East Tip, Haulbowline Island, Cork

EPA EIS Scoping Query
(Addendum to Detailed Quantitative Risk Assessment)

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	Yvonne Buchanan	**Cecilia MacLeod**	**Yvonne Buchanan**
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Cork County Council
Comhairle Contae Chorcaí

SKM ENVIROS

DETAILED QUANTITATIVE RISK ASSESSMENT PEER REVIEW

In February 2012 SKM Enviros (SKME) were appointed by Cork County Council from their Multi-Disciplinary Environmental Advisory Services in relation to the waste licensing and land remediation/reclamation project at Haulbowline Island, Co Cork. Under the scope of services relating to this framework agreement is the requirement to undertake peer review of a number of technical reports and studies carried out by other consultancy providers appointed by Cork CC under a parallel framework agreement.

In May 2012 Cork CC requested that SKME provide on-going technical peer review related services to assist in the delivery of a Detailed Quantitative Risk Assessment (DQRA) and supporting investigations at the East Tip in order to progress towards assessment of potential remedial options to support remediation and reclamation of the site.

WYG Environmental Planning and Transport Ltd (WYG EPT Ltd) have undertaken detailed site investigations and a quantitative risk assessment of the East Tip, details of which are contained within the attached report.

SKM Enviros have undertaken an independent technical review of the investigations and subsequent report, which has included a review of the overall approach adopted and a review of work and methodologies employed against current relevant national and international best practice and guidance. Having completed our review we are in agreement with the methodologies applied, the report findings, and the conclusions and recommendations contained therein. It should be noted that in completing our review, factual information presented within the report such as geological data, testing and analysis data compiled by WYG EPT Ltd. has been taken at face value by SKM Enviros as being factually correct.

For and on behalf of SKM Enviros

M. McDonald

Mike McDonald

Project Manager

18th October 2013

Executive Summary

Instruction and outline	WYG Environment, Transport and Planning (WYG EPT) were appointed by Cork County Council (CCC) on 27th January 2012, for the provision of multi-disciplinary environmental consultancy services for the site investigation and Detailed Quantitative Risk Assessment (DQRA) of the East Tip, on Haulbowline Island in Cork Harbour. This project relates to geo-environmental services required under Phase IV of the Council's regularisation programme of the waste in the East Tip (http://www.corkcoco.ie/haulbowline) which involved the completion of intrusive site investigations and a Detailed Quantitative Risk Assessment (DQRA). (CCC, 2013) WYG were further instructed to assess the post-remediation contamination potential of groundwater in the waste and potential risks to Cork Harbour water as an addendum to the DQRA as the result of an EIS scoping query raised by the EPA on whether concentrations in groundwater in the waste would increase following remediation. Proposed remediation includes for a low permeability capping layer and perimeter engineered structure.
Aims	The overall aim of the works completed at the East Tip was to undertake an assessment of the significance of the risks to human health and the environment receptors, in order to assist in identifying risks which may require mitigation as part of the licensing process. Specifically, this report aims to address a query raised by the EPA, which is whether concentrations of potential contaminants in groundwater in the waste will increase following remediation which currently includes providing a low permeable capping layer and perimeter engineered structure. The aim was to complete this by evaluating and predicting post-remedial concentrations of contaminants of concern in groundwater in the waste and assess their significance in regard to their potential to pollute Cork Harbour waters.
Predicting Post Remedial Groundwater Concentrations	The Tier 2 Remedial Target Methodology has been used conservatively to predict concentrations in groundwater in the waste following remediation with a reduced infiltration capping layer and perimeter engineered structure as these will control leachate generation and dilution from tidal water ingress. The RTM model utilising data presented in the DQRA report (WYG, 2013), including the permeability of the capping layer as the infiltration input and permeability of the proposed perimeter engineered structure as the hydraulic conductivity input, predicted that concentrations of chromium, chromium VI, copper, zinc nickel and manganese as key contaminants of concern would decrease slightly when compared to the averages calculated from actual measured concentrations in the DQRA report (WYG, 2013).
Geochemical Modelling	It is likely that the proposed remediation for the East Tip through the use of a perimeter engineered structure and capping system will change the geochemical profile of the groundwater within the waste. In order to assess these possible changes, modelling using the well known and internationally recognized geochemical equilibrium partitioning model (MINOTEQ) has been undertaken. The geochemical modelling completed for chromium and manganese (particular contaminants of potential concern in groundwater within the waste highlighted in the DQRA) using MINTEQ showed that under increasingly reducing conditions which might be reasonably expected to occur following remediation the concentrations of hexavalent chromium species (which are potentially the contaminants that present the greatest risk to the water environment) are expected to decrease with the trivalent form of chromium being the most stable form under reducing conditions, considered to be likely following remediation. Furthermore, as conditions change beneath the capping layer with reduced infiltration of rainwater and reduced infiltration of tidal water through the perimeter engineered structure some precipitation of chromium oxide is predicted to occur.
Water DQRA Context and Conclusions	The concentrations predicted from the RTM and geochemical modelling for the post remediation scenario are less than those utilised in the DQRA bespoke flux and dilution model which were shown to be attenuated by the permeability (10^{-5}m/s) proposed for the perimeter engineered structure. As a result the concentrations predicted in groundwater in waste post remediation which are less than those predicted during the DQRA, following discharge through the perimeter engineered structure and dilution, are unlikely to result in a WQSs being exceeded for Cork Harbour waters.

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1 Introduction

1.1 Instruction

WYG Environment, Transport and Planning (WYG EPT) were appointed by Cork County Council (CCC) on 27th January 2012, for the provision of multi-disciplinary environmental consultancy services for the site investigation and Detailed Quantitative Risk Assessment (DQRA) of the East Tip, on Haulbowline Island in Cork Harbour, (Figure 1 and Figure 2). This project relates to geo-environmental services required under Phase IV of the Council's regularisation programme of the waste in the East Tip (http://www.corkcoco.ie/haulbowline) which involved the completion of intrusive site investigations and a Detailed Quantitative Risk Assessment (DQRA) (CCC, 2013).

