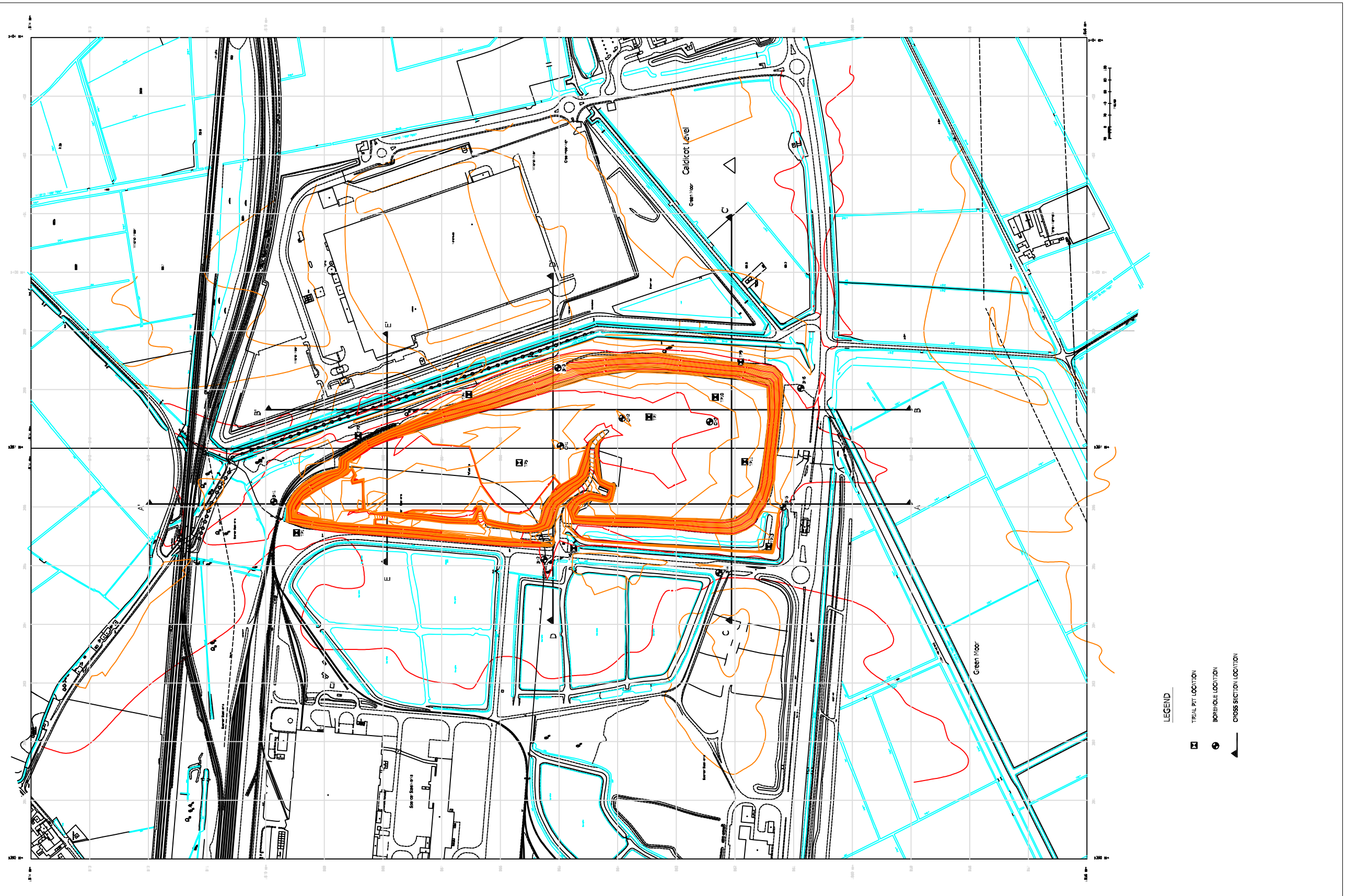


Figure HRA5 Geological Sections

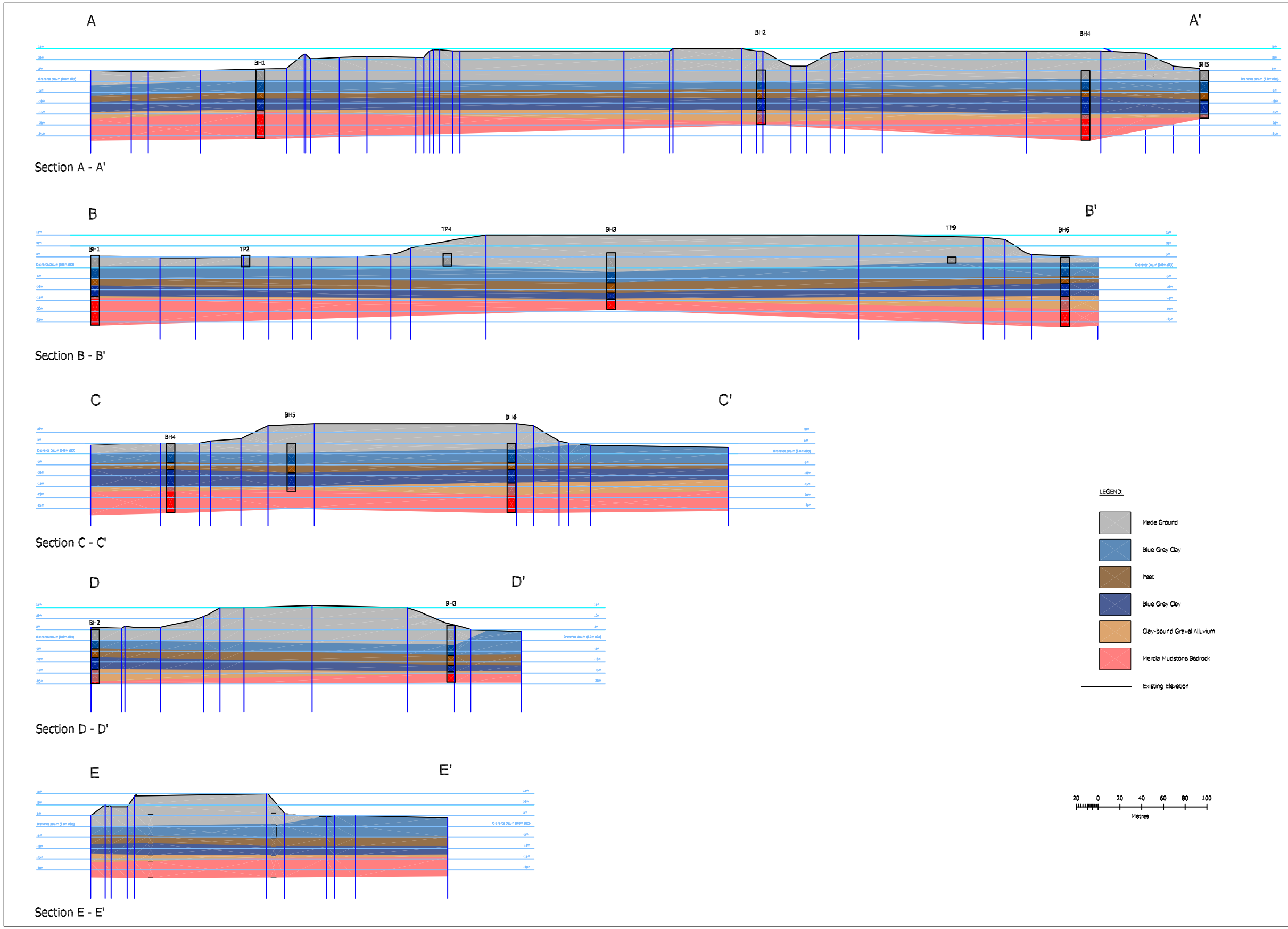
