LLANWERN EAST WASTE MANAGEMENT SITE
TATA STEEL
LLANWERN

Restoration Soil pH Review
Environmental Effects

Report Number 1546r1v1d0716

Instructed by
Tata Strip Products
Port Talbot Works
Port Talbot
SA13 2NG

JULY 2016

Table of Contents

1 INTRODUCTION 1

2 CURRENT RESTORATION SOIL SPECIFICATION 2
2.1 Restoration Objectives 2
2.2 Current Criteria for Restoration Layer 2
2.3 Placement of Compost/Seed Application 5
2.4 Amended Soil Testing Schedule 5
2.5 Current Soil Importation 6

3 PROPOSED AMENDMENT TO SOIL SPECIFICATION 8
3.1 Objective 8
3.2 Limitations and Application 9

4 EVALUATION OF PROPOSED AMENDMENT 11
4.1 Potential Source of Increased pH 11
4.2 Environmental Context 11
4.2.1 Location and Description of the Site 11
4.2.2 Surrounding Areas 12
4.2.3 Historical Landfilling 12
4.2.4 Geology 12
4.2.5 Hydrogeology 13
4.2.6 Shallow Groundwater Flow 14
4.2.7 Deeper Groundwater Flow 15
4.2.8 Groundwater Quality 15
4.2.9 Surface Water 15
4.3 Impact on Receiving Water 16
4.4 Impact on Human Health 16
4.5 Impact on Flora and Fauna 17

5 MONITORING OF PROPOSALS 18
5.1 Current Phase 18
5.2 Following Current Capping Phase 18

6 CONCLUSIONS AND SUMMARY 19

List of Tables

Table 2-1 Chemical testing schedule for evaluation of materials to be considered for use in landfill restoration 4
Table 2-2 Geotechnical testing schedule for evaluation of materials to be considered for use in landfill restoration 5
Table 2-3 Soil Sources provided by Contractor 7
Table 3-1 pH Values of Soil Sources (Supplied and Candidate) 8
Table 4-1 Waste Breakdown 12
Table 4-2 Lithological sequence beneath landfill 13

List of Figures

1. Site Investigation Locations
2. Geological Cross Sections
3. Available Monitoring Network
4. Hydrogeological Conceptual Site Model
5. Historical Groundwater Levels

List of Appendices

1. Soil pH Evaluation
2. ADAS Evaluation of Soil pH on Plant Growth

1 INTRODUCTION

Tata Steel (UK) Ltd (Tata) is currently capping the closed non-hazardous landfill at its Llanwern works known as East Waste Management Site (EWMS). The capping is being undertaken in accordance with a Design and Specification approved by Natural Resources Wales (NRW). The Specification details the site setting, the materials used in the cap construction, storage and handling procedures and the method of placement/incorporation into the final works. The testing requirements necessary at each stage of the construction are also specified.

- The Specification document is referenced 1314r1v1d1114 – Capping Design and Specification

Additional procedures are required by the Construction Quality Assurance Plan (CQA) which specifies separately the verification of work and materials against the Specification.

- The CQA Plan is referenced 1314r2v1d1114 – CQA Plan

Tata appointed Cuddy Group (Cuddy) in 2015 to undertake the capping works as Principal Contractor. The scheme, which is being implemented through phased working during the summer months, is currently scheduled to be completed by 2018.

As part of the capping works a significant amount of restoration soil is required – some 400,000 tonnes. From the outset, Cuddy aimed to secure a small number of large greenfield soil sources. Soils have proven difficult to secure and to date only 50,000 tonnes of soil has been secured by Cuddy, only part of which is from greenfield sources. As a consequence, smaller volumes from many brownfield sources are now being utilised.

Several candidate sources have been found where the pH of the soil is higher than the upper limit of 8.5 pH units detailed in the restoration soil Specification. This has led to the sources not being approved for use in the works. Following discussion between Tata and Cuddy, Geotechnology Ltd (Designers and CQA Consultant for the restoration scheme) has been requested by Tata to investigate the scope for adjusting the pH upper limit on some or all of the soils so that soil can be more readily sourced. This report, therefore, considers the effects of adopting a higher soil pH limit in the Specification.

Tata may accept a relaxation of the upper pH limit if it does not unduly affect the quality of the restoration or pose unacceptable risks to the environment and human health. Tata would only consider an amendment to the Specification if NRW accepts any proposed revision.

This report presents an evaluation of the potential environmental impact of increasing the upper soil pH limit by one pH unit, from a limit value of 8.5 to a limit value of 9.5. This report also documents the new soil testing regime already agreed with NRW (by correspondence) for the testing of candidate soil sources of various sizes.

2 CURRENT RESTORATION SOIL SPECIFICATION

2.1 Restoration Objectives

The Specification states that restoration soils to be used at EWMS will be sourced externally from approved soil sources. The soils used will be tested for both chemical and geotechnical properties. Once these values have been established and are shown to be acceptable, the soils can be brought in and used as the restoration soil.

When the Specification was prepared it was envisaged that the restoration soils would comprise principally clay and silt or other approved soil forming material which will be seeded. Fit for purpose in the context of the final restoration layer means that the materials must be capable of providing a stable landfill cap that supports a grass sward over most of the surface and limited tree and shrub planting.

Given the geographical and environmental setting of the landfill, Tata currently has no intention of creating an area for residential, commercial or industrial after-use. Consequently, the criteria used to evaluate the suitability of soils need to reflect the main restoration objective, which is to develop a stable landform that is visually aesthetic and is able to support the proposed planting.

2.2 Current Criteria for Restoration Layer

To assess the chemical suitability of any candidate soil source, the Specification outlines the process to be followed in a flowchart which is reproduced below along with the acceptance criteria in Table 2-1. In addition to the chemical evaluation of the restoration soils, their geotechnical and index properties also have to be evaluated.

The Specification requires that restoration soils are cohesive in nature and free from excessive amounts of granular materials and contraries. This is because excessively stony materials could damage the underlying HDPE capping geomembrane. Also, if the soils have too high a moisture content, their placement would be difficult and there is the possibility of localised instability. In addition, cohesive soils result in smaller infiltration rates and are compatible with the surrounding natural soils surrounding EWMS. A specific grading was therefore given to the restoration soils in the Specification as shown in Table 2-2.

In the Specification, two different grades of material are considered (see Table 2-1), with Grade A being of better quality than Grade B, which is reflected in the testing frequency. The intention is for the better quality Grade A soils to be placed above Grade B soils during restoration.

For each suitable soil source identified, the following information is required:

- Site Location of Source
- Site History of source
- Contaminant Status
- Greenfield or Brownfield site
- Quantity Available
- Treatment of soil undertaken
- Chemical Analysis
- Geotechnical suitability

The Specification suggests that the analytical schedule and testing frequency should be evaluated as restoration progresses and further detailed information regarding potential material sources becomes available.

Flowchart - Minimum Testing Schedule for Materials to be Considered for use at East Waste Management Site

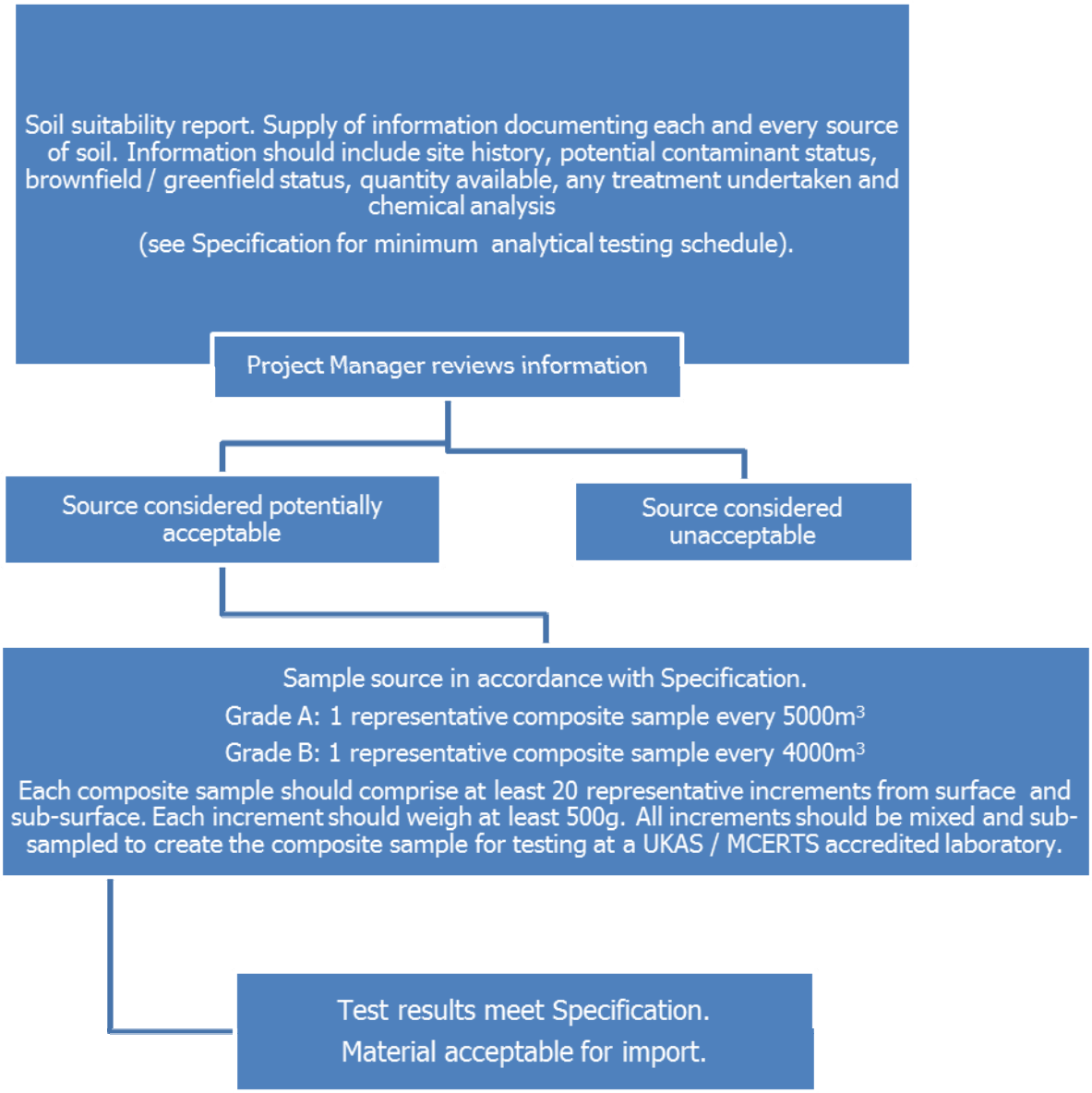


Table 2-1 Chemical testing schedule for evaluation of materials to be considered for use in landfill restoration