WYG were further instructed to assess the post-remediation contamination potential of groundwater in the waste and potential risks to Cork Harbour water as an addendum to the DQRA as the result of an EIS scoping query raised by the EPA on whether concentrations in groundwater in the waste would increase following remediation. Proposed remediation includes for a low permeability capping layer and perimeter engineered structure.

1.2 Legal Context and Assessment Framework

The European Court of Justice ruling in case C494/01 requires that the East Tip is regularised in accordance with the Waste Framework Directive (WFD) (licensing requirements) and in particular an application will be made to the Environmental Protection Agency (EPA) for a waste licence.

The Environmental Risk Assessment for the East Tip, including site investigations and monitoring, completion of DQRA and design of an appropriate outline remediation plan, are required to support this process and have been presented in a DQRA report (WYG, 2013). The assessment work, as an addendum to the DQRA report (WYG, 2013) and as presented in this report, has been completed in accordance with best practice guidance documents including "Framework Approach for the Management of Contaminated Land and Groundwater at EPA Licensed Facilities" (EPA, 2012); the "Code of Practice: Environmental Risk Assessment for Unregulated Disposal Sites" (EPA, 2007) and the "Model Procedures for the Management of Land Contamination – Contaminated Land Report" (EA, 2004). This latter piece of guidance is specifically relevant to land contamination in the United Kingdom (UK), however it is relevant as the EPA's framework has been broadly based on it.

The framework approach identifies three stages as outlined below:

- Stage 1 – Site Investigation and Assessment including
    - Preliminary Site Assessment
    - Detailed Site Investigation
    - Quantitative Risk Assessment
- Stage 2 – Corrective Action Feasibility and Design
    - Outline Corrective Action Strategy (Objectives)
    - Feasibility study and outline design
    - Detailed design
    - Final Strategy and implementation plan
- Stage 3 – Corrective Action Implementation and Aftercare
    - Enabling works
    - Corrective Action Implementation and Verification
    - Aftercare

This assessment presented in this report presents the results of predictive geochemical and detailed quantitative risk assessment under potential post remedial conditions for metal contaminants in groundwater in waste in the East Tip, in accordance with Stage 1 above.

The risk assessment process is underpinned by the establishment and continual refinement of a Conceptual Site Model (CSM). A CSM describes the potential sources of contamination at a site, the contaminant migration pathways it may follow and the receptors that could be or are being impacted. When all three are present i.e. source, pathway and receptor, then a potential pollutant linkage is considered to be present, requiring characterisation and assessment in order to determine whether remedial works are needed to adequately address any potentially unacceptable risks.

1.3 Limitations of the Report

Attention is drawn to the report conditions, included in Appendix A.

1.4 Aims and Objectives

The overall aim of the work completed at the East Tip and this report is to present the results of an assessment of the significance of the risks to human and the environment receptors, in order to assist in identifying risks which may require mitigation as part of the waste licensing process.

Specifically, this report aims to address a query raised by the EPA as item 6 in a response on the EIS scoping request from An Bord Pleanála, which is whether concentrations in groundwater in the waste will increase following remediation which currently includes providing a low permeable capping layer and perimeter engineered structure.

The scope of work included:

- Predicting post-remedial contaminants of concern concentrations in groundwater in the waste;
- Assessment of predicted contaminants of concern concentrations in groundwater in the waste to assess their significance through comparison with relevant standards and thresholds;
- Assessment of impact of remediation on speciation of contaminants in shallow groundwater beneath the site;
- Consideration in the context of the DQRA and assessment of potential impacts to Cork Harbour waters;
- As necessary, presentation of a revised conceptual site model should any unacceptable pollutant linkages be identified.

It should be noted that the term “waste” utilised within this report refers to non-natural materials which have been deposited in the East Tip above alluvium or natural sediments. Any use of the term “soil” within this report refers to natural materials, soils or sediments, including alluvium, sands, silts, clays and gravel.

1.5 Initial Conceptual Site Model

In regard to post remediation conditions the following conceptual site model has been presented for consideration and assessment in the following sections of this report.

Table 1 - Initial Conceptual Site Model – Water

Source	Pathway	Receptor
Potential for post remedial increasing metal concentrations in groundwater in the waste	leaching from unsaturated zone (Reduced)	Cork Harbour waters
	Reduced leaching within tidal zone through wetting and drying (Reduced)	Cork Harbour waters
	Lateral and vertical water movement (with decreased dilution)	Cork Harbour waters
	Uptake by flora and fauna	Flora and fauna in Cork Harbour particularly on foreshore

1.6 Report Content

This report sets forth the findings of this study in the following chapters:

Chapter 2	Predicting Concentrations, RTM Tier 2
Chapter 3	Geochemical Modelling
Chapter 4	Water DQRA Context
Chapter 5	Conclusions

2 Predicting Concentrations RTM Tier 2

The following sections present the results of Remedial Targets Methodology (RTM) Tier 2 DQRA model runs for key metal contaminants of concern in the solid phase (i.e. within the wastes contained within the East Tip) leaching to groundwater. The Tier 2 RTMs have been used conservatively to predict metal concentrations in groundwater in the waste following remediation of the site through the use of a capping layer which will have the effect of reducing infiltration and a perimeter engineered structure as these will control leachate generation and dilution from tidal water ingress.

2.1 Methodology

To assess the potential risk posed by solid phase contaminants leaching to impact groundwater, the following guidance and model have been utilised: Environment Agency 2006, Remedial Targets Methodology – Hydrogeological Risk Assessment for Land Contamination (EA, 2006).

This guidance defines a tiered system to assess risks to controlled waters from impacted soils and groundwater. These tiers can be summarised as follows.

- Tier 1 assesses the partitioning of a contaminant from the solid phase into the aqueous phase and compares calculated contaminant concentrations in 'pore water' to the target concentration;
- Tier 2 considers dilution by the receiving groundwater and whether this is sufficient to reduce contaminant concentrations to acceptable levels;
- Tier 3 considers whether natural attenuation (including dispersion, retardation and degradation) of the contaminant as it moves through the unsaturated and saturated zones to the receptor are sufficient to reduce contaminant concentrations to acceptable levels; and
- Tier 4 considers dilution in the receptor.