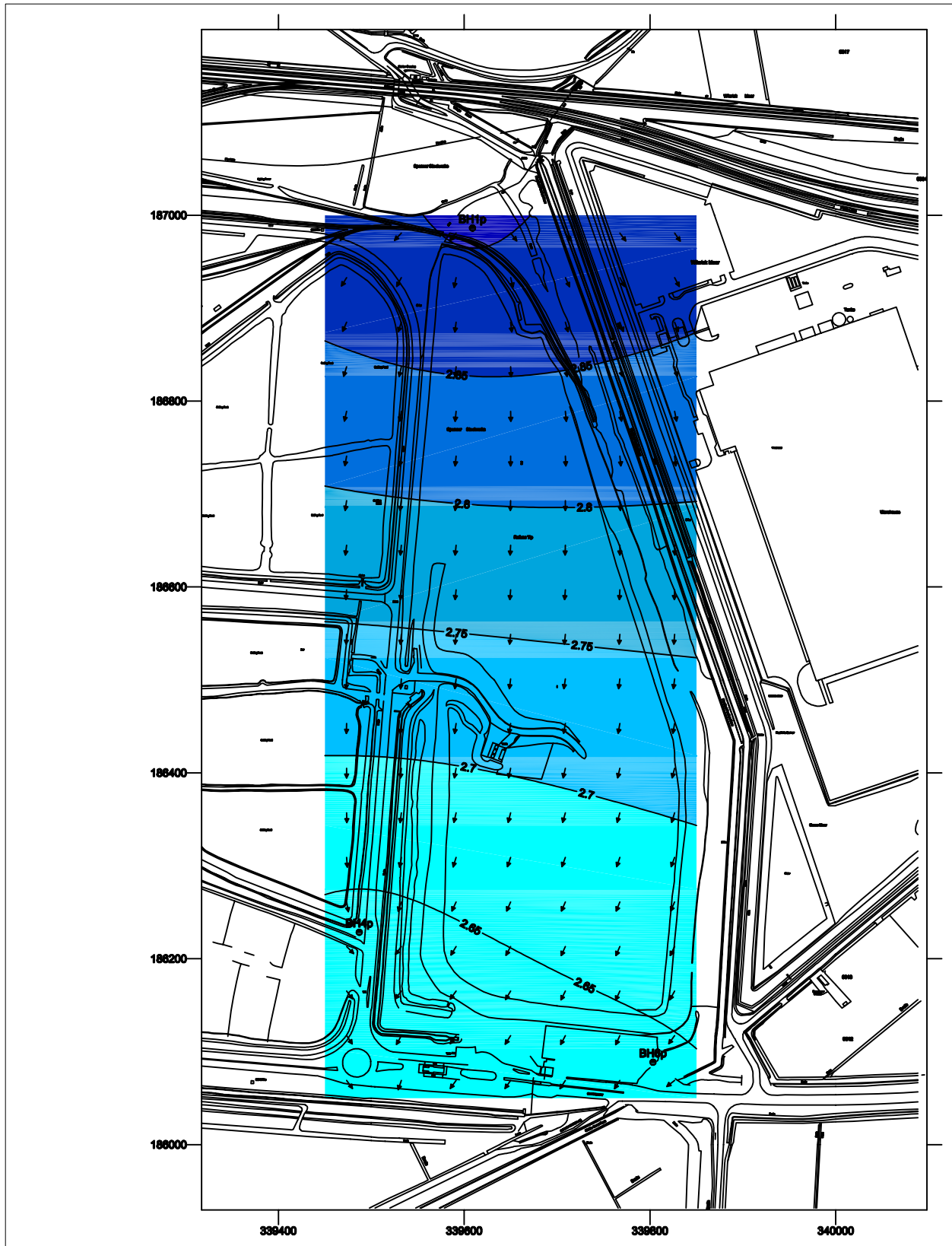
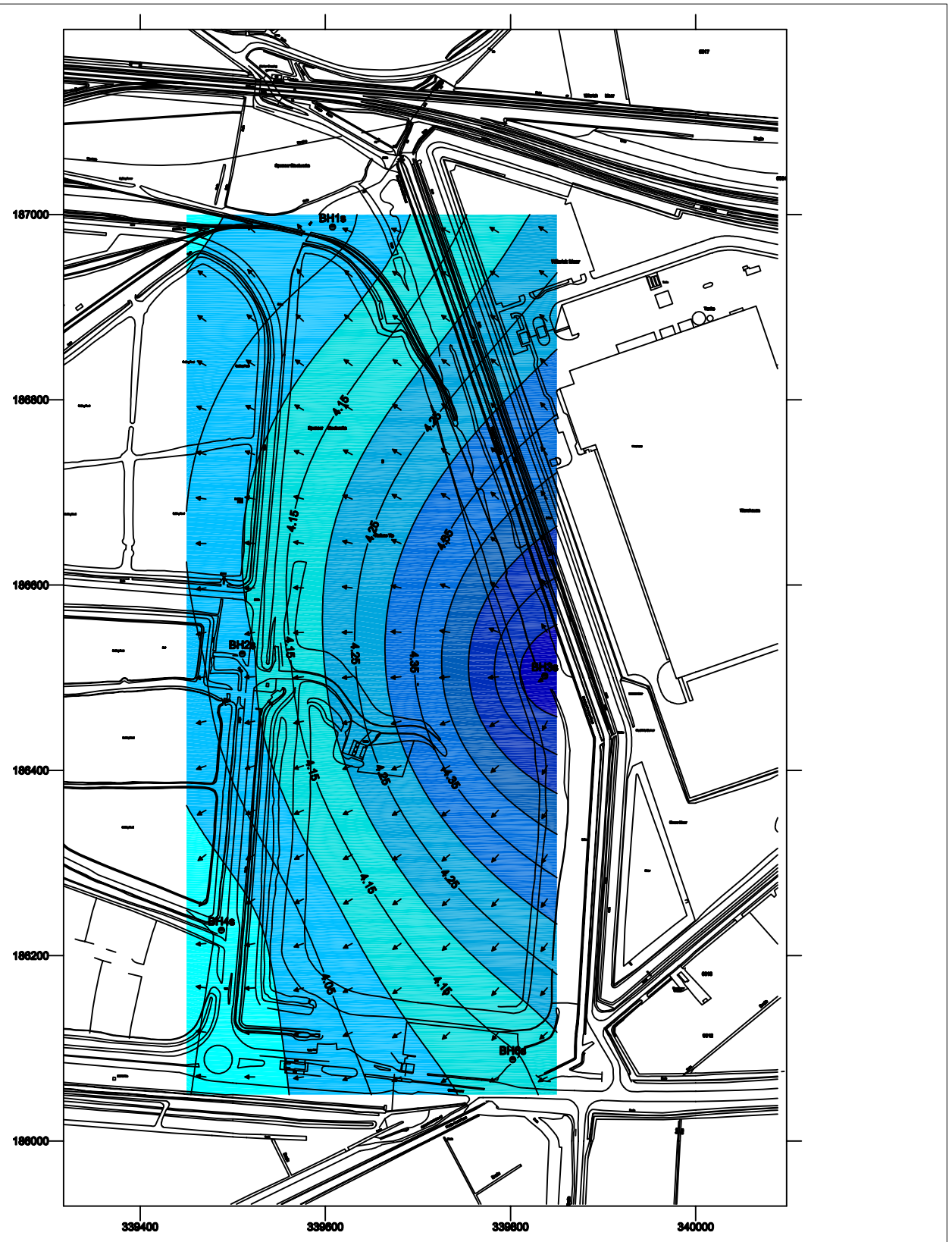