Minimum Testing Requirements and Specification for Chemical Quality (all values mg/kg unless specified)			
	Testing Frequency	**Specification**	
		A Grade	**B Grade**
pH (unitless)	Grade A: 1 composite sample every 5000m^3 Grade B: 1 composite sample every 4000m^3	5.5 – 8.5	5.5 – 8.5
Total Petroleum Hydrocarbons (C6 - C40)		500	1000
Total PAH		100	Speciated (see below)
Total BTEX		6	Speciated (see below)
Polychlorinated Biphenyls (PCBs)		1	1
TOC (%)			
Total phenol		420	2000
Asbestos (% w/w)		Non detect	Non detect
Arsenic		43	400
Beryllium		55	400
Boron Water Soluble		45	5000
Cadmium		1.8	150
Cr III		8000	8000
Cr VI		2.1	20
Copper		500	500
Lead			500
Mercury (Inorganic)		80	100
Nickel		230	1500
Selenium		120	10000
Vanadium		18	2500
Zinc		618	2000
Sulphate (g/l)		0.4	0.4
Total Cyanide		10	10
Benzene			50
Toluene			50
Ethylbenzene			50
Xylene (o, m & p)			50
Acenaphthene			50
Acenaphthylene			50
Anthracene			50
Benz(a)anthracene			8
Benzo(a)pyrene			8
Benzo(b)fluoranthene			10
Benzo(ghi)perylene			50
Benzo(k)fluoranthene			18
Chrysene			8
Dibenzo(ah)anthracene			2
Fluoranthene			50
Fluorene			50
Indeno(123cd)pyrene			5
Naphthalene			18
Phenanthrene			50
Pyrene			50

NOTE:
PM – Project Manager
Exceedance of Specification may be acceptable following review by PM and consultation with Tata and NRW.
Material may be rejected even if chemical Specification is satisfied if PM considers visual or olfactory observations are unsatisfactory.
If material is a waste it must not be classified as hazardous waste
Other parameters may need to be tested and leachate tests performed depending upon soil source.

Table 2-2 Geotechnical testing schedule for evaluation of materials to be considered for use in landfill restoration

Minimum Testing Requirements and Specification for Physical Quality of Soil		
	Testing Frequency	**Specification**
Particle Size Distribution BS 1377 Part 2 Method 9	1 per 5000m^3/ minimum 1 per source	100% passes 125mm, 90%-100% passes 63mm, 15% to 100% passes 2mm, >15% passes 0.063mm
Un-drained Shear Strength of Remoulded material	1 per 5000m^3/ minimum 1 per source	>45kPa
Direct Shear using Large Shear Box Test to determine interface shear strength parameters of soil against Pozidrain 6S250D.NW8	Per source	Low normal stress distribution of 10, 15 and 20 kPa to applied for test. Testes to be completed under dry conditions with remoulded soil at natural (as placed) moisture conditions
Contraries (e.g. metal, wood, glass, plastic)	1 per 5000m^3/ minimum 1 per source	<1% w/w contraries. Contraries must not compromise grading
Inspection for visible invasive weeds and fibres & olfactory signs of contamination	Visual inspection of all sources	No invasive weeds or fibres visible and no olfactory signs of contamination
Sharp objects that may comprise capping system	Visual inspection of all sources	No visible sharp objects capable of potentially damaging capping systems
NOTE: Material will be inspected at source and upon arrival. Material found to be potentially unacceptable will be quarantined pending further evaluation.		

2.3 Placement of Compost/Seed Application

Following placement of the restoration soils the Specification indicates that compost generated/manufactured from the initial vegetation strip clearance will be placed provided it is acceptable with no signs of invasive species.

The Specification also indicates that the restoration soil surface quality should be reviewed to determine a seed mixture and appropriate fertilizer application (if necessary). The Specification also details that it is important that a vegetative medium is quickly established in order to prevent soil erosion and the clogging of perimeter surface water drains.

2.4 Amended Soil Testing Schedule

At the time that the Specification was drafted it was envisaged that the soil would be procured from a small number of large sources, and a scheme of verification testing was specified that was tailored to a small number of large sources. The contractor has found it impossible to provide soil from large single sources and accordingly, to date, numerous small sources of soil of highly variable quality have been proposed. The testing scheme provided in the Specification is not practical for small sources, and with the agreement of NRW a revised testing scheme was developed for small sources. The revised sampling and testing scheme was agreed by NRW in an e-mail on 21 October 2015.

The agreed amended soils testing scheme continues with the sampling and testing for each source and evaluates site history to ensure that no contaminated soils are received for the project. The sampling frequency and testing is amended from the original Specification to the following:

"Sources <5000 tonnes = for chemical analysis as per Table 4.11 - minimum 1 composite soil sample regardless of quantity"

"Sources >5000 tonnes = for chemical analysis as per Table 4.11 - as required 1 per 5000 tonnes or part thereof"

"For soil sources less than 5000 tonnes, only a Particle Size Distribution Test will be required, with the soil designated for placement on the plateau area of the cap."

"For soil sources in excess of 5000 tonnes, the full geotechnical suite as described in the Specification Table 4.12 shall be completed."

As shown above, geotechnical testing is reduced to just particle size distribution (PSD) for testing for soils to be placed on the stable plateau of the landfill. This reduces the amount of testing the Contractor needs to do for small sources whilst still providing Tata with some control over the soil properties. The original full testing schedule as proposed in the Specification has to be applied to soil to be used on the side slopes. In brief, each soil source would still as a minimum have:

a) A chemical analysis completed
b) A Particle Size Distribution test

The Contractor has to stockpile each source separately at site as per the original Specification. The CQA Engineer continues to evaluate the nature and quantity of each soil source delivered to the site and implements composite sampling for chemical validation where applicable.

For geotechnical validation the CQA Engineering staff would visually inspect the material to evaluate its size fractions, based on the provided PSD.

2.5 Current Soil Importation

The Contractor is supplying waste soils to the scheme either via the CI:aire Code of Practice or via a Mobile Plant Licence held by Cuddy Demolition & Dismantling Ltd (Permit number EPR/PB3090HK). This Permit is a Standard Rules Permit (SR2010No11) that enables the use of mobile plant for the treatment of waste to produce soil, soil substitutes and aggregate. The Permit allows Cuddy to treat up to 75,000 tonnes under a single deployment using mobile plant consisting only of sorting, separation, screening, crushing and blending of waste for recovery as a soil, soil substitute or aggregate.

Table 2-3 provides a summary of the soil sources supplied to the scheme by the Contractor to date. Also included are several sources currently being considered but not yet supplied. An indication of the candidate site status is also provided. Most soil sources are currently brownfield.

Table 2-3 Soil Sources provided by Contractor

Source Reference	Supplied to Site	Tonnage Supplied	Brownfield / Greenfield
Lysaght 1	Yes	17826	Greenfield
Newport Docks	Yes	3206 concrete, 3646 soil as of 22/10	Brownfield
Pyle	Yes	6927	Greenfield
Orb	Yes	7288	Brownfield
Calidcot (School)	Yes	2093	Brownfield
Argus	Yes	5524	Brownfield
Trefforest	Yes	2784	Brownfield
Pentwyn	Yes	1807	Brownfield
Cwmbran	Yes	851	Greenfield
Pontprennau	Yes	1302	
Bargoed	Yes	274	Brownfield
Merthyr	Yes	3142	Brownfield
Rogerstone	Yes	1404	Brownfield
Birchgrove	Yes / partial	1956	Brownfield
Goytre	Yes	653	Brownfield
Always	Yes	3386	Brownfield
Pontypool	Yes	2475.58	Brownfield
Caldicot Bridge	Yes	340	Brownfield
HOV-Brynmawr	Yes	465	Brownfield
Pyle 2	Yes		Brownfield
Gaer	Yes		Brownfield
Church Village	No	Not supplied	Greenfield
Llanfoist	No	Not supplied	Greenfield
Miskin	No	Not supplied	
Wenvoe	No	Not supplied	Greenfield

3 PROPOSED AMENDMENT TO SOIL SPECIFICATION

3.1 Objective

The current Specification criteria for restoration soils is based on a combination of several sources including selected published Soil Guideline Values, Generic Assessment Criteria intended for the protection of human health from chronic risks and British Standards for topsoil and subsoil quality. In the case of the soil pH criteria, (pH 5.5 – 8.5 for Grade A and B soils) the Specification is aligned with the recommendations in the British Standards for multipurpose topsoil and subsoil. The Standards recommend such a pH range as this should ensure the availability of essential minerals and nutrients required for plant growth. As surface water runoff and percolating water is likely to retain a signature of the soil chemistry, it is also important to apply pH limits so that local water quality is not compromised.