The assessment presented in this report comprises a Tier 1 and Tier 2 assessment which have been used to predict groundwater concentrations.

The Remedial Target Methodology (RTM) Spreadsheet uses analytical models to quantify the fate and transport of contaminants through the subsurface. The spreadsheet can then be used to predict contaminant concentrations in groundwater within waste.

To determine inputs into the RTM spreadsheets, sources, pathways and receptor points have been characterised as in the sections below with a detailed sensitivity analysis to assess the relative importance of the different parameters.

2.2 Source Zone Characterisation

For the purposes of this assessment, the Contaminants of Concern to controlled waters are those key contaminants that were identified during the DQRA, as metal concentrations that were measured in excess of conservative water quality standards in groundwater within waste in the first instance, underlying the East Tip and primarily include:

- chromium;
- chromium VI;
- copper;
- zinc;
- manganese; and
- nickel.

Table 2 identifies the pollutant linkage being considered during the Tier 2 assessment.

Table 2 – Tier 2 RTM Pollutant Linkages

Source	Pathway	Receptor
Potentially leachable chromium, chromium VI, copper, nickel, manganese and zinc	Leaching from unsaturated zone	Shallow groundwater in slag material
	Leaching within tidal zone through wetting and drying	Shallow groundwater in slag material

The rationale for the selection of the model source areas is provided below:-

The source area for each contaminant of concern is considered to be the entire East Tip site area extending to the proposed location of the perimeter engineered structure on the foreshore, an area of approximately 426m by 301m and has utilised average contaminant concentrations which were calculated from actual measured groundwater concentrations in the DQRA report (WYG, 2013) as the starting (background) concentrations.

Metals considered during this Tier 2 assessment are outlined in Table 3 for the contaminants of concern along with the average concentrations measured in waste as included in the DQRA report (WYG, 2013).

Table 3 – COCs for Tier 2.

Contaminant	WQS (µg/l)	Average Measured Conc. (µg/l)
Chromium	4.6	11
Chromium VI	0.6	22
Copper	5	12
Zinc	40	9
Nickel	20	6
Manganese	30	535

Note: WQS and average concentrations determined from DQRA report (WYG, 2013)

2.3 Model Parameterisation

The following tables define the base model used to predict dissolved groundwater contaminant concentrations using RTM. A sensitivity analysis has been undertaken to assess the relative importance of all parameters and ensure the base model defined below results in a reasonably conservative assessment of potential risks.

Wherever possible, site specific data has been used to populate the RTM worksheets. Where site-specific data was not available, in accordance with the guidance, cited reference values have been used where these were considered appropriate and these are clearly referenced in Tables 4-6 below.

The input parameters used in the RTM worksheets are summarised below in Tables 4-6 for each level of assessment.

Table 4- RTM Worksheet Input Parameters – Level 1 Assessment

Input Parameter	Units	Input Value	Justification / Reference Source
Unsaturated Zone			
Water Filled Porosity	Fraction	0.193	Calculated using RTM, bulk densities and moisture content. Material in East Tip would be classified as a cobbly sandy gravel. (Appendix B)
Air Filled Porosity	Fraction	0.076	Calculated using RTM, bulk densities and moisture content. Material in East Tip would be classified as a cobbly sandy gravel (Appendix B)
Bulk Density	g/cm^3	2.03	Average site data from waste material in East Tip (Appendix C)
Partition Coefficient, K_d	l/kg	Various	Contaminant specific – See Table 6

Table 5 - RTM Worksheet Input Parameters – Level 2 Assessment (All Sources)

Input Parameter	Units	Input Value	Justification / Reference Source
Unsaturated Zone (Source S2 only)			
Infiltration	m/sec	1 x 10^{-9}	Capping layer to have permeability range of 1 x 10^{-9} -1 x 10^{-12}
Saturated Zone			
Length of Source	m	426m	Length of East Tip within perimeter engineered structure
Saturated Aquifer Thickness	m	5	Site data, approximate based groundwater levels in waste
Hydraulic Conductivity	m/day	0.864	Proposed permeability of perimeter engineered structure
Hydraulic Gradient	Fraction	0.004	Same as utilised in DQRA report (CCC, 2013)
Width of Contaminant Source	m	301	Width of East Tip within perimeter engineered structure

Table 6 - RTM Model Input Parameters – Geochemical Input Parameters

Contaminant of Concern	Average Partician coefficient (kd) (l/kg)	Minimum Partician coefficient (kd) (l/kg)
Chromium	1,038,640	745
Chromium VI	43	0.22
Copper	12,589,459	284,713
Zinc	1,164,794	111,808
Nickel	685,371	8,814
Manganese	373,383,458	2,208,696

Appendix D – Provides data which has been used in the above table to calculate site specific Kds.

2.3 Model Outputs – Tier 2 Post Remediation Predicted Concentrations

The RTM Tier 2 predicted concentration outputs are presented in Table 7 in comparison with WQSs and show that the post remediation predicted groundwater concentrations are expected to be slightly less than those that were actually measured during the site investigation completed for the DQRA report (WYG, 2013). RTM spreadsheets are presented in Appendix E.

Table 7 - RTM Tier 2 Outputs Waste

Contaminant	WQS (µg/l)	DQRA Measured Average Concentration in Groundwater within Tip* (µg/l)	Post Remediation Tier 2 Predicted Concentration using RTM (µg/l)
Chromium	4.6	11	8
Chromium VI	0.6	22	15
Copper	5	12	8
Zinc	40	9	6
Nickel	2,860	6	4
Manganese	70,800	535	439

Note: * source DQRA report (WYG, 2013)

2.3 Sensitivity Analysis

A sensitivity analysis has been undertaken to assess the relative importance of the model input parameters. It should be noted however that significant effort has been made to utilise site specific data where possible to allow for the development of robust site specific risk assessment. However, a number of the parameters adopted in this assessment have utilised values from the DQRA report (WYG, 2013) which are specific to the site in its current condition, thus a sensitivity analysis is considered important to consider those parameters such as the hydraulic gradient which is likely to change post remediation and for which site-specific input values are not currently available.