Figure HRA6 Groundwater Flow in the Aquifer and Made Ground

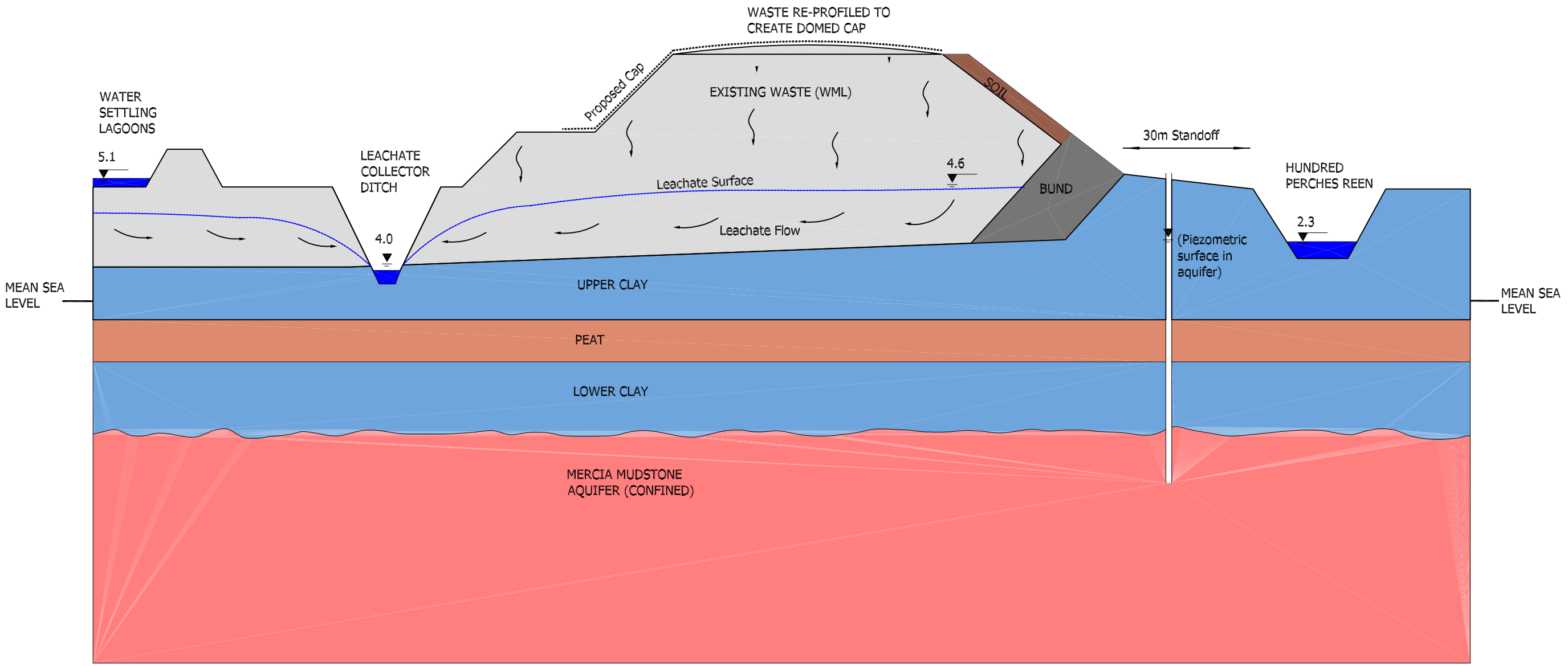


AQUIFER FLOW



LEACHATE FLOW

Figure HRA7 Conceptual Hydrogeological Modelnd Made Ground



LLANWERN EAST WASTE MANAGEMENT SITE LANDFILL CORUS WORKS LLANWERN

APPENDIX 2
GAS RISK
ASSESSMENT

Report Number 525.1/Appendix 2/0207

LLANWERN EAST WASTE MANAGEMENT SITE LANDFILL CORUS WORKS LLANWERN

GAS RISK ASSESSMENT

Report Number 525.1/Appendix 2/0207

Commissioned by

Corus (UK) Limited
Port Talbot Works
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SA13 2NG

FILE REF: **Y:\Data501-550\525 LEWMS Closure\Closure_report\Appendix 2 Gas RA\525 Gas RA Report.doc**

DECEMBER 08

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1 INTRODUCTION

This report has been prepared to inform the proposal for continued waste acceptance at the Llanwern East Waste Management Site (LEWMS). The location of the site is shown on Figure 1, whilst the environmental setting of the site is shown on Figure 3.

LEWMS has the capacity to generate typical landfill gases because a small fraction of the waste input is degradable. However, the landfill is dominated by industrial waste and accordingly its' gas generating potential is completely different to conventional landfill. This report, therefore, examines the risk that this site presents to the local environment from the migration of landfill gas likely to be evolved at this site.

Following Agency guidance on risk assessment, and with particular reference to "Guidance on the Management of Landfill Gas, 2002", this report identifies local receptors, models the gas production over a 40 year post closure period.

LEWMS is a landraise occupying an area of some 200,000m^2 at the eastern end of the Llanwern Steelworks. It has accepted approximately 2.5 million tonnes of non-hazardous industrial and commercial wastes from the steel plant since its inception in 1978. Corus (UK) Ltd the operator of the site, applied to the Environment Agency (EA) for a Pollution Prevention and Control Permit for the landfill as it still has a significant void space available within its planning consent. However, the permit application has been refused and the site now has to initiate closure in accordance with current regulations.

The EA served a Closure Notice on Corus on 14th November 2006, requiring a series of risk assessments to be undertaken to inform the closure process. This Gas risk assessment is one of those required, and characterises the future risk from landfill gas if the site continues to accept wastes for a limited period and if the site is to close immediately.

2 SITE DESCRIPTION AND ENVIRONMENTAL SETTING

Llanwern Eastern Waste Management Site is located at Ordnance Survey Grid Reference ST 397 864, as shown on Figure 1. It lies at the eastern edge of the Corus Llanwern Steelworks, and has accepted steelmaking and general wastes from the Llanwern site since the late 1970's. The waste management site is a landraise, with wastes being deposited initially into very shallow excavations (circa 1 metre) onto natural ground. Disposal has developed a raised landform that now reaches 15m above Ordnance Datum, or some 10m above surrounding ground level. The current topography of the site (Jan 2007) and the surrounding area is shown on Figure 2.

The site occupies an area of 197,835m^2 (19.78 Ha) which is fully occupied by deposited wastes. Disposal activities have attained two thirds of the final landform height over all but a small part of the western of the site.