A review of the factors that led to the pH limits in the Specification has been carried out and these have been found to be entirely appropriate. Accordingly, the Specification limits are appropriate and describe soil quality that is appropriate for its intended use and is protective of the environment. Whilst the Specification limits are appropriate, experience so far has revealed that soils meeting these criteria are in limited supply and raising the limit would enable more sources to contribute soil to the scheme. In order to step away from the properly derived criterion for pH it would have to be shown that the objectives of the scheme are not undermined nor the risks to the environment increased. This assessment, therefore, considers these aspects to determine whether the upper pH limit could be revised for some or all of the soil.

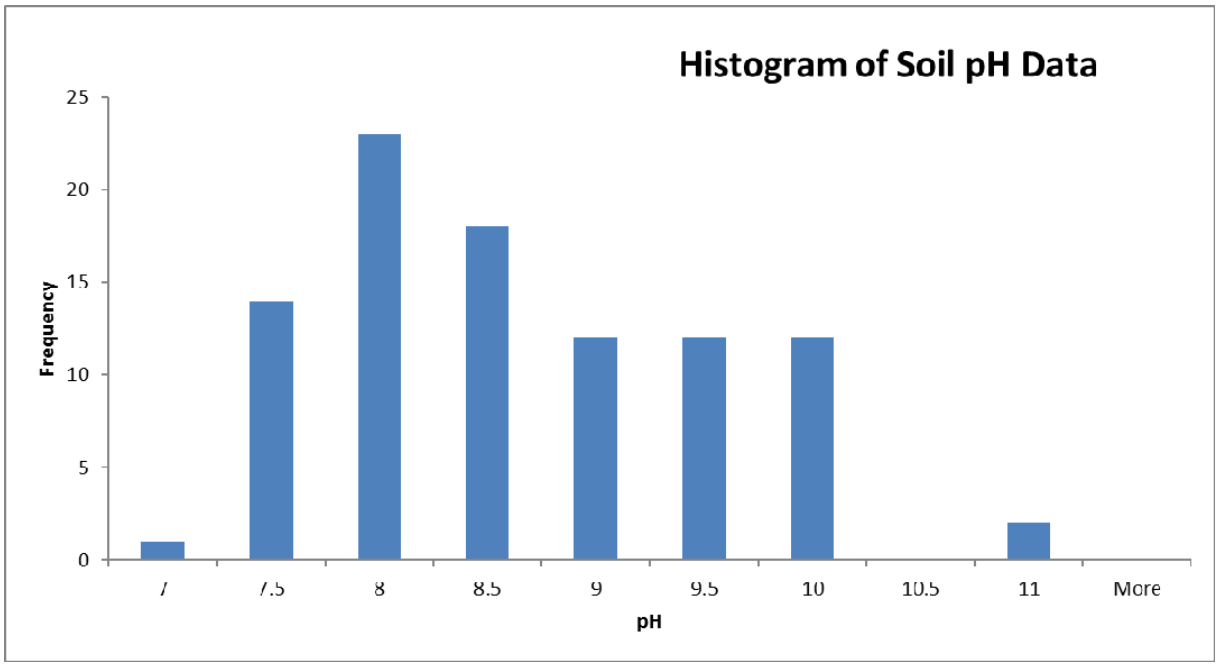
The contractor has found it difficult to source soils that fall entirely within the Specification. In particular, many potential sites have been found where all of the soil chemistry criteria have been met except for pH, which has often been found to be a little higher than the upper limit. A summary of the currently available pH data is provided in Table 3-1. Interestingly, the sites with few or no exceedance of the current upper pH limit of 8.5 are the sites classified as greenfield.

Table 3-1 pH Values of Soil Sources (Supplied and Candidate)

Source Reference	Tonnage	Status	Soil pH
Lysaght 1	17826	Brownfield	8.1, 10.8, 9.9, 9.8, 8.95, 9.31, 8.99, 9.38, 9, 8.2, 7.8, 8.2, 7.4, 7.9, 7.4, 7.4, 7.8, 7.21, 7.38, 8.5, 8.7, 8.8, 8.9, 7, 8.1
Newport Docks	3206 concrete, 3646 soil as of 22/10	Brownfield	9.6, 7.61
Orb	7288	Brownfield	9.5, 10
Calidcot (School)	2093	Brownfield	7.5, 7.6, 7.5, 7.2, 7.7, 7.6, 7.7, 7.3, 7.7, 7.2, 8.2, 7.2, 7.7, 9.1
Argus, Pentwyn, Pontprennau, Trefforest		Brownfield	7.9, 7.8, 8.4, 7.9, 7.9, 7.6, 8, 7.9, 7.7, 8, 7.8, 7.3, 8.3, 9.9, 9.8, 9.6, 9.4, 9.7, 9.5, 9.7, 9.8, 9.7, 9.6, 9.1, 8.9, 9, 9, 10.9
Cwmbran	851	Greenfield	8.26, 8.1
Bargoed	274	Brownfield	8.1, 8.3, 8
Merthyr	3142	Brownfield	9.5
Birchgrove	1956	Brownfield	8.4, 8.5
Goytre	653	Brownfield	8.4
Pontypool & Always	2475.58	Brownfield	9.5, 8.3, 9.4, 8.8, 8.2, 9.2, 8.3, 8.6
HOV-Brynmawr	465	Brownfield	7.8, 7.8, 7.6, 7.5
Pyle 2		Brownfield	9.2
Gaer		Brownfield	8.6
Church Village		Greenfield	8.3, 10.3, 8, 7.9, 7.3, 7.1
Llanfoist		Greenfield	7.5, 7.4, 7.2
Miskin			11.4, 8.9, 8.9
Wenvoe		Greenfield	7.6, 7.6, 7.3, 8.4

Further analysis of this dataset is presented in Appendix 1. Using only the data from the soil imported to site, the arithmetic pH mean has been calculated using two approaches. The first approach uses the reported pH value whilst the second approach takes into account the fact that pH is the negative of the logarithm to the base ten of the hydrogen ion concentration i.e. pH=-log[H+]. In this second approach the hydrogen ion concentration has first been calculated from the individual pH readings, the average of these values has then been calculated and the average value has then been converted back into pH using the above relationship. As most of the pH values are relatively close in value to each other (and the few values below 7 have been ignored), it is apparent that the two approaches result in similar average values but the average calculated from the ion concentration is lower. For this report, the first approach (using the reported pH values) is used as this can be readily understood, is simple and provides a conservative approach.

The analysis in Appendix 1 reveals that the arithmetic mean of the available soil pH is 8.5. The analysis also reveals, as shown by the histogram below, that most of the soil identified by the Contractor has a pH below 9.5. On this basis, the assessment of a revised pH upper limit is to consider a revision upward from the current limit of 8.5 to a new limit of 9.5.



3.2 Limitations and Application

A review of the original method of determining limits for pH has been undertaken and this review has concluded that the limits set are appropriate for soils that can be used throughout the scheme. In particular, the upper pH limit is set to be protective of the grasses and plants that will become established on the restoration surface. The limit is also important to limit the pH of surface water run-off that will leave the site into the surrounding surface water system. These factors lead to the conclusion that all soils that will lie within the root zone of the grass and are near surface should retain the existing upper pH limit of 8.5. Accordingly, the Specification is not undermined.

The extra dimension of the lack of available soil has required examination of the potential use of soils with adjusted limits; to avoid undermining the Specification rationale this would

be restricted to uses where the soils are not in contact with the root zone and are not near surface. This means that the use of any such soils would be restricted to the lowest layer of the restoration soil layer and would also be restricted in terms of the proportion of soil.

In recognising that the adjustment of the upper pH limit is not ideal, and to ensure that the capping scheme minimises the use of soil between pH 8.5 and pH 9.5, the original Specification limits are not to be adjusted. Instead, it is proposed that a sub-group of Grade B soil is considered with an upper pH limit of 9.5. For clarity, the Grade B soils that meet the current Specification will be termed Grade B whilst the soil with an increased pH limit will be termed Grade Bi. The following limitations will be implemented through the Construction Quality Assurance process:

- New pH criteria (upper limit 9.5) only applies to Grade Bi sources. Grade A soil criteria remain unchanged as do Grade B soil criteria.
- Grade Bi soils that meet the new pH criteria are only to be placed in a layer of no greater than 300mm thickness at the base of the restoration soil profile.
- The Grade Bi soils will be placed as the first layer above the capping membranes and will be overlain with a greater thickness of Grade A or Grade B soils.
- No more than 30% of the total soil input to the site is to be Grade Bi.
- This revision does not require the use of Grade Bi soils, in fact the avoidance of these soils would be better, but where Grade Bi has to be used it is to be used in accordance with these limitations.

4 EVALUATION OF PROPOSED AMENDMENT

This section evaluates the potential impact that the proposed use of Grade Bi soil would have of the environment and human health.

4.1 Potential Source of Increased pH

Natural soil pH in the UK is not commonly found above pH 8.5. Values beyond this range, particularly in soils from urban areas of South Wales, tend to suggest an additional unnatural source of alkalinity i.e. anthropogenic.

Many sources of alkalinity are plausible but given the brownfield nature of several of the soil sources and visual observation of the materials, the most likely source is considered to be concrete, particularly where it has been partly crushed, perhaps during handling, and is present as a 'flour' intimately intermixed with some of the natural matrix. In such cases, the concrete has a high surface area and due to the cement content the material can readily produce an alkaline eluate during contact with water (as occurs during a lab test to measure pH). If the dominant soil matrix is unable to buffer the source of alkalinity during the test the pH of the eluate is alkaline.