2.1.1 Tier 1 (Soil) – Partitioning

Porosity and bulk density have been calculated from site specific data using RTM spreadsheets as presented in Appendices B and C. For the chromium RTM spreadsheet the porosity value and bulk density value was increased and decreased by 50%. This did not change the predicted concentration.

2.1.2 Tier 2 (Soil) – Dilution

Infiltration has been based on the specific proposed properties of the proposed remediation capping layer. The permeability of the capping layer has been specified in the range of 10^{-9}m/s to 10^{-12}m/s. Decreasing the infiltration to 10^{-12}m/s resulted in a significant decrease to the predicted concentrations as presented in Table 8 below.

Table 8 – Sensitivity Analysis – Infiltration

Contaminant	WQS (µg/l)	Post Remediation Tier 2 Predicted Concentration with infiltration of 10^{-9}m/s (µg/l)	Post Remediation Tier 2 Predicted Concentration with infiltration of 10^{-12}m/s (µg/l)
Chromium	4.6	8	0.02
Chromium VI	0.6	15	0.05
Copper	5	8	0.03
Zinc	40	6	0.02
Nickel	2860	4	0.01
Manganese	70800	439	3

Note: * source DQRA report (WYG, 2013)

The hydraulic gradient utilised within RTM, is that which has been used in the DQRA for the main East Tip risk assessment. A sensitivity analysis has been completed by increasing and decreasing the hydraulic gradient by an order of magnitude. Decreasing the hydraulic gradient by an order of magnitude from 0.004 to 0.0004 resulted in a slight increase in predicted chromium VI concentrations from 15µg/l to 20µg/l and increasing the gradient to 0.04 resulted in a decrease in the predicted concentration to 4µg/l. A similar exercise was also completed for manganese, whereby decreasing the hydraulic gradient from 0.004 to 0.0004 resulted in a slight increase in predicted manganese concentrations from 442µg/l to 554µg/l and increasing the gradient to 0.04 resulted in a decrease in the predicted manganese concentration to 172µg/l.

It should be noted that the perimeter engineered structure will reduce the flux of groundwater through the site over the long term.

3 Geochemical Modelling

The DQRA (WYG, 2013) identified the potential for impacts of certain heavy metals, specifically manganese and chromium to leach from the waste into groundwater exiting the site and entering Cork Harbour. As part of the risk assessment the significance of this impact was assessed and it was determined that although there is currently no measurable off site impact within the harbour waters, there is a potential risk which could be managed through the use of a perimeter engineered structure and capping system to retard off site transport, control infiltration of rainwater from above and cut off a direct contact human health pathway. In implementing such a system, it is acknowledged that changes will occur within the geochemical profile of the groundwater within the waste. In order to assess these possible changes, modelling using geochemical equilibrium partitioning models has been undertaken.

Geochemical modelling examines the reactions that occur between a fluid and the rock with which it is in contact. The models can be powerful tools in assessing water: rock interactions and are routinely used in the evaluation of hydrothermal fluids and groundwater quality. There are a number of well known and well recognised models available that can be employed by geochemists assessing groundwater quality, these include the MINTEQ, PHREEQC and WATEQ models developed by the U.S. Geological Survey and USEPA. For this assessment the MINTEQ database was used.

There are slight differences within each of the databases and the MINTEQ database allows for the input of both manganese and chromium as trace elements within the solution, neither PHREEQC nor WATEQ have chromium within the default database and therefore MINTEQ was used as the basis for the modelling.

Actual site based information on water from two boreholes installed within the waste was assessed to determine the potential change in speciation that might occur as a function of increasing reducing conditions which would reasonably be expected to occur post remediation. Water quality data collected in June and November 2012 was used in the modelling for boreholes 301A and 310A. The model input data included the pH, temperature, Eh (redox) and dissolved oxygen data collected on site during sample collection and major, minor and trace element analytical results. Eh or redox is a key water measurement parameter that indicates whether reducing conditions are likely to be present.

3.1 Predicted speciation of Manganese and Chromium in groundwater within the waste at the East Tip prior to remediation.

The initial run of the model was conducted considering current site conditions. The data used in the geochemical modelling and modelling output is presented in Appendix F.

Chromium is primarily present within the groundwater as the trivalent species. The model predicts that for water from borehole 310A in July 2012 there are very trace levels of divalent (1.069×10^{-30} moles/l) and hexavalent (1.851×10^{-22} moles/l) chromium present in solution. The trivalent chromium is primarily in the form of CrO_2^- (71.9% of Cr^{+3}) and $Cr(OH)_4$- (27.4% of Cr^{+3}). The November input dataset was limited with fewer chemical constituents used in the model. However the results were similar with predicted hexavalent chromium species significantly less than the trivalent and divalent forms. However, trivalent chromium is primarily present as oxyhydroxides $Cr(OH)_3$ and $Cr(OH)_2^-$. Hexavalent chromium for both samples is primarily present as the dichromate oxyanion and divalent chromium present as the divalent cation.

Water from borehole 301A collected in November 2012 had a manganese concentration of 1.782 mg/l. The speciation modelling found that there is no predicted Mn^{+6} or Mn^{+7} with only a trace of Mn^{+3} and 99.99% of the manganese as Mn^{+2} in the forms of Mn^{+2} (87.8%), $MnOH^+$ (12.2%) and $Mn(OH)_3^-$ (0.005%).

The models were re-run under increasingly reducing conditions (decreasing Eh/redox) to evaluate what might reasonably be expected to occur in the waste following remediation, stopping at the point where the model was unable to converge without also changing the major element chemistry of the solution.

3.2 Predicted speciation under reducing conditions.

Table 9 and Table 10 show that under increasingly reducing conditions (ranging from Eh conditions from -0.4 to -0.7V which is indicative of reducing conditions, the concentrations of hexavalent chromium species are expected to decrease as presented for the data from BH310A using the July 2012 water quality data set. The trivalent form of chromium is the most stable form under reducing conditions present primarily as the oxyanion CrO_2^-, hydroxyanion $Cr(OH)_4^-$ and a chromium hydroxide $Cr(OH)_3$. Review of the saturation indices indicates that while most chromium contain minerals and chromium metal tend towards the dissolved phase, the trivalent chromium oxide (Cr_2O_3) is precipitated from solution. Thus as conditions change beneath the cap with reduced infiltration of rainwater and reduced infiltration of tidal water through the perimeter engineered structure some precipitation of chromium oxide should occur.