The landform of the site comprises a steep sided plateau, with only 1m of relief across the top of the landraise. LEWMS measures approximately 830m long by 300m wide with the long axis oriented north to south. In the northern half of the site, the boundary tapers to point at its northern limit whilst the southern half of the site boundary is a uniform rectangle measuring 300m wide by 400m long.

To the east the landform slopes gently down to the plant boundary at Hundred Perches Reen, a slow flowing man-made ditch draining the surrounding levels. Mature vegetation has established itself along the eastern batter of the landfill, forming a tree and vegetation screen to the landraise. The western and southern boundaries of the site are steep waste slopes which drop from the waste plateau to site roads within the steel plant. These boundaries have leachate collection ditches running along 50% of their length set between the toe of the waste slope and the site roads. Surface water flows in the open collection ditches are directed into Drain 10 of the works effluent treatment system.

The north-eastern boundary of the site is marked by a shunting spur to the works railway system. Between the toe of the waste slope and the railway a ditch has been excavated to collect leachate moving through the slag starter layer beneath the waste. Leachate from this ditch is piped into Drain 9 of the works effluent treatment system.

With the exception of the eastern batter, each of the existing slopes comprise waste materials (principally steel slag) with a thin, impersistent covering of dredgings from the water courses around the plant. Vegetation is locally established on these flanks, comprising mainly invasive species such as Budlea and Thistle. The plateau area has also experienced colonisation of the intermediate surface with these same species throughout, with the exception of the active disposal areas in the west of the site.

The land surrounding LEWMS is flat lying, and form part of the Gwent levels. This is an area of reclaimed coastal marshland that extends through several counties surrounding the Severn Estuary. Though the site is 3.5km from the current estuary boundary this is the case only because of extensive land drainage and sea flood defences maintenance since Roman times.

Current levels typically comprise low grade arable and grazing land in a system of fields separated by drainage ditches or reens. The reens form an inter-bedded network of drainage ditches with levels controlled by a series of sluices at the sea defence to the south of the site. Surface water discharges at low tide and at periods of high water the sluices are

closed to prevent seawater incursion into the reen system. The nominal elevation of the ground surface surrounding the site is 5m AOD with a reen water level of 2.3m AOD.

Examination of the Environmental Setting Plan (Figure 3) reveals that the site lies in a remote area. There are 5 dwellings within 500m of the site, one warehouse and an industrial building (on the Llanwern site). Several public roads lie within 500m of the site as does the main South Wales to London railway line. All the land surrounding the perimeter of the eastern end of the Llanwern site is designated SSSI, part of the Gwent levels SSSI.

The principal watercourse close to the site is the Hundred Perches Reen which flows along the eastern boundary of the site.

There are no buildings or service ducts on or near the site so consideration of the accumulation of gases in, or the migration of gases through voids, has been eliminated.

3 EXISTING WASTE MASS CHARACTERISTICS

An examination of past disposal records shows that only a very small proportion of the waste stream is biodegradable. The remainder of the wastes comprise steel making wastes and demolition rubble which do not evolve landfill gas. A breakdown of the recent waste stream is presented in Table 2.1 below.

Table GRA 3-1 Waste Breakdown

Biodegradable	-	Canteen Waste	0.18%
	-	Office Waste/General Rubbish	15.58%
	-	Horticultural Waste	0.14%
	-	Timber	0.45%
Non-Biodegradable	-	Steel (BOS) Slag	32.4%
Inert Cover			12.7%
Dusts			1.71%
Demolition Rubble			18.82%
Other Non-degradable Wastes			18.02%

The existing waste mass has been placed by admixing all waste streams. This gives a diffuse distribution of biodegradable wastes and the landfill gas evolved during their decomposition is accordingly extremely diffuse. The very high permeability of the waste stream allows gas to effuse from the landfill surface in an uncontrolled manner.

The landraise comprises a layer of waste placed onto a thick low permeability saturated clay. Vertical downward gas migration is unlikely to be of any consequence at this site. With migration inhibited downward and lateral migration controlled by the low permeability clays, gases evolved at the site will effuse at the landfill surface. When capped the landfill gases will be contained so an extraction system will be required to allow gases to drain from the wastes.

A collection system is therefore required and this will be constructed sequentially as the site is capped. Thus, during the operational period, gases have passed passively through the uncapped wastes as fugitive emissions.

4 PREDICTED GAS PROFILE

Landfill gas emissions over the simulation period have been predicted using the landfill gas simulation software GasSim. The software has been developed by the Environment Agency to provide a reproduceable method to predict the emission rates and masses of bulk gases (methane and carbon dioxide) and a large number of common trace gases.

The model predicts gas emission by calculating the decay rate for cellulose and hemi-cellulose in the waste stream. Thus, a clear understanding of the waste stream composition and filling rate is essential if the data are to be reliable.

4.1 Waste Composition

A model of the waste stream has been developed from an understanding of the past inputs to the site, in terms of both filling rates and waste composition. This has been relatively simple for this site as the landfill is an in-house facility, taking a predictable waste stream.

The source of the gas has been quantified into an overall waste composition and this has been carried out by examining past data from the existing site. The appropriately specified waste composition has also recognised the input of slag wastes to stabilise and form cover to the biodegradable wastes.

Using the Waste Breakdown provided on Table 4-1 (based upon an audit of past waste input records) it has been possible to generate a site specific waste composition for GasSim use. The waste composition profile (LlanwernWasteStream.wst) has been calculated by proportioning the GasSim required waste fractions from the available audit. This has resulted in a robust specification of the wastes profile in the existing waste mass, as shown on Table 4-1.

Table GRA 4-1 Waste Composition (by Waste Fraction)

Paper/Card	Newspapers Magazines Other Paper Liquid Cartons Card Other Card	1.59% 0.47% 4.67% 0.31% 0.78% 0.0%
Textiles	Textiles	0.78%
Miscellaneous	Disposables Other Miscellaneous	0.0% 4.22%
Putrescible	Garden Waste Other (Wood)	0.0% 1.1%
Fines	10mm Fines	28.66%
Sewage Sludge	Sewage Sludge Composted Incinerator Ash	0.0% 0.0% 0.0%
Non-degradable	Non-degradable	57.0%

The composition is appropriate for the existing waste mass, though the proposal to continue limited waste acceptance for a 12 month period requires an assessment of future waste composition. A review of the acceptable wastes has been carried out and it has been determined that both the horticultural waste and the canteen wastes should be excluded. Volume calculations reveal that in order to complete the landform a further 9000 tonnes of material is required. It is assumed that this will be comprised of 4000 - 7500 tonnes of site wastes (of the above composition without the putrescible fraction) and 1500 - 5000 tonnes

of imported inert material and slope reprofiling arisings. Accordingly, the 9000 tonnes of additional waste has had its composition changed by proportioning the waste composition profile within 50% inert material.

GasSim also requires landfill design parameters to be input so that waste moisture content and the migration of gas can be accounted for. These parameters have been transcribed from the LandSim model developed in the HRA.

4.2 GasSim Simulations

A series of numerical simulations has been made which examines the gas emission from the site annually throughout its operational life (the past 29 years) a three year restoration period and for 40 years thereafter.

In order to evaluate the influence of a further year of waste acceptance and the use of a flare system a series of four simulations have been run. Each of the four simulations reveal a similar trend : gas evolution has increased from the commencement of activities until 2000, when the waste disposal quantities decreased due to the closure of steel making activities. Despite continued waste input since 2000, the modest quantities have resulted in a fall in gas generation. From 2007 onward the rate of gas generation falls exponentially, reducing rapidly at first and then persisting at a low level to the end of the simulation. This pattern is shown graphically on GRA1.