4.2 Environmental Context

4.2.1 Location and Description of the Site

The EWMS lies at the eastern edge of the Steelworks and has accepted steelmaking and general wastes from the Llanwern site for four decades. The waste management site is a land raise, 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 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 land raise. EWMS 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 steelworks 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 land raise. 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 within the open collection ditches are directed into Drain 10 of the works effluent treatment system.

The northeastern 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 Buddleia and Thistle.

4.2.2 Surrounding Areas

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. The site is 3.5km from the current estuary boundary which is due to extensive land drainage and sea flood defences maintenance since Roman times. Land use comprises 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.

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 a SSSI, part of the Gwent levels SSSI.

4.2.3 Historical Landfilling

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. A breakdown of the most recent wastes landfilled is provided in Table 4-1.

Table 4-1 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 mixing all waste streams. This gives a diffuse distribution of biodegradable wastes intermixed with very high permeability steelmaking wastes (principally slag based), which themselves have a very high pH.

These wastes have been placed onto the underlying natural ground without an engineered lining system.

4.2.4 Geology

Through a combination of desk study and site investigation the site has been previously found to be underlain by a very uniform sequence of marine (estuarine) clays, freshwater

peat, gravels and Mercia Mudstone bedrock. Some of the investigation locations are indicated on Figure 1. Based on the observations made at these positions a series of interpretive geological cross sections are presented in Figure 2. In each of the boreholes and trial pits the sequence summarised in Table 4-2 was encountered.

Table 4-2 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 AOD the upper clay lies just above Ordnance Datum (i.e. mean sea level). All other strata, including the peat horizon, lies below mean sea level.

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 10-15 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.

4.2.5 Hydrogeology

Ground conditions around the site have previously been investigated through drilling and the installation of groundwater wells. Therefore, groundwater can be monitored and sampled at several locations around the perimeter of the site (see Figure 3). The wells are screened in the shallow waste deposits (shallow groundwater) and in the deeper bedrock. This monitoring is ongoing as part of the Aftercare management.

Groundwater in the waste is typically 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 have been previously found to be approximately 10^{-4} ms^{-1}. The water body in the fill materials has been found to be perched on the Upper Clay layer. This underlying layer has been found to have permeability values of 3.9×10^{-10}, 4.2×10^{-10} and 9.2×10^{-10} ms^{-1}, indicating a stratum of consistently very uniform low permeability.

An examination of the cross sections in Figure 2 and the conceptual hydrogeological model in Figure 4 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, damp peat has been found in each of the boreholes previously drilled with no discernible water strikes. Based on field measurements, the peat has been previously found to have low permeability, ranging from 7.2×10^{-6} to 4.83×10^{-7} ms^{-1} with an average of 2×10^{-6} ms^{-1}.

In every borehole a second, lower clay layer was previously encountered beneath the peat horizon. Samples of the clay has been 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 previous 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 3.6×10^{-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 1.5×10^{-6} to 2.9×10^{-4}, with an average of 1.3×10^{-4} ms^{-1}. Geotechnology considers 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).

4.2.6 Shallow Groundwater Flow

Groundwater flow in the shallow fill has been historically examined by contouring the piezometric surface, as shown using historical data in Figure 5. 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 is considered to act as a fixed head in the fill materials, controlling the rise of groundwater above this level. This mechanism, therefore, also 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 shallow groundwater levels are elevated in

the east. Along this eastern boundary is a low permeability bund that was used to contain the original water settlement ponds. Consequently, a steady state flow system may be established from east to west due to the combination of infiltration recharge through the wastes and the head maintenance at the ditches.

4.2.7 Deeper Groundwater Flow

The groundwater levels in the underlying Mercia Mudstone are sub-artesian and confined by the lower clay layer. Groundwater flow and movement between the upper shallow 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 with variable interconnectivity.

4.2.8 Groundwater Quality

The overall risk from the site to groundwater and environmental receptors was previously described in the Hydrogeological Risk Assessment (HRA) submitted as part of the original Closure Report (see Geotechnology report 525.1/0/0207).

The LandSim model identified that at no time do List 1 substances reach groundwater below the facility. Therefore, the site is not considered to pose a risk to groundwater quality from Hazardous substances throughout the facilities full life cycle and complies with the requirements of the Groundwater Directive. With respect to non-hazardous pollutants, all predicted concentrations at the compliance point were below the established Environmental Assessment Levels, indicating that there is no significant deterioration in groundwater quality.

To ensure that the LandSim predictions are calibrated and that the risks posed are continually monitored, a groundwater monitoring programme was developed and is currently being implemented. This monitoring reveals that shallow groundwater in close proximity to the site is impacted by the passage of infiltration through the unlined waste body and into the made ground, which largely comprises slag waste. This seepage is characterised by elevated pH, electrical conductivity and alkalinity. Groundwater in close proximity to the landfill typically contains low levels of non-hazardous substances which infrequently exceed Environmental Quality Standards and on rare occasions cadmium is detectable, but at low concentrations (<0.02 microg/l).

The levels of non-hazardous and hazardous substances in the deep groundwater is similar to that observed in the shallow groundwater i.e. low and rarely in excess of EQS values. However, the deep groundwater is distinct in terms of pH as pH is significantly lower at approximately pH 8. As this pH is lower than that encountered in the shallow groundwater, the data suggests that there is limited hydraulic connection between the two water bodies, as would be expected due to the low permeability sequence of sediments present.

4.2.9 Surface Water

Due to the inclusion of a low permeability bund on the eastern side of the landfill, there is normally a low risk of surface run-off from the waste body entering the reen system to the east. However, to ensure that the situation is monitored, two sample points have been identified upstream and downstream of the landfill. Also, this situation will be improved once the capping is complete.

Shallow groundwater below the landfill is essentially leachate due to the lack of a formal lining system. As the level and passage of shallow groundwater is influenced by the surface ditches surrounding most of the other parts of the site, the surface water quality is characterised by strongly alkaline pH (typically >12 pH units) and low levels of metals due to predominance of slag based wastes.

4.3 Impact on Receiving Water

Once the capping scheme is complete, rainfall falling onto the site will pass through vegetation before encountering the gently profiled restoration soils. As the restoration soils comprise cohesive soils with low permeability, run-off would then be expected to report to the leachate collection ditches surrounding the site. Therefore, the principal receiving waterbody for run-off from the restoration soils is the collection ditches around the landfill.

Monitoring and visual observation of these ditches clearly reveals that historical and ongoing leaching of the predominantly slag based wastes has resulted in surface water characterised by a strongly alkaline pH. Once the capping works are complete, infiltration to the wastes will become reduced and with time, the water quality in the ditches will likely be mostly influenced by run-off from the restoration soils, ingress of shallow groundwater from below EWMS and localised infiltration through the surrounding slag layers. Once the cap casts a rainwater shadow, the ditches will likely receive much less seepage from infiltration leaching the waste mass in EWMS. In this (long-term) scenario, the quality of the restoration soils will be important but due to the dominance of slag based wastes surrounding the channels, the water quality is likely to remain strongly alkaline until the sources of alkalinity in the slag have been exhausted. This is why these ditches are directed to the on-site water treatment works and do not directly enter the wider environment.

Allowing the lower layer of the restoration soils to have a wider pH window of acceptability will not unduly influence surface water quality. Rainfall landing on the restored cap will report to evapotranspiration, run-off and infiltration, with the infiltration fraction dividing into soil moisture (field capacity) and through-flow. It is only the through-flow component that will contact the lower restoration soil and therefore only a small proportion of the antecedent rainfall reporting to the surface water ditches will have any potential to have a raised pH. In any event, the pH levels will be dramatically lower than those currently experienced in the surface water ditches. By restricting the proportion of Grade Bi soils, applying the upper limit of pH 9.5 and using Grade Bi soils in the particular manner outlined in this report the expected long-term improvements of surface water quality that will be initiated by the capping will not be compromised.

4.4 Impact on Human Health

Tata currently has no intention of an after-use that would be utilised in terms of either residential, commercial or industrial use. Consequently, the only people likely to be accessing the site following the placement of the capping systems will be personnel involved with long-term maintenance and monitoring. Given the use of the Grade Bi soil is restricted to the initial 300mm of cover to the capping system and a Grade A or B cover of at least the same thickness there is no risk of human exposure encountering the sub-soils. Further, by limiting the upper limit to pH 9.5 the consequence of any negative impact potentially occurring is reduced. The likelihood of exposure will also be limited by vegetation being encouraged and the top layer of restoration soil having a pH that meets the Specification.

4.5 Impact on Flora and Fauna

Tata is not intending to create a restoration scheme that requires the use of high quality selective grass mixes for specialist purposes. Instead, the intention is to create a stable platform that will support selected species tolerant of the site conditions. As increased pH can potentially affect root growth and plant health, ADAS has provided specialist input specifically on this aspect. Their assessment is included in Appendix 2. ADAS concludes that modifying the Specification to accommodate a 300mm starter layer with pH up to 9.5 is not likely to undermine the achievement of the restoration objectives.

5 MONITORING OF PROPOSALS

Due to the duration of the capping works there is an opportunity to validate the acceptability of Grade Bi soil during the current phase and before the next phase commences.

5.1 Current Phase

Samples of run-off will be collected during the works to enable the measurement of pH from uncovered Grade Bi soil surfaces and also from covered surfaces (Grade A and B).

5.2 Following Current Capping Phase

Prior to the capping works scheduled for 2017, samples of run-off from the capped areas will continue to be collected and analysed for pH. This data will be reviewed prior to the 2017 capping works.