Table 9 - Chromium BH 310A (Concentrations in Molality)

eH (volts)	**-0.4**	**-0.5**	**-0.7**	**Initial conditions**
Cr^{+2}	$7.427x10^{-29}$	$3.168x10^{-27}$	$1.841x10^{-25}$	$1.069x10^{-30}$
Cr(3)	$2.44x10^{-6}$	$2.44x10^{-6}$	$2.44x10^{-6}$	$2.44x10^{-6}$
CrO_2^-	$1.755x10^{-6}$	$1.755x10^{-6}$	$1.763x10^{-6}$	$1.755x10^{-6}$
$Cr(OH)_4^-$	$6.68\ x10^{-7}$	$6.68x10^{-7}$	$6.703x10^{-7}$	$6.68\ x10^{-7}$
$Cr(OH)_3$	$1.631x10^{-8}$	$1.631x10^{-8}$	$6.916x10^{-9}$	$1.631x10^{-8}$
$Cr(OH)_2^+$	$1.213x10^{-13}$	$1.213x10^{-13}$	$2.168x10^{-14}$	$1.213x10^{-13}$
Cr (6)	$5.51\ x10^{-28}$	$7.106x10^{-33}$	0.00	$1.851x10^{-22}$
CrO_4^-	$4.00\ x10^{-28}$	$5.16x10^{-33}$		$1.344x10^{-22}$
$NaCrO_4^-$	$1.478x10^{-28}$	$1.905x10^{-33}$		$4.960x10^{-23}$
$KCrO_4^-$	$3.234x10^{-30}$	$4.166x10^{-35}$		$1.085x10^{-24}$

Table 10 - Chromium BH 310A (Concentrations in µg/l)

eH (volts)	**-0.4**	**-0.5**	**-0.7**	**Initial conditions**
Cr^{+2}	3.862E-24	1.647E-22	9.572E-21	5.558E-26
Cr(3)	0.127	0.1269	0.1269	0.127
CrO_2^-	0.0913	0.0913	0.0917	0.0913
$Cr(OH)_4^-$	0.0347	0.0347	0.0349	0.0347
$Cr(OH)_3$	0.0008	0.0008	0.0004	0.0008
$Cr(OH)_2^+$	6.307E-09	6.307E-09	1.1273E-09	6.307E-09
Cr (6)	2.865E-23	3.695E-28	0	9.624E-18
CrO_4^-	2.08E-23	2.683E-28		6.988E-18
$NaCrO_4^-$	7.685E-24	9.905E-29		2.579E-18
$KCrO_4^-$	1.682E-25	2.166E-30		5.642E-20

When modelling the predicted changes in speciation for BH301A, the November dataset was used. The July dataset consistently failed to converge when making the cation / anion balance as the Eh was reduced which suggests that there is an analytical error in the dataset. Which parameter is in error is unknown.

Table 11 - Speciation of Manganese under Reducing Conditions (Concentration in Molality).

eH (volts)	**-0.2**	**-0.5**	**-0.7**	**Initial conditions**
Mn(2)	3.247×10^{-5}	3.247×10^{-5}	3.247×10^{-5}	3.247×10^{-5}
Mn^{+2}	2.852×10^{-5}	2.852×10^{-5}	2.852×10^{-5}	2.852×10^{-5}
$MnOH^{+}$	3.954×10^{-6}	3.954×10^{-6}	3.954×10^{-6}	3.954×10^{-6}
$Mn(OH)_3^-$	1.652×10^{-9}	1.652×10^{-9}	1.652×10^{-9}	1.652×10^{-9}
Mn(3)	3.233×10^{-33}	4.165×10^{-38}	0	1.008×10^{-30}
Mn^{+3}	3.233×10^{-33}	4.165×10^{-38}	0	1.008×10^{-30}
Mn(6)	0	0	0	0
MnO_4^{-2}	0	0	0	0
Mn(7)	0	0	0	0
MnO_4^-	0	0	0	0

Under reducing conditions most manganese minerals are soluble, thus Mn will tend to be present within the groundwater and concentrations may increase with increasing reducing conditions. However, speciation modelling suggests that a cationic species will predominate thus Mn can be expected to attenuate to clay minerals which may be present within the sediments which underlie the waste materials.

4 Water DQRA Context

The DQRA report (CCC, 2013) presented the results of a conservative bespoke assessment (Mass Transport model) of theoretical impact to the Cork Harbour waters, specifically from dissolved phase contaminants within the saturated parts of the entire East Tip site. This approach determined a conservative estimate of the mass of dissolved phase contaminant flux potentially leaving the site as part of the local tidal regime.

There were two key component parts to the Mass Transport model. The first was a flux model which quantified the volume of water flux from the site and the second was a dilution model based on the calculation and application of dilution factors which were applied to representative concentrations of identified contaminants in the groundwater being discharged into the receptor, in this instance, the tidal waters of Cork Harbour.

Section 2 of this report has used RTM to predict potential post-remediation concentrations following the construction of a low permeable capping layer and a perimeter engineered structure with a maximum permeability of x10^{-5}m/s. These concentrations together with the results of the geochemical modelling presented in Section 3 have been considered in this section in the context of the DQRA and the calculated dilution factors to ensure that the predicted concentrations will not exceed applicable WQSs in the Cork Harbour following site remediation.

Table 7 presented in Section 2.2 shows that the RTM predicted concentrations are less than the average concentrations that have been utilised in the bespoke flux and dilution model. Additionally the DQRA provided that the DQRA average concentrations are not predicted to exceed WQS when a permeability (10^{-5}m/s), that provided by the perimeter engineered structure, is present. Consequently the lower post remedial groundwater concentrations predicted in this assessment are unlikely to result in a WQS being exceeded following installation of a perimeter engineered structure.