An examination of graphical output for the comparative simulations (additional disposal against immediate cessation) reveals such similar results that the comparison has to been made numerically. Table GRA4-3 provides the predicted emissions from the landfill without gas flaring for both cases, whilst Table GRA4-4 provides the predicted emissions from the landfill for both cases with flaring.

Table GRA 4-2 Predicted Landfill Gas Emissions without flaring

	Continued Disposal	**Immediate Cessation**
2007		
Carbon Dioxide	3050t	3050t
Carbon Monoxide	542kg	551kg
Methane	1100t	1100t
Toluene	12.4kg	4.45kg
2017		
Carbon Dioxide	402t	395t
Carbon Monoxide	12.2kg	11.7kg
Methane	120t	118t
Toluene	205g	70.2g
2027		
Carbon Dioxide	197t	194t
Carbon Monoxide	1.09kg	1.14kg
Methane	58.5t	57.6t
Toluene	16.2g	6.83g
global warming potential	1260000	1260000

Table GRA 4-3 Predicted Landfill Gas Emission with Flaring

	Continued Disposal	Immediate Cessation
2007		
Carbon Dioxide	3050t	3050t
Carbon Monoxide	528kg	551kg
Methane	1100t	1100t
Toluene	7.09kg	4.45kg
2017		
Carbon Dioxide	402t	395t
Carbon Monoxide	11.4kg	11.7kg
Methane	119t	118t
Toluene	129g	70.2g
2027		
Carbon Dioxide	196t	194t
Carbon Monoxide	967kg	1.14kg
Methane	58.4t	57.6t
Toluene	8.35g	6.83g
global warming potential	1270000	1270000

5 LANDFILL GAS RISK ASSESSMENT

5.1 The Nature of the Landfill Gas Risk Assessment

An initial screening assessment has revealed that the site has the potential to generate landfill gas, though a simple hand calculation has indicated that the limited biodegradable waste proportion and the slow rate of waste import results in low emissions. This fact, combined with the isolated location of the site, with no residential receptors within influencing distance, indicates that a simple risk assessment will adequately inform the gas management measures required.

This assessment has been undertaken using the Agency's gas assessment software GasSim. This has been used to provide a verified model of bulk gas production as well as performing trace gas screening.

5.2 The Proposed Assessment Scenarios

5.2.1 Lifecycle Phases

The landfill has been considered over its 29 year operational period, a 3 year restoration period and a 40 year post closure period. This timescale has been chosen as it fully represents the timescale over which gas evolution will be of sufficient magnitude to allow modelling. Due to the unconventional nature of the waste materials and the uncommonly low rate of input the evolution of landfill gas will be largely complete before the effects of degradation of engineering systems are noticed.

5.2.2 Accidents and their Consequences

Accidents that could have a consequence on gas emissions are confined to damage to the gas extraction infrastructure. Damage to the basal system leading to increased off-site migration is not considered feasible as the liner comprises thick naturally occurring in-situ clays. Damage to gas management infrastructure would have an implication for this risk assessment as a greater proportion of the gas would be emitted as a fugitive emission (from both suction and delivery sides of the gas collection pump). However, the quantities of gas generated are so small that individual defects are not likely to have any significant effect on the emissions, though it is accepted that this represents a site management issue that could influence the efficiency of gas collection. Accordingly, this is considered in the Accidents Plan. There is no need to consider such an event quantatively.

5.2.3 The Generated Gases to be Modelled

GasSim modelling has been used to predict the rate of evolution of the bulk landfill gases Carbon Dioxide and Methane. As well as the principal gases trace gases have also been simulated, including Carbon Monoxide and toluene. GasSim default gases have been used as these can be used in the Tier 1 screening function in order to establish whether further assessment is required.

5.3 Numerical Modelling

5.3.1 Justification for Modelling Approach and Software

GasSim has been selected for modelling as this is the Environment Agency's preferred software for landfill gas risk assessment. It's design allows the conditions of this assessment time to be modelled in a single run as the gas evolution period is relatively short.

5.3.2 Model Parameterisation

Parameters for the model have been obtained using the available waste composition data together as described previously.

5.3.3 Sensitivity Analysis

A sensitivity analysis has not been undertaken as the predicted emission of bulk and trace gases have been screened from the need for complex risk assessment. The model is considered conservative as initiative to reduce biodegradable wastes is already resulting in a decline in those fractions responsible for landfill gas generation. In the event that the Tier 1 screening assessment had revealed concentrations at the closest receptor that approached the screening level (1% of EAL) then sensitivity analysis would have been undertaken.

5.3.4 Model Validation

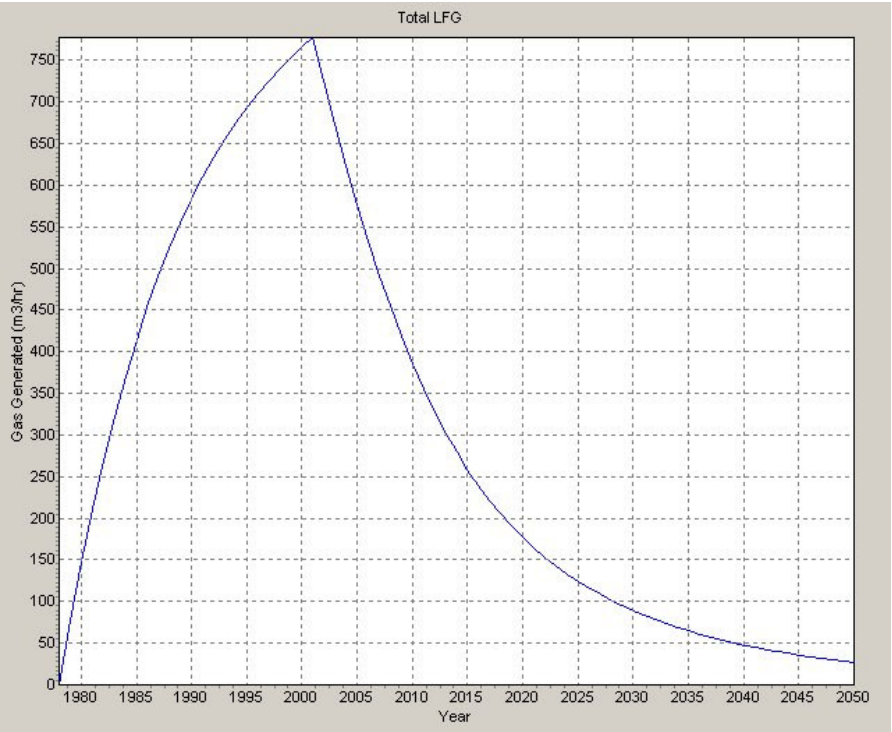
There is currently very limited landfill gas monitoring infrastructure available to validate the model, though it is anticipated that as restoration progresses infrastructure will be placed allowing this assessment to be revisited.