6 CONCLUSIONS AND SUMMARY

As part of the ongoing EWMS capping works a significant amount of restoration soil is required. The contractor has failed to find large single sources of soils meeting the Specification and instead several smaller sources have been imported and are candidates. In some cases, the soil pH of the candidate sources identified to date is higher than the upper limit of 8.5 pH units detailed in the restoration soil Specification. In order to allow the site to continue in a timely manner, Tata has requested that the environmental impact of using soils with slightly higher pH is considered.

An evaluation of the potential impact of allowing the soil upper pH limit to be increased to pH 9.5 has been made. In doing so Geotechnology, and specialist advisers, have considered how such soils could be used at the site and have identified ways in which the soils could be placed within the scheme without unduly influencing the surrounding environment or undermining the restoration objectives. The assessment suggests that incorporating a proportion of soils with this raised pH level into the lowermost restoration layer should not compromise the long-term capping objectives provided the overlying soils continue to meet the Grade A and Grade B requirements. Samples of run-off should be collected to assess the behaviour of placed soils.

Raising the pH limit in Grade Bi soils should help the Contractor locate acceptable soil sources whilst still enabling Tata to achieve its capping objectives. Grade Bi soils will be limited to 30% of the soil total or 120,000tonnes, whichever is smaller. Grade Bi soils will only be placed as a starter layer directly onto the capping geosynthetics, and then in a layer no thicker than 300mm. Grade Bi soils without acceptable shear box test results will only be permitted on the plateau area. Grade Bi soils will be directly overlain with no less than 300mm of Grade A or Grade B soils.

Figure 1 Site Investigation Locations

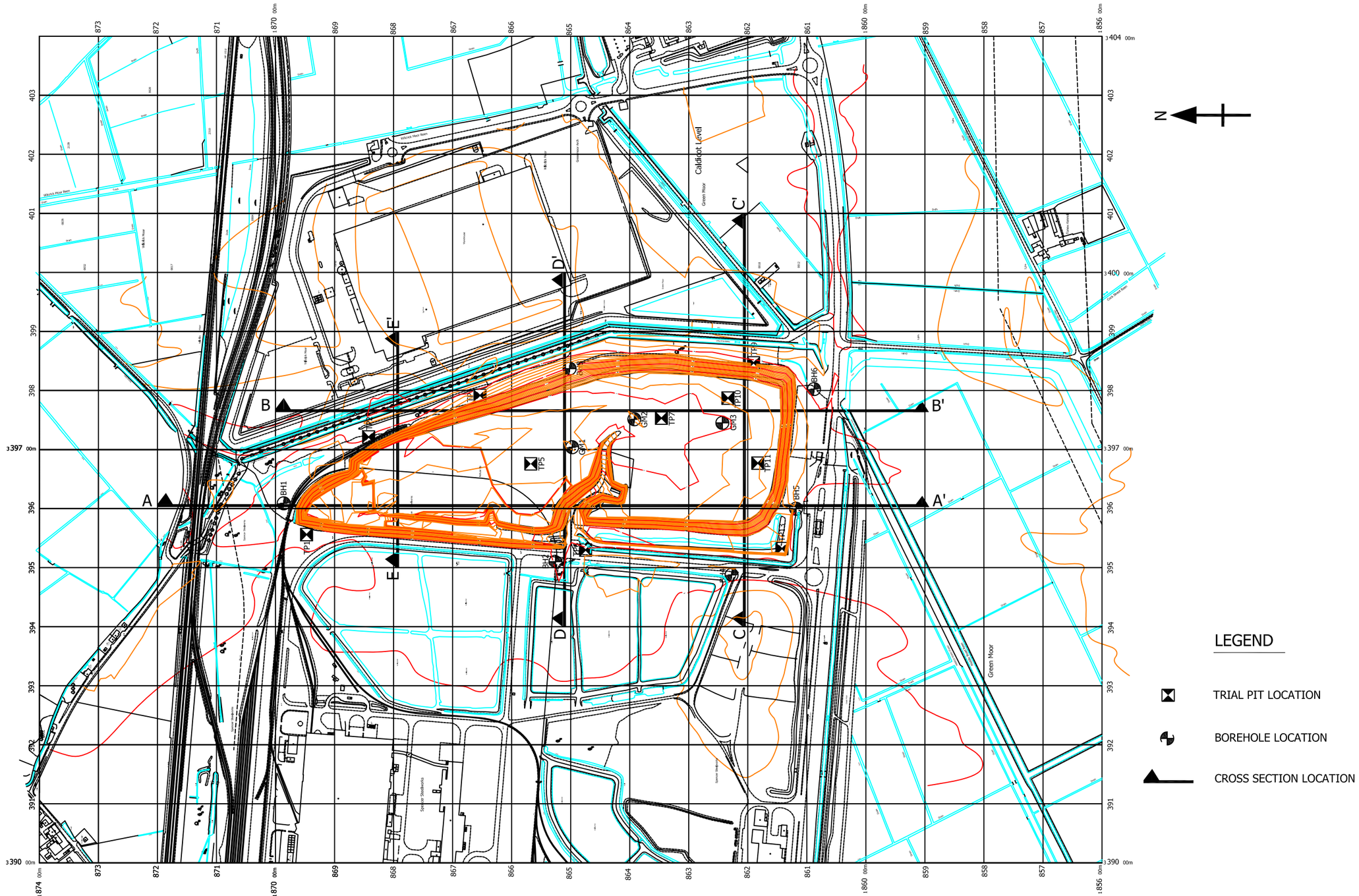
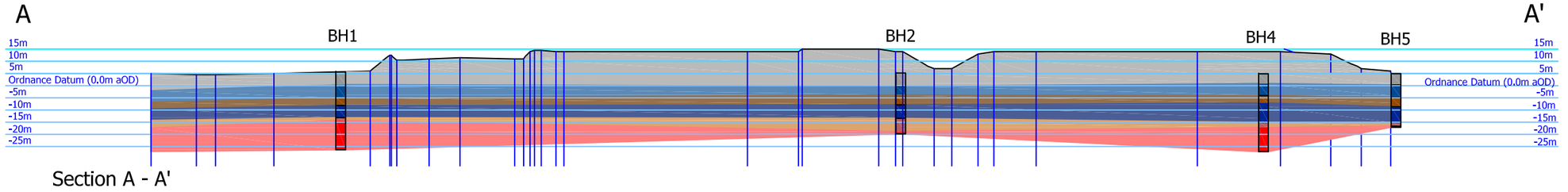
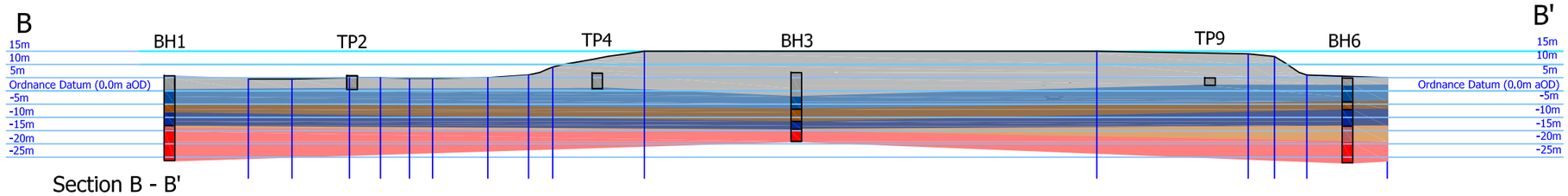
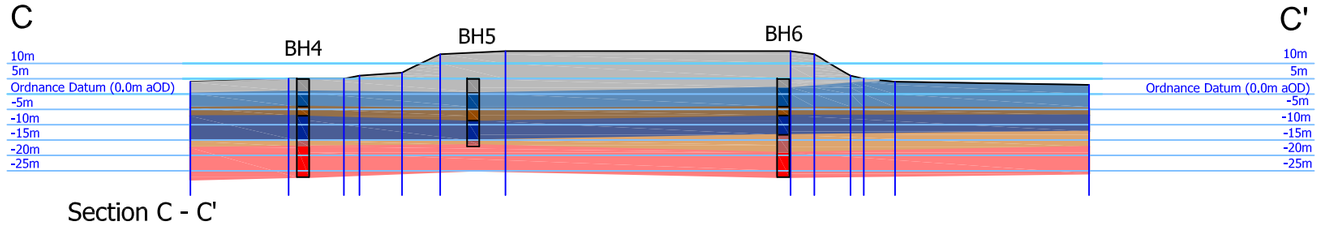
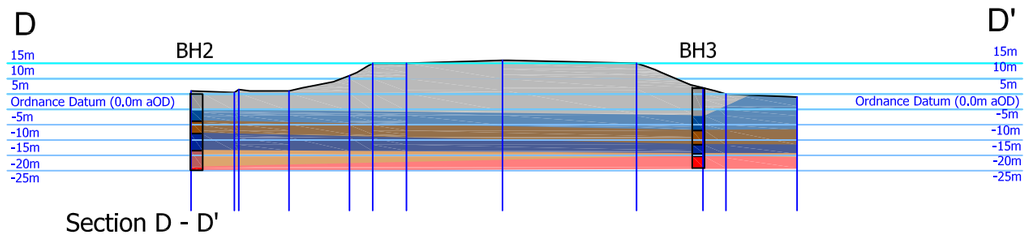