5 Conclusions

The following conclusions have been determined from the preceding sections:

- RTM Tier 2 modelling has been completed for key metal contaminants of concern to predict post remedial concentrations in groundwater in the waste. This was in response to an EPA query on the EIS scoping exercise as to whether the introduction of a low permeable capping layer and perimeter engineered structure will result in concentrations increasing.
- The RTM model utilising data presented in the DQRA report (WYG, 2013), including the permeability of the capping layer as the infiltration input and permeability of the proposed perimeter engineered structure as the hydraulic conductivity input, predicted that concentrations of chromium, chromium VI, copper, zinc nickel and manganese as key contaminants of concern would decrease slightly when compared to the averages calculated in the DQRA report (WYG, 2013)
- The geochemical modelling completed for chromium and manganese using MINTEQ showed that under increasingly reducing conditions that can be reasonably anticipated to occur following site remediation the concentrations of hexavalent chromium species are expected to decrease with the trivalent form of chromium being the most stable form under reducing conditions. Furthermore, as conditions change beneath the capping layer with reduced infiltration of rainwater and reduced infiltration of tidal water through the perimeter engineered structure some precipitation of chromium oxide should occur.
- The concentrations predicted from the RTM and geochemical modelling are less than those which were utilised in the DQRA bespoke flux and dilution model which were also shown to be attenuated by the permeability proposed for the perimeter engineered structure. As a result the concentrations predicted as part of the assessment which are less than those predicted during the DQRA are also unlikely to exceed WQSs when a permeability of 10^{-5}m/s is present.

Abbreviations

BH	Borehole
BS	British Standard
CCC.	Cork County Council
CIEH	Chartered Institute of Environmental Health
CIRIA	Construction Industry Research and Information Association
CLAIRE	Contaminated Land Applications in the Real Environment
CLEA	Contaminated Land Exposure Assessment
COC	Contaminants of Concern
Conc.	Concentration
CV-AF	Cold Vapour Atomic Fluorescence
DoEHLG	Department of the Environment, Heritage and Local Government
DQRA	Detailed Quantitative Risk Assessment
EA	Environment Agency
Eh	Reduction or Redox potential
EPA	Environmental Protection Agency
EQS	Environmental Quality Standards
FOC	Fractional Organic Content
GSV	Gas Screening Value
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
IGVs	Interim Guideline Values
Kd	Partician Co-efficent
LOD	Laboratory Detection Limit
mAOD	Metres Above Ordnance Datum
mbgl	Metres Below Ground Level
NRA	National Rivers Authority
OD	Ordnance Datum
PAHs	Polycyclic aromatic hydrocarbons

PCBs	Polychlorinated biphenyls
PCOC	Preliminary Contaminants of Concern
PGL	Priority Geotechnical Limited
ppm	Parts per Million
PSD	Particle size distribution
QRA	Quantitative Risk Assessment
RTM	Remedial Targets Methodology (developed by the UK's Environment Agency)
SGV	Soil Guideline Values
SI	Site Investigation
SSTL	Site Specific Target Level
SVOC	Semi-Volatile Organic Compounds
TOC	Total Organic Carbon
TP	Trial Pit
TPH	Total Petroleum Hydrocarbons
UCL	Upper Confidence Limit
UK	United Kingdom
UK EA EQS	United Kingdom (UK) Environment Agency (EA) Environmental Quality Standard (EQS).
US EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WQS	Water Quality Standard
WFD	Waste Framework Directive
WFD	Water Framework Directive

GLOSSARY

Aquifer A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water.

Carboniferous The Carboniferous is a geologic period and system that extends from the end of the Devonian period, about 359.2 ± 2.5 Ma (million years ago), to the beginning of the Permian period, about 299.0 ± 0.8 Ma.

Conceptual Site Model A conceptual model represents the characteristics of a site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors (pollutant linkages).

Contaminant a substance that is in, on or under the land and has the potential to cause harm or to cause pollution of the surrounding environment.

Contaminants of concern refer to contaminants which should be considered within future investigations and risk assessments due to the expectation that they are likely to be present in elevated concentrations. and therefore this determination indicates that further consideration should be given with respect to future investigations and risk assessments. It has not yet been determined that they are capable of causing risks to receptors that would require remedial action.

Composite Sampling – the formation of a composite sample which is obtained by blending or mixing two or more individual samples.

Cyanide Cyanide is any chemical compound that contains the cyano group (C≡N), which consists of a carbon atom triple-bonded to a nitrogen atom.

Dataloggers Instruments placed in boreholes that can record frequent measurements of water levels/

Dioxins and Furans 'Dioxins' is a collective term for the category of 75 polychlorinated dibenzo-para-dioxin compounds (PCDDs) and 135 polychlorinated dibenzofuran compounds (PCDFs). Seventeen PCDD and PCDF compounds are likely to be of toxicological significance. The most toxic of these is 2,3,7,8-tetrachlorodibenzo-pdioxin (2,3,7,8-TCDD). The toxicity of each compound depends on the number and position of the chlorine atoms within the molecules.

Eh or Reduction or Redox potential is a measure of the tendency of a chemical species to be reduced by acquiring electrons. It is measured in volts (V), or millivolts (mV) and is a common measurement for water quality. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species' affinity for electrons and tendency to be reduced.

EPA Environmental Protection Agency. The agency protects the environment through its licensing, enforcement and monitoring activities in Ireland.

EPA EQS AA Environmental Protection Agency Environmental Quality Standard Annual Average. This means that for each representative monitoring point within the water body, the arithmetic mean of the concentrations measured over a 12 month monitoring period does not exceed the standard.

EPA EQS MAC Environmental Protection Agency Environmental Quality Standard Maximum Allowable Concentration. This means for each representative monitoring point within the water body no measured concentration exceeds the standard.

Foreshore Also known as the intertidal zone, the foreshore is the area that is exposed to the air at low tide and submerged at high tide.

Generic Assessment Criteria (GACs) Contaminant concentrations values used for comparison purposes to assess risk associated with contaminant concentrations found on site and are derived using non-site-specific information.

Groundwater Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations.

Groundwater abstraction is the process of taking water from a ground source, either temporarily or permanently.