5.4 Risks to the Environment and Human Health

5.4.1 Landfill Gas Emissions

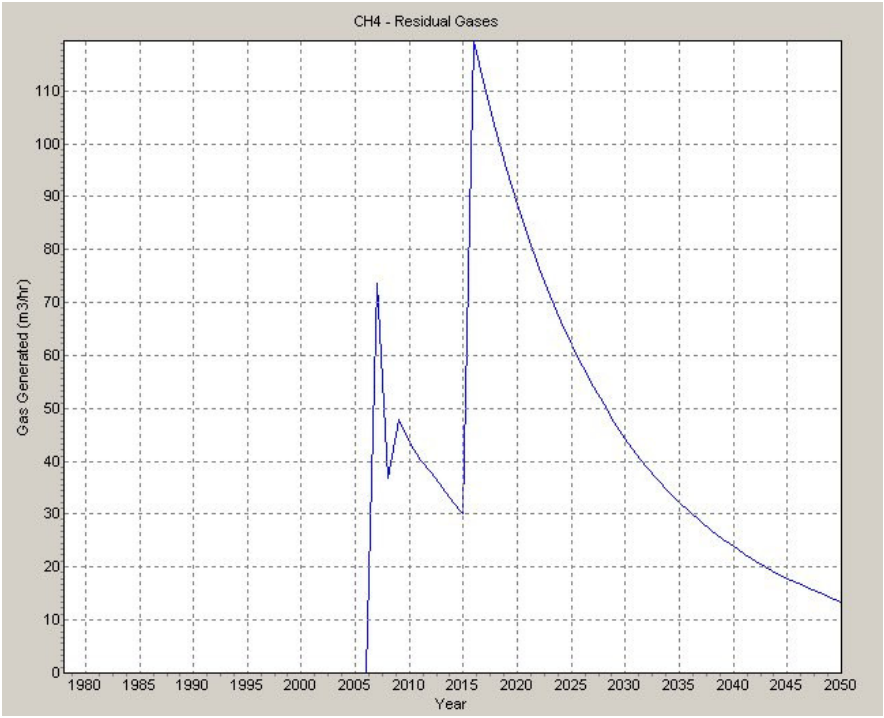
GasSim simulation has predicted the emission profile of landfill gas shown in graph GRA 1 below. This reveals a peak emission in 2001 of 750m^3/hr. The composition of the bulk gas is 50% methane and 50% carbon dioxide, giving peak rates for methane of 380m^3/hr. Using a gas management system to collect and treat the gas is therefore required for the period until flaring becomes impractical due to low volumes. A gas flare has been included within two of the simulations to examine the effect of flaring on emissions. Graph GRA2 shows that the flare is effective at reducing residual methane emissions until gas volumes fall below the minimum rate required to sustain the flare (200m^3/hr).

Graph GRA1 – Bulk Landfill Gas Emission



Carbon dioxide will also be generated at a rate of up to 380m^3/hr.

Graph GRA2 – Residual Methane Emission with Flaring



5.4.2 Atmospheric Dispersion and Odour

The maximum predicted environmental concentration of each trace gas at the closest receptor (industrial building) is below 1% of the appropriate EAL (Agency Horizontal Guidance Note H1), and consequently has been screened out from this assessment. The extremely low concentration leads to the conclusion that odour will not be an issue at this site. The GasSim Tier 1 risk screening has screened out the need for a complex assessment of these issues.

5.4.3 Global Atmospheric Impact

SSQNHL is estimated to contribute 1,270,000 tonnes of carbon dioxide warming potential. No ozone depletion potential has been determined. Each of the four cases considered presents the same global warming potential.

5.5 Landfill Gas Completion Criteria

To achieve landfill completion the site must not represent a risk to the environment or human health caused by the emission of landfill gas. In order to fully understand how long gas production could cause pollution or harm the concentration of gasses which represent a risk must first be specified. Completion criteria of 1.5% CO_2 v/v and 1% CH_4 v/v are suggested, based upon 20% of the lower explosive limit for methane and 20% of the 8 hr time weighted average for CO_2. Thus, active management will be required until these criteria have been met. A simulation in GasSim indicates this is likely to be achieved in excess of 60 years. Active management and monitoring will remain in place until this time.

6 LANDFILL GAS MANAGEMENT PLAN

6.1 Control Measures

The Landfill Regulations requires that gases evolved at landfill sites are subject to energy recovery, principally by electrical power generation, and where this is not technically feasible are flared. As the site produces insufficient gas for energy recovery the Environment Agency Guidance on the Flaring of Landfill Gas will apply. This document provides advice on flaring systems and provides a calculation strategy to determine when gases should be collected for flare treatment.

The net rated thermal input for the gases evolved at LEWMS peaked in 2001 and has already fallen from 3.8 MW to 2.3 MW. Flaring is stated in the guidance to be practical only when gas yields exceed $100m^3$/hr at 50% methane concentration, i.e. a net thermal input 0.5 MW. Gases evolved at a slower rate than this cannot be practically treated by flaring or by energy recovery plants. For this reason, the GasSim simulations have been undertaken with a flare which becomes active at a gas flow rate of $100m^3$/hr and inactive below this.

Any decrease in input due to recycling or plant changes would reduce the viability of gas treatment. The site is expected to continue to evolve gases at a rate that could be potentially treatable by batch flaring until 2020, when yields are dropping as the waste stabilises. Outside these periods, the self-sustained thermal treatment of gas by flaring is not a viable option.

In the absence of a viable self-sustaining thermal treatment process there are few options for gas treatment. The potential treatment methods are:

Fuel support to landfill gas flaring
Incineration
Biological oxidation of methane in bio-filter
Biological oxidation in cover soils

Each of these options has been examined and compared with available guidance. The conclusion of this assessment is that both fuel support flaring and incineration are not good environmental options. Available guidance indicates that no more than 10% fuel support should be used in gas disposal/treatment, and both of the thermal treatment options will require significantly more than 10% fuel support to be viable. Thermal treatment does not therefore represent BAT for gas treatment.

The two remaining options both address the emission of methane, and to a lesser degree volatile trace gases. Both rely upon biological activity to oxidise the methane into carbon dioxide and water. The principle objective of utilising this treatment will be to reduce greenhouse gas emission to atmosphere.

Biological oxidation of methane takes place naturally in soils and the oxidation of methane in landfill cover soils has been used in several sites generating low calorific landfill gases. It has been shown to have measurable effects on methane at concentrations as low as 2%. However, the cover soils that have been shown to be effective at supporting communities of appropriate micro-organisms are loam soils with high moisture contents. For ecological reasons the cover soils at this site will be a low moisture content under-drained sand. It is therefore unlikely that methane oxidation in cover soils will be effective.

The elimination of other options has left the bio-filter as the only potential option for landfill gas treatment outside batch flaring with support fuel. Biofiltration is a bespoke technology in its infancy. Formal guidance on its use is not yet available, though the Environment Agency has commissioned research into biological methane oxidation as a mechanism for treating low calorific landfill gas. Such a system has the potential to offer reduced methane emission from this site, though a clear understanding of how such a system may be designed, installed, monitored and operated is not currently available.

As the site is progressively capped from the south to the north, a gas drainage and collection infrastructure will be placed with the cap. By covering with a gas drainage blanket, surface emissions from the waste will be collected though these are not expected to be of significance.

The gas flare will comprise an enclosed ground flare with pre-aeration. A minimum retention time of 0.3 seconds at an operating temperature exceeding 1000^0C shall be maintained. The stack shall be nominally 3m in height and the process control shall be automatically adjusted. The gas pressure is expected to be low and therefore a booster will be fitted to boost pressure to the barrier and to produce suction within the header main. Knockout pots will remove condensate and particulates from the gas prior to burning.