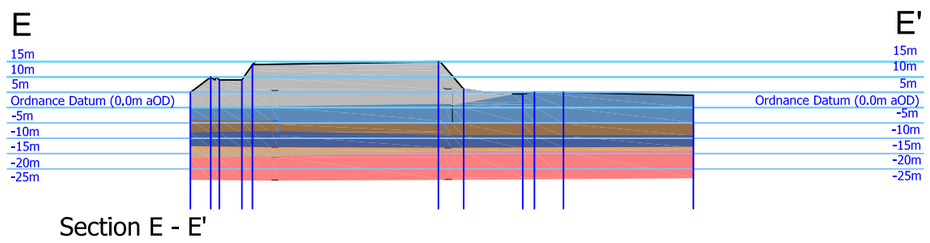
Figure 2 Geological Cross Sections













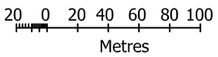


Figure 3 Available Monitoring Network

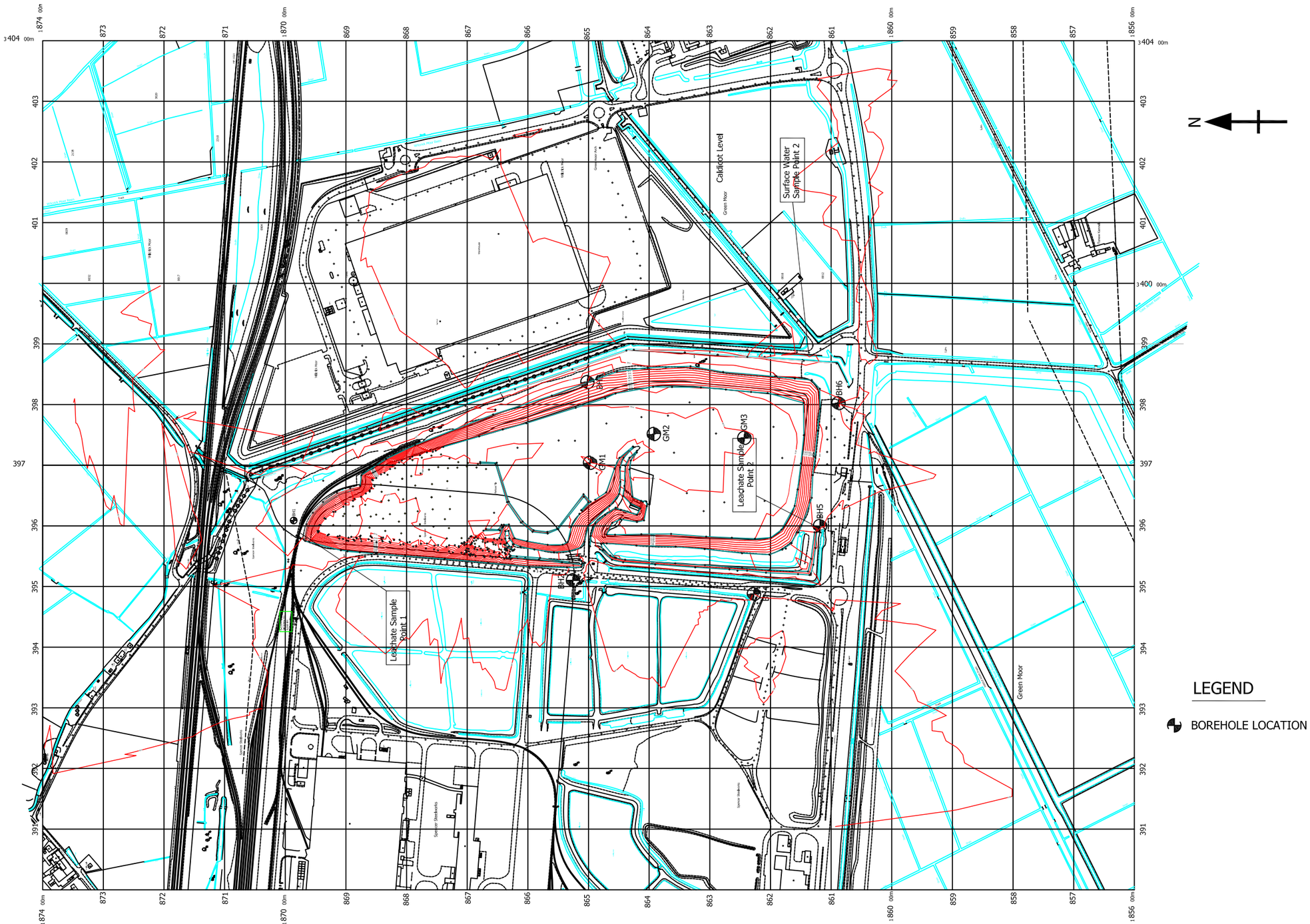


Figure 4 Hydrogeological Conceptual Site Model

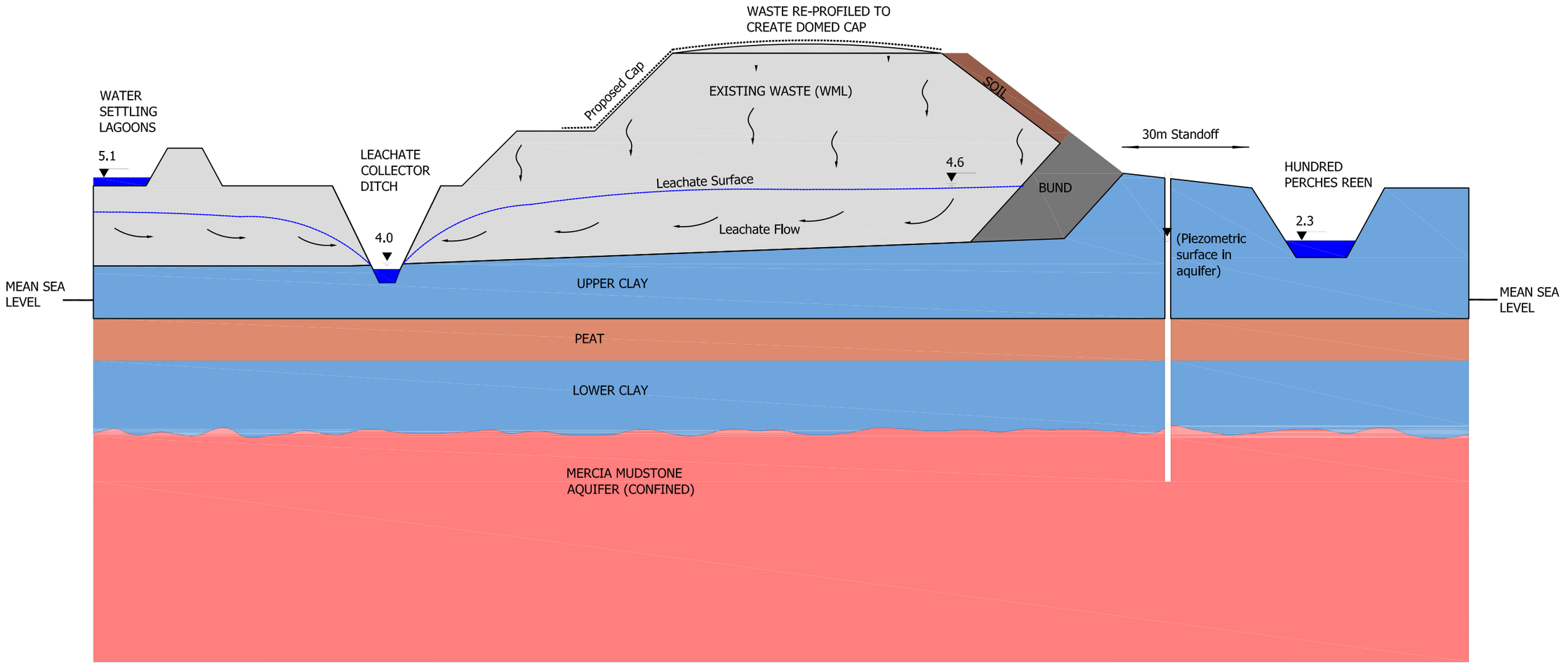
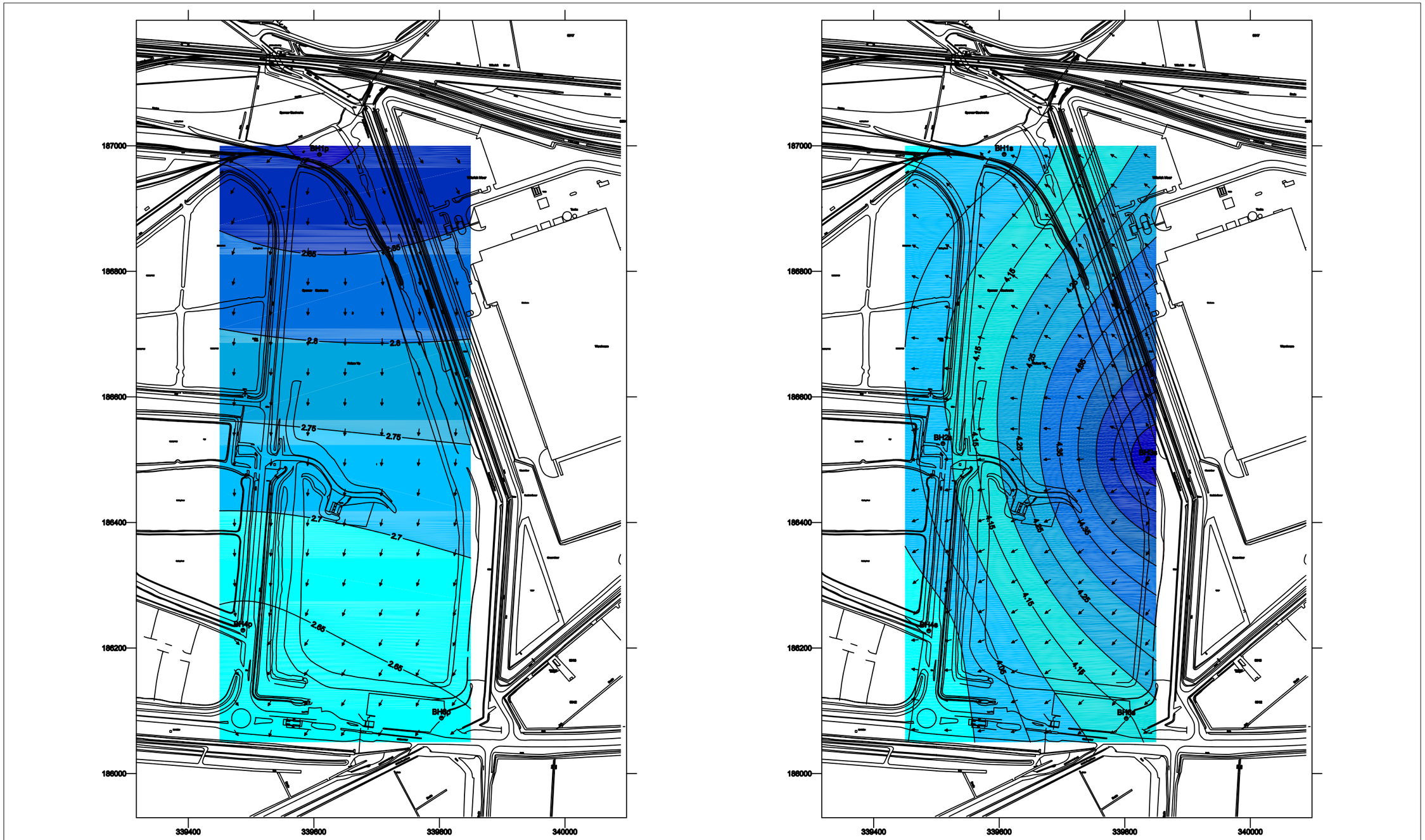