Hexavalent Chromium Chromium a transition metal exists in the environment in a number of oxidation states ranging from -2 to +6. The Cr (III) or trivalent state is the most stable form. Cr(VI) hexavalent chromium is the form primarily used in the manufacture of steel. Both forms are present as cations in solution as well as forming several different oxyanions and oxide or hydroxyl compounds. In natural groundwaters, trivalent Cr is the prevalent form as hexavalent Cr is readily reduced to the trivalent form. Hexavalent chromium is considered toxic to human health through the inhalation pathway.

ICP Inductively Coupled Plasma spectrometry is a technique for elemental analysis which is applicable to most elements over a wide range of concentrations.

Leachate A solution resulting from leaching, as of soluble constituents from soil, landfill, etc., by downward percolating ground water.

Millscale Mill scale is a milling waste generated while rolling the metal in metal extrusion industries.

NRA Leachability Tests A laboratory test derived from the UK's Environment Agency Recommended Test (R&D note 301). The leaching fluid used in this method is intended to represent materials coming into contact with acid rain. Leaching is carried out by adding to the required sample weight, a volume of water left overnight to attain carbonate equilibrium (pH ~ 5.6) to give a 10:1 ratio of water to soil. The bottle is tumbled at a rate of ~0.5 revolutions per minute at room temperature for 24 hours. The resultant leachant can then be analysed for any parameters desired.

PAHs Polycyclic aromatic hydrocarbons are chemical compounds that consist of fused aromatic rings and do not contain heteroatoms or carry substituents. They are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco

Partician Coefficent (Kd) The Kd parameter is a factor related to the partitioning of a contaminant between the solid and aqueous phases.

Pathway a route or means by which a receptor can be exposed to, or affected by, a contaminant.

PCBs Polychlorinated Biphenyls are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl which is a molecule composed of two benzene rings each containing six carbon atoms. The chemical formula for all PCBs is C12H10-xClx.

Phenol Phenol is both a manufactured chemical and a natural substance. It is a toxic, colourless crystalline solid with a sweet tarry odour.

Pollutant linkage The relationship between a contaminant, pathway and receptor.

Receptor is something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body.

Refractory A refractory is a material that retains its strength at high temperatures.

Seepages where groundwater exits the waste during low tide onto the foreshore.

SGV Soil Guideline Values are a series of measurements and values used by the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA) to measure contamination of the soil.

Slag Slag is the by-product of smelting ore to purify metals.

Source A substance that is capable of causing harm

TPH Total Petroleum Hydrocarbons is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil.

VOCs Volatile Organic Compound(s) are organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporize and enter the atmosphere.

Waulsortian Limestone Formation Waulsortian Limestone consists of poorly bedded, dense, pale grey mudstone-wackestone and fine-grained packstonegrainstone.

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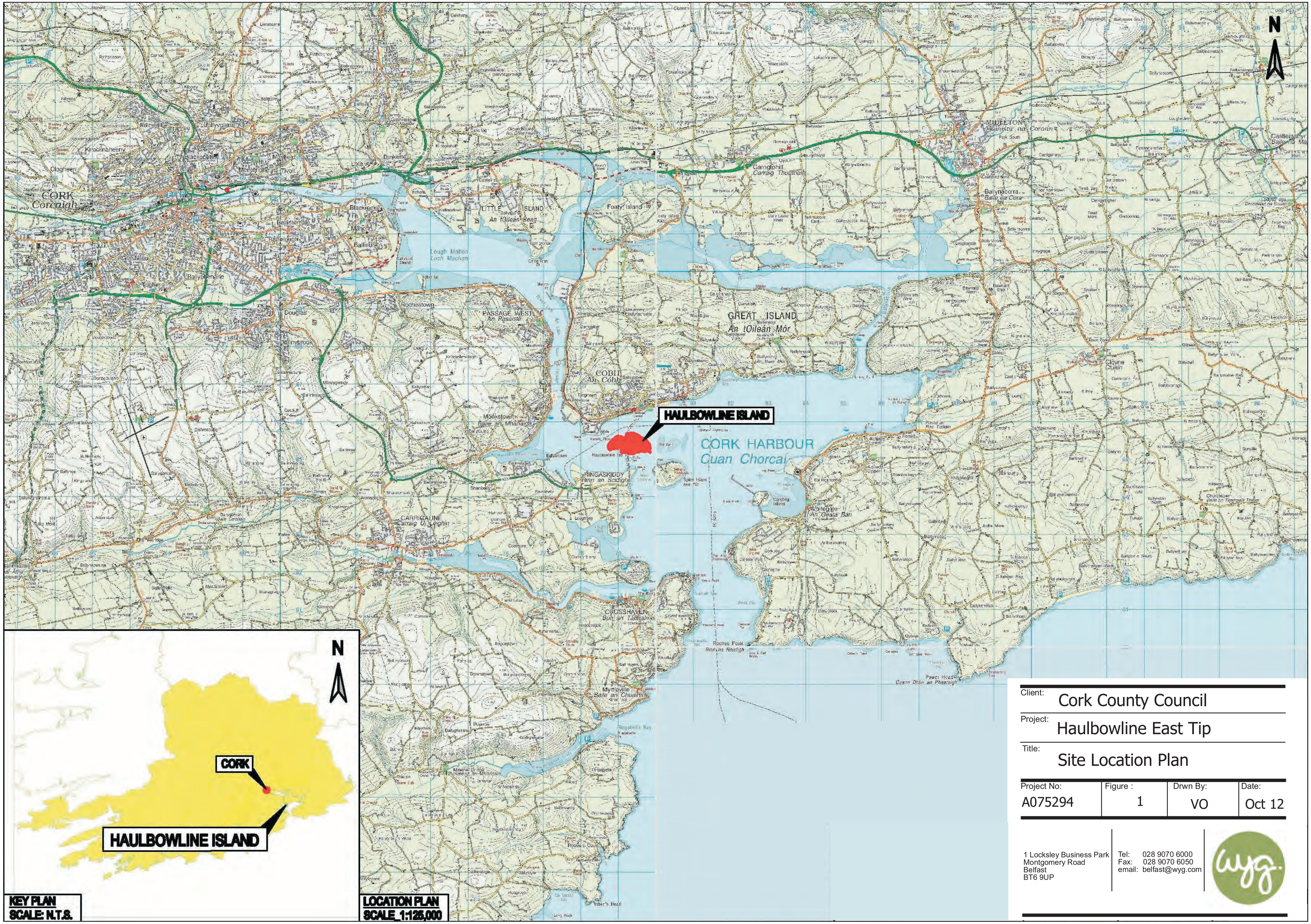
Figures



KEY PLAN
SCALE: N.T.S.