Emissions from the burner will be controlled by carefully controlling the combustion process. The manufacturer of the plant will be required, prior to installing the system, to undertake an evaluation of the emissions based upon the burner performance and the gas composition sampled at the time. The burner will be required to meet any statutory emission limits and a detailed assessment will be carried out to predict total emissions. This has been undertaken using the GasSim predictive model and the results indicate that oxides of sulphur and nitrogen formed by the combustion process can be screened out as insignificant. Methane emission is predicted to fall by 65% as a result of flaring as shown on GRA2.

Monitoring will be carried out on the flarestack to ensure that it meets its emission requirements. Carbon monoxide, oxides of nitrogen and unburnt hydrocarbons will be monitored to ensure that the emission standard of CO 50mg/Nm^3, NO_x 150mg/Nm^3 and unburnt hydrocarbons 10mg/Nm^3 is met. The stack will be monitored continuously for CH_4, CO_2, 0_2, flow rate as inlet gases and temperature as an output to ensure full functionality of the system. Second level monitoring will be undertaken annually to demonstrate the performance of the stack. Monitoring will be carried out in accordance with the recommendations of the Monitoring protocol for enclosed flares (EA, 2005).

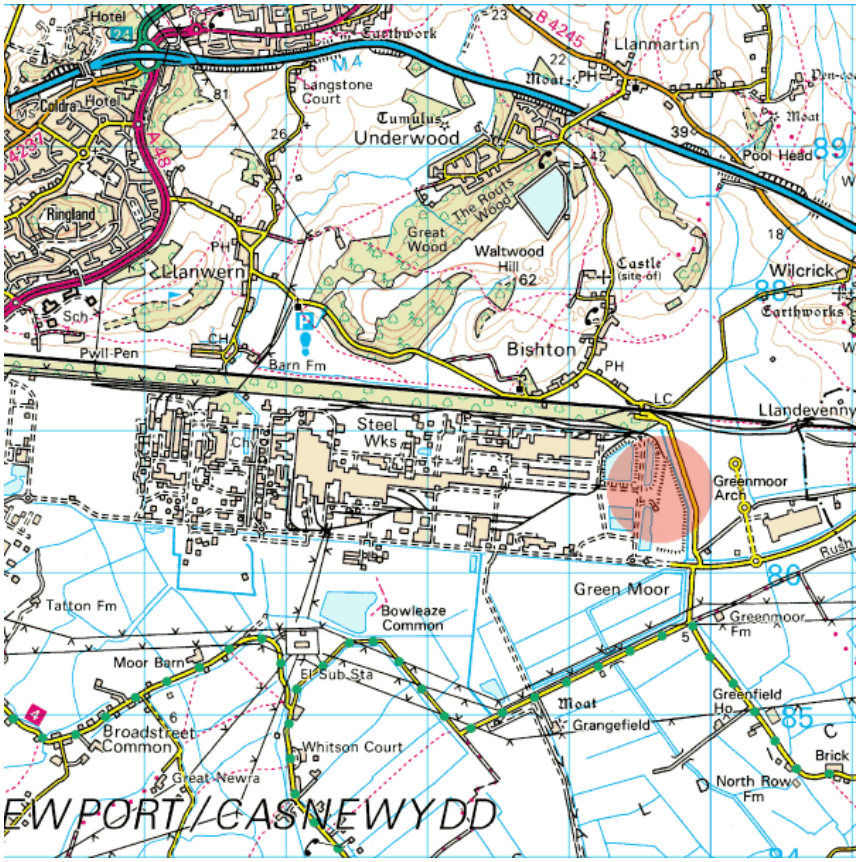
7 CONCLUSIONS

The GRA has shown that gases are generated within the LEWMS in sufficient quantities to merit flaring. Flaring will be effective at reducing emissions for approximately 10 years, and maybe beyond that subject to an appropriate burner system being procured. The restoration system design will include the detailed design of a gas extraction and treatment system.

Emissions from the site in its current configuration have been compared with those from the site if it continues to accept waste for a further 12 months. The emissions comparison tables 4-2 and 4-3 reveals that there are insignificant differences in gas emission profiles from the two cases.

The assessment therefore shows that continued waste acceptance for a further 12 months will not alter the risk profile from the site.

Figure GRA1 Site Location Plan



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Figure GRA2 Topographic Plan