Figure 5 Historical Groundwater Levels



AQUIFER FLOW

LEACHATE FLOW

LLANWERN EAST WASTE MANAGEMENT SITE
TATA STEEL
LLANWERN

Restoration Soil pH Review
Environmental Effects

Appendix 1
Soil pH Evaluation
Report Number 1546r1v1d0716

	Cuddy Data		Validation Data		
	Approach 1	Approach 2	Approach 1	Approach 2	
	pH	H+	pH	H+	Comment
Arithmetic mean (pH)	**8.5**	**1.3E-08 (pH 7.87)**	**8.9**	**3.2 E-09 (pH 8.5)**	**Comment**
Bargoed	8.1	7.94E-09	8.3	5.01E-09	
	8.3	5.01E-09			
	8	1.00E-08			
Pyle 2	9.2	6.31E-10			
Gaer	8.6	2.51E-09	9.3	5.01E-10	Inert WAC
Merthyr	9.5	3.16E-10	10.6	2.51E-11	
Newport Docks	9.6	2.51E-10	8.9	1.26E-09	
	7.61	2.45E-08			
Birchgrove	8.4	3.98E-09	8.7	2.00E-09	
	8.5	3.16E-09			
HOV Brynmawr	7.8	1.58E-08	8.8	1.58E-09	
	7.8	1.58E-08			
	7.6	2.51E-08			
	7.5	3.16E-08			
Pontypool & Always	9.5	3.16E-10	9.4	3.98E-10	
	8.3	5.01E-09	9.2	6.31E-10	
	9.4	3.98E-10			
	8.8	1.58E-09			
	8.2	6.31E-09			
	9.2	6.31E-10			
	8.3	5.01E-09			
	8.6	2.51E-09			

	Cuddy Data		Validation Data		
	Approach 1	Approach 2	Approach 1	Approach 2	
	pH	H+	pH	H+	Comment
Caldicot Bridge			8.4	3.98E-09	
Goytre	8.4	3.98E-09	8.5	3.16E-09	
Cwmbran	8.26	5.50E-09	8.3	5.01E-09	Inert WAC
	8.1	7.94E-09			
Argus, Pentwyn, Pontprenr	7.9	1.26E-08	8.3	5.01E-09	Inert WAC
	7.8	1.58E-08	9.27	5.37E-10	
	8.4	3.98E-09	10.5	3.16E-11	
	7.9	1.26E-08	9.05	8.91E-10	
	7.9	1.26E-08	8.36	4.37E-09	
	7.6	2.51E-08	8.1	7.94E-09	
	8	1.00E-08			
	7.9	1.26E-08			
	7.7	2.00E-08			
	8	1.00E-08			
	7.8	1.58E-08			
	7.3	5.01E-08			
	8.3	5.01E-09			
Additional argus, orb pentv	9.9	1.26E-10			
	9.8	1.58E-10			
	9.6	2.51E-10			
	9.4	3.98E-10			
	9.7	2.00E-10			
	9.5	3.16E-10			
	9.7	2.00E-10			
	9.8	1.58E-10			
	9.7	2.00E-10			
	9.6	2.51E-10			
	9.1	7.94E-10			
	8.9	1.26E-09			
	9	1.00E-09			
	9	1.00E-09			
	10.9	1.26E-11			
Caldicot	7.5	3.16E-08			
	7.6	2.51E-08	7.8	1.58E-08	
	7.5	3.16E-08			
	7.2	6.31E-08			
	7.7	2.00E-08			
	7.5	3.16E-08			
	7.7	2.00E-08			
	7.3	5.01E-08			
	7.7	2.00E-08			
	7.2	6.31E-08			
	8.2	6.31E-09			
	7.2	6.31E-08			
	7.7	2.00E-08			
	9.1	7.94E-10			

	Cuddy Data		Validation Data		
	Approach 1	Approach 2	Approach 1	Approach 2	
	pH	H+	pH	H+	Comment
Orb	9.5	3.16E-10			
	10	1.00E-10			
Lysaght and Pyle	8.1	7.9433E-09			
	10.8	1.5849E-11			
	9.9	1.2589E-10			
	9.8	1.5849E-10			
	8.95	1.122E-09			
	9.31	4.8978E-10			
	8.99	1.0233E-09			
	9.38	4.1687E-10			
	9	1E-09			
	8.2	6.3096E-09			
	7.8	1.5849E-08			
	8.2	6.3096E-09			
	7.4	3.9811E-08			
	7.9	1.2589E-08			
	7.4	3.9811E-08			
	7.4	3.9811E-08			
	7.8	1.5849E-08			
	7.21	6.166E-08			
	7.38	4.1687E-08			
	8.5	3.1623E-09			
	8.7	1.9953E-09			
	8.8	1.5849E-09			
	8.9	1.2589E-09			
	7	0.0000001			
	8.1	7.9433E-09			

LLANWERN EAST WASTE MANAGEMENT SITE
TATA STEEL
LLANWERN

Restoration Soil pH Review
Environmental Effects

Appendix 2
ADAS Evaluation of Soil pH on Plant Growth
Report Number 1546r1v1d0716



Report

Review of the potential effect on plant growth of using high pH soil for capping at Tata Steel Llanwern East Waste Management Site

Reference No:

Issued by: Phil Metcalfe

Date: July 2016

Submitted to: Mr Ewan Thomas Geotechnology Ltd

Contents

1 Executive Summary 1

2 Introduction 2

3 Objectives 2

4 Soil pH 3

5 Plant growth on high pH soils imported to EWMS 5

6 Conclusions and recommendations 8

1 Executive Summary

- The contractors carrying out the capping of the Tata Steel Llanwern East Waste Management Site (EWMS) are experiencing difficulties in sourcing sufficient soil that satisfies the Design and Specification maximum pH requirement of 8.5 for Grade A and Grade B soils. There is a proposal to increase the maximum pH allowable to 9.5 for a starter layer 300mm thick. The soil with a Design and Specification proposed permitted maximum pH of 9.5 is referred to as Grade Bi. The purpose of this report is to assess the potential effect on plant growth of raising the maximum allowable pH to 9.5 (for Grade Bi soil) in a 300mm starter layer.

- **pH and Nutrients:** The main potential effect of high pH on plant growth is reduced trace element availability from the soil and plant uptake. As major plant nutrient and trace element uptake is mainly from the upper layers of soil the pH of a 300mm starter layer is unlikely to significantly affect major nutrient and trace element supply to plants.
- **Tests and analysis:** Currently the chemical testing of soils to be used for capping focuses on pH, potentially toxic metallic elements, polyaromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), polychlorinated biphenyls (PCBs), phenols and asbestos i.e. potentially toxic substances. To determine the suitability of the final restoration surface, analysis for major plant nutrients (available phosphorus, potassium and magnesium) should also be carried out. The sampling for this analysis could be undertaken on a grid basis after the soil has been spread over the site. From these phosphate, potash and magnesium requirements are assessed e.g. for seeding the site with grass. For the up to pH 9.5 Grade Bi soil to be used as a lower capping layer the risk of soil structure instability should be assessed by checking the exchangeable sodium percentage (ESP) e.g. an estimate from extractable (in Molar ammonium nitrate solution) potassium, magnesium, calcium and sodium or more accurately from exchangeable potassium, magnesium, calcium and sodium and cation exchange capacity (CEC).
-

2 Introduction

Tata Steel (UK) Ltd is currently capping the closed non-hazardous landfill at its Llanwern works known as the East Waste Management Site (EWMS). The area of the site is 19.78ha. As part of the capping works 400,000 tonnes of imported soil is required. The Design and Specification approved by Natural Resources Wales (NRW) for the capping includes a maximum pH of 8.5 for the imported soil. The contractors (Cuddy) carrying out the capping had aimed to secure the soil required from a small number of greenfield sites but soils have proved difficult to secure. Currently only 50,000 tonnes have been secured of which only a part is from greenfield sites. Smaller volumes from many brownfield sites are now being considered. Most of the brownfield sourced soils have a pH slightly above the Design and Specification maximum of 8.5. This has led to the sources not being approved for use as capping soil. Following discussion being Tata and Cuddy, Geotechnology (Designers and CQA Consultant for the restoration scheme) has been requested by Tata to investigate the scope for adjusting the pH upper limit on some or all of the soils so that soil can be more readily sourced. Tata may accept a relaxation of the upper pH limit if it does not unduly affect the quality of the restoration or pose unacceptable risks to the environment and human health. Tata would only consider an amendment to the Specification if NRW accepts any proposed revision. Geotechnology has produced a report evaluating the potential environmental impact of increasing the upper pH limit by one pH unit, from a limit of 8.5 to 9.5. The report suggested that incorporating a proportion of soils with this raised pH level into the lowermost restoration layer should not compromise the long-term capping objectives provided the overlying soils continue to meet the Grade A and Grade B requirements. The suggested capping specification using higher pH soil (up to 9.5) [referred to as Grade Bi soil] involves a layer of this soil no thicker than 300mm placed as a starter layer directly onto the capping geosynthetics. Also Grade Bi soils used for the capping should not represent more than 30% of the total or 120,000 tonnes, whichever is the smaller.