LOCATION PLAN
SCALE_1:125,000

Client: Cork County Council			
Project: Haulbowline East Tip			
Title: Site Location Plan			
Project No: A075294	Figure : 1	Drwn By: VO	Date: Oct 12

1 Locksley Business Park
Montgomery Road
Belfast
BT6 9UP

Tel: 028 9070 6000
Fax: 028 9070 6050
email: belfast@wyg.com

Cork County Council - Haulbowline
Aerial Photograph

Figure No. 2.

Job No. CE08671
Date. Aug. 2012
Finalised By - DH
Office - 1404
Drawn By: J Farrar - CS2,Illustrator

NOTE: Drawing is for diagrammatic purposes only. No measurements to be taken.

Appendices

Appendix A – Report Conditions

WYG Environmental (EPT) Ltd

Report Conditions

East Tip, Haulbowline

This report is produced solely for the benefit of Cork County Council and no liability is accepted for any reliance placed on it by any other party unless specifically agreed in writing otherwise.

This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to WYGE. In time improved practices, fresh information or amended legislation may necessitate a re-assessment. Opinions and information provided in this report are on the basis of WYGE using due skill and care in the preparation of the report.

This report refers, within the limitations stated, to the environment of the site in the context of the surrounding area at the time of the inspections. Environmental conditions can vary and no warranty is given as to the possibility of changes in the environment of the site and surrounding area at differing times.

This report is limited to those aspects reported on, within the scope and limits agreed with the client under our appointment. It is necessarily restricted and no liability is accepted for any other aspect. It is based on the information sources indicated in the report. Some of the opinions are based on unconfirmed data and information and are presented as the best obtained within the scope for this report.

Reliance has been placed on the documents and information supplied to WYGE by others but no independent verification of these has been made and no warranty is given on them. No liability is accepted or warranty given in relation to the performance, reliability, standing etc of any products, services, organisations or companies referred to in this report.

Whilst skill and care have been used, no investigative method can eliminate the possibility of obtaining partially imprecise, incomplete or not fully representative information. Any monitoring or survey work undertaken as part of the commission will have been subject to limitations, including for example timescale, seasonal and weather related conditions.

Although care is taken to select monitoring and survey periods that are typical of the environmental conditions being measured, within the overall reporting programme constraints, measured conditions may not be fully representative of the actual conditions. Any predictive or modelling work, undertaken as part of the commission will be subject to limitations including the representativeness of data used by the model and the assumptions inherent within the approach used. Actual environmental conditions are typically more complex and variable than the investigative, predictive and modelling approaches indicate in practice, and the output of such approaches cannot be relied upon as a comprehensive or accurate indicator of future conditions. The potential influence of our assessment and report on other aspects of any development or future planning requires evaluation by other involved parties.

The performance of environmental protection measures and of buildings and other structures in relation to acoustics, vibration, noise mitigation and other environmental issues is influenced to a large extent by the degree to which the relevant environmental considerations are incorporated into the final design and specifications and the quality of workmanship and compliance with the specifications on site during construction. WYGE accept no liability for issues with performance arising from such factors.

Appendix B RTM Porosity Calculations

Porosity Calculator

These results are not carried through to any of the other worksheets

DRY BULK DENSITY DATA

Variable	Value	Unit	justification
Natural Moisture Content	9.50	% wt	
Particle Density	2.78	tonnes/m^3	(Change this number only if you have specific information)
Dry Bulk Density	2.03	tonnes/m^3	
Calculated Parameters			
Voids Ratio	0.37	fraction	
Initial Saturation	71.61	%	
Total porosity	**0.269**	**fraction**	
Air Filled Porosity	**0.076**	**fraction**	
Water Filled Porosity	**0.193**	**fraction**	

WET BULK DENSITY DATA

Variable	Value	Unit	
Moisture Content	0.00	% wt	
Particle Density	2.78	tonnes/m^3	(Change this number only if you have specific information)
Actual (wet) Bulk Density (i.e. at natural MC)	0.00	tonnes/m^3	
Calculated Parameters			
Voids Ratio	#DIV/0!	fraction	
dry bulk density	0.00	tonnes/m^3	
Initial Saturation	#DIV/0!	%	
Total porosity	**1.000**	**fraction**	**#DIV/0!**
Air Filled Porosity	**#DIV/0!**	**fraction**	
Water Filled Porosity	**#DIV/0!**	**fraction**	

Analytical solutions provided by David Hall, Golder Associates (UK) Ltd

Appendix C Bulk Densities

Waste - Dry Bulk Density

location	depth	moisture content %	dry bulk density Mg/m3		SI logs description	lab description
BH301A	0.6-1	13.5	2.32		Dark grey, Mill Scale/ possible flue dust.	MADE GROUND dark brown very silty sand & gravel.
BH301A	6	12	1.95		Unprocessed SLAG with metal, timber and domestic refuse and or Light to dark grey, unprocessed, pockmarked SLAG in granular and cobble sized form with some waste metal.	brown very gravelly sand or very sandy gravel
BH302	7	3	2.32		Light to dark grey, unprocessed SLAG in granular form.	Brown sandy GRAVEL or MADE GROUND brown sandy gravel of ash
BH304	5.5	6.3	1.83		Light to dark grey, unprocessed SLAG in granular and cobbles sized form with sand.	Dark brown very sandy slightly silty GRAVEL.
BH305	5.5-6	4.3	2.17		Light to dark grey, unprocessed SLAG.	Brown SAND & GRAVEL or MADE GROUND dark brown sandy gravel of ash.