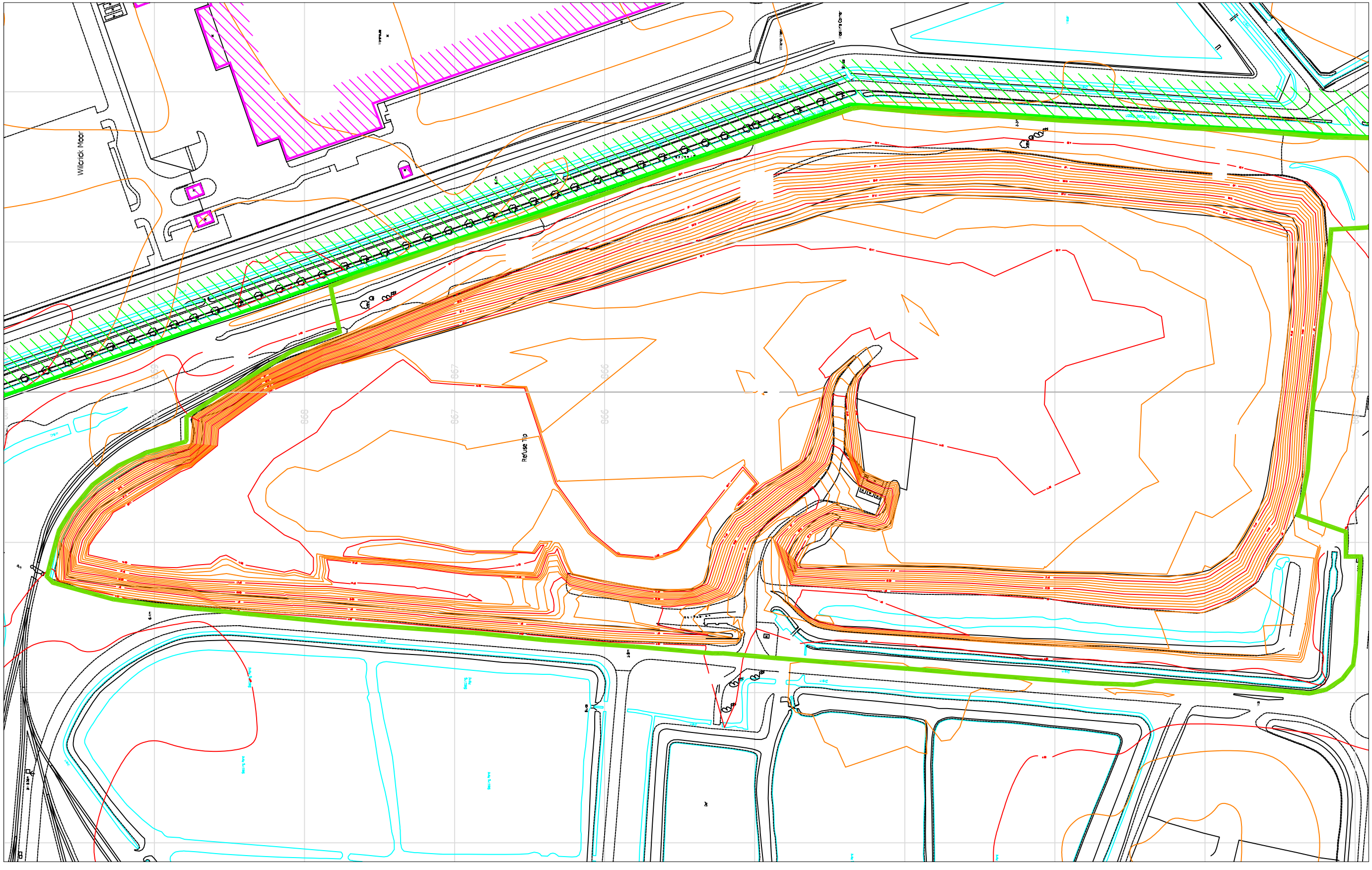


Figure GRA3 Environmental Setting Plan

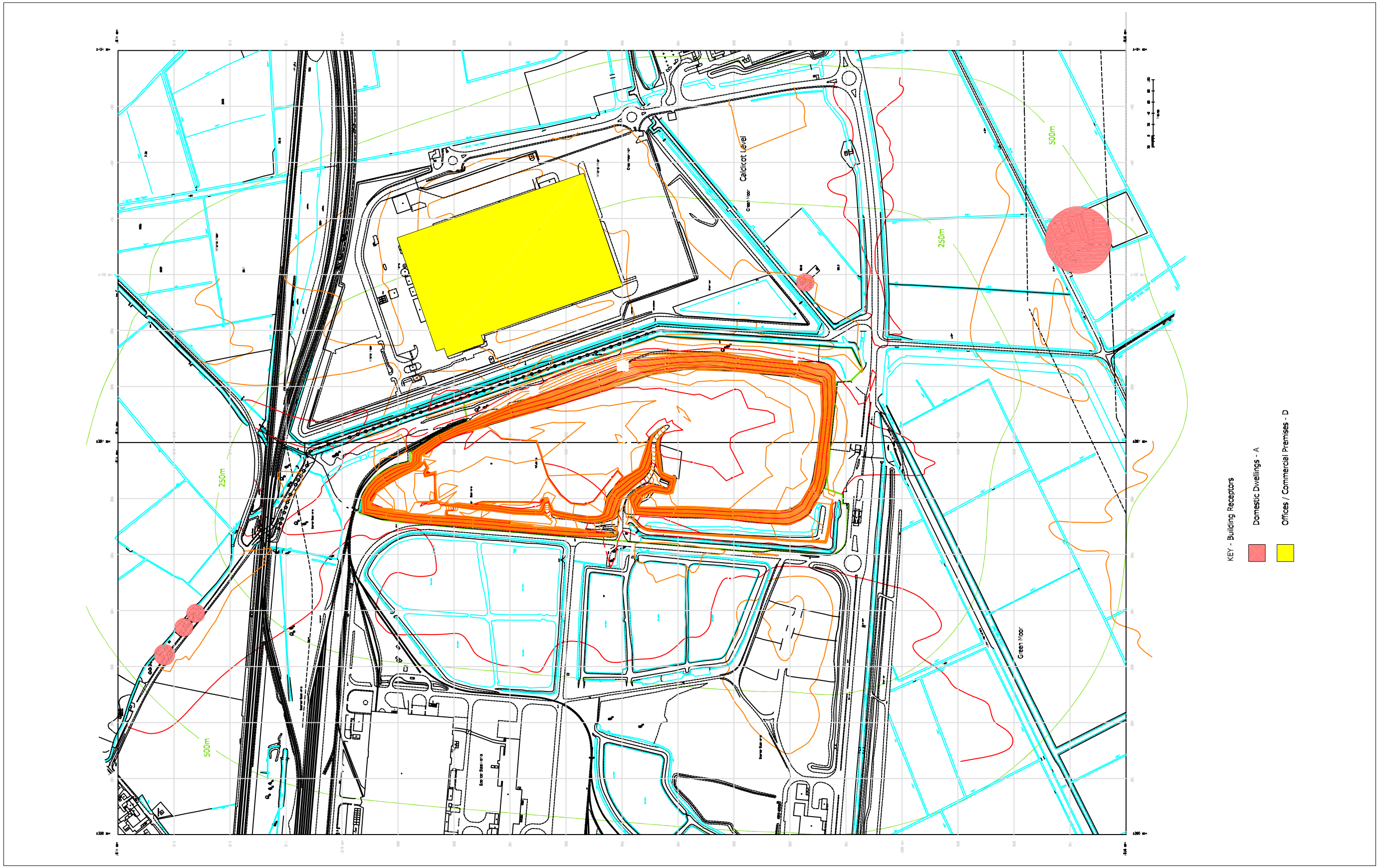


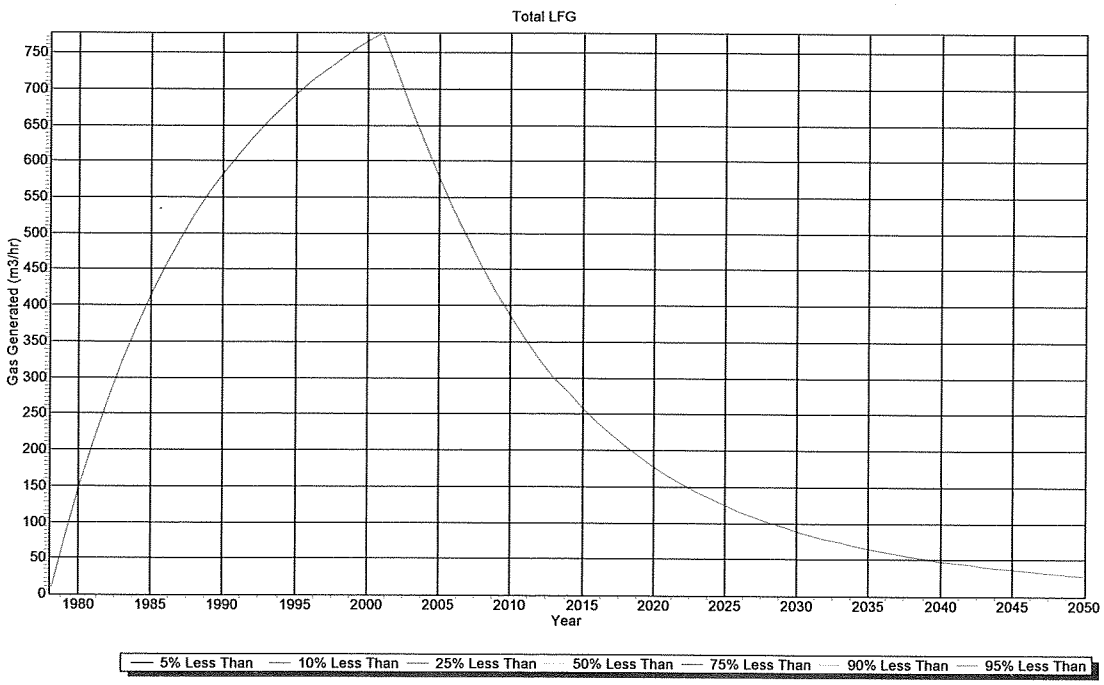
Figure GRA4 Bulk Landfill Gas Generation

GasSim Version V 1.52

Project Name: Eastern WM Facility, Llanwern

Project Client: Corus UK Ltd

Total Bulk LFG Produced



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