3 Objectives

The objectives of this report are to:

- Review the effects of increasing the specification pH from 8.5 to 9.5 for a 300mm starter layer on plant establishment and growth.
- Provide evidence that the available soils will be able to sustain grassland in pursuance of the permitted restoration

Tata's intention is not to restore EWMS for agricultural crop production. The intention is to create soil conditions on the site that will support selected species tolerant of the site condition.

4 Soil pH

The 'natural' pH of soil depends on the parent material. Soils which naturally contain calcium carbonate e.g. soils developed on chalk, limestone or in calcareous clays have pHs up to around 8. Mainly in arid and semi-arid regions high soil pHs (up to around 10) can occur when irrigation is carried out with water containing high quantities of sodium and bicarbonate. The main problem in this situation is that the sodium can cause 'defloculation' of clay by replacing calcium on the soil exchangeable complex. This can cause soil structure deterioration with consequent risk of reduced water infiltration.

The high pH of some of the brownfield site soils being considered is likely to be caused by calcium (and not sodium) containing alkaline materials (mainly calcium carbonate, calcium hydroxide and calcium oxide) derived from small amounts of concrete entrained in the soil. This is particularly the case when some of the concrete fragments have partly disintegrated to produce a 'flour'.

In terms of plant nutrition, the main effect of high soil pH is reduced availability for plant uptake of trace elements (iron, manganese, boron, copper and zinc). This is illustrated in Figure 1. Furthermore, Molybdenum, a trace element that is not shown in Figure 1, becomes more available as soil pH increases. The bulk of plant nutrient uptake is from the upper soil layer. This is reflected in the depths of soil analysis recommended for determining plant nutrient requirement. These are 150mm for arable crops and short term grass leys or for permanent and long term grass 75mm. The pH of the soil in a 300mm starter layer is therefore unlikely to affect the quantities of major nutrients and trace elements taken up by plants.

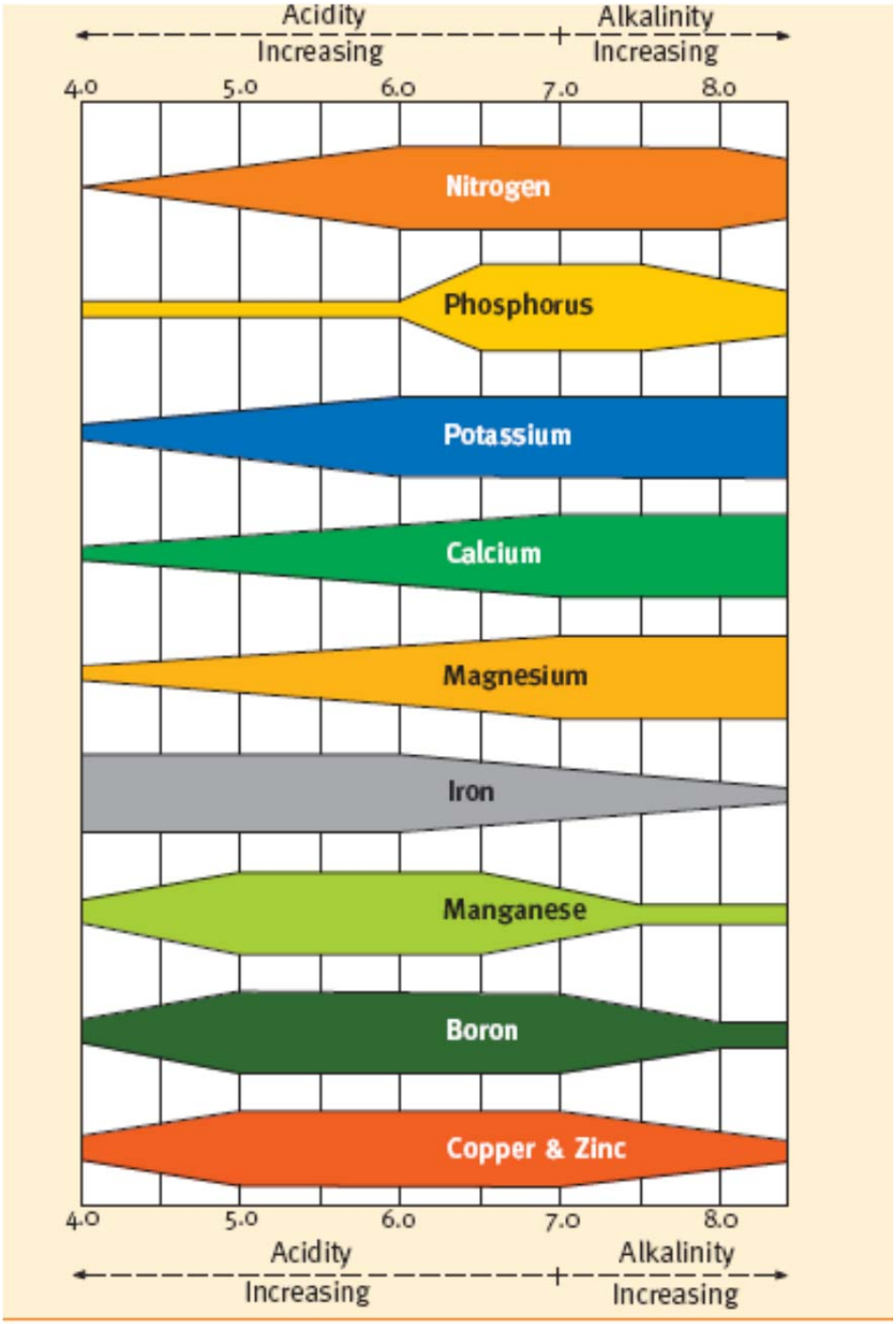


Figure 1: Effect of soil pH on major nutrient and trace element uptake by plants

5 Plant growth on high pH soils imported to EWMS

Vegetation is growing on the stockpiles of brownfield soils imported to EWMS. Photos 1, 2, 3 & 4 were taken during the site visit on Monday 13th June 2016. Photos 1 & 2 show the vegetation growing on untreated (by screening) imported brownfield site soil. Photos 3 & 4 show the vegetation growing on treated (by screening) imported brownfield site soil.

Photo 1: Vegetation growth on untreated (by screening) imported brownfield site soil



Photo 2: Vegetation growth on untreated (by screening) imported brownfield site soil



Photo 3: Vegetation growth on treated (by screening) imported brownfield site soil



Photo 4: Vegetation growth on treated (by screening) imported brownfield site soil



6 Conclusions and recommendations

- As it is proposed that the revised Design and Specification Grade Bi soils (maximum pH 9.5) will only be used as a 300mm starter layer it is not likely to have a significant impact on plant growth.
- Currently the chemical testing of soils to be used for capping focuses on pH, potentially toxic metallic elements, polyaromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), polychlorinated biphenyls (PCBs), phenols and asbestos i.e. potentially toxic substances. To determine the suitability of the final restoration surface, analysis for major plant nutrients (available phosphorus, potassium and magnesium) should also be carried out. The sampling for this analysis could be undertaken on a grid basis after the soil has been spread over the site. From these phosphate, potash and magnesium requirements are assessed e.g. for seeding the site with grass. For the up to pH 9.5 Grade Bi soil to be used as a lower capping layer the risk of soil structure instability should be assessed by checking the exchangeable sodium percentage (ESP) e.g. an estimate from extractable (in Molar ammonium nitrate solution) potassium, magnesium, calcium and sodium or more accurately from exchangeable potassium, magnesium, calcium and sodium and cation exchange capacity (CEC).
- Table 4 shows the phosphate, potash and magnesium requirements for seeding with grass according to the Index found by soil analysis.

Table 4: Phosphate, potash and magnesium recommendations for grass establishment

	Phosphorus, potassium or magnesium Index				
	0	1	2	3	Over 3
	kg/ha				
Phosphate (recommendation as P_2O_5)	120	80	50	30	Nil
Potash (K_2O)	120	80	60 (2-) 40 (2+)	0	0
Magnesium (recommendation as MgO)	50	0	0	0	0

Notes

- In addition 30-60kg/ha nitrogen would also be recommended – 60kg/ha if grass establishment is in the spring and 30kg/ha if grass establishment is in the autumn. On agricultural land no nitrogen is recommended for autumn grass establishment but some would advisable on restored land.
- The recommendations can be met by manufactured fertilisers or a combination of manufactured fertilisers and organic manures.



Geotechnical &
Environmental Services

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

T 01639 775293
F 01639 779173

enquiries@geotechnology.net
www.geotechnology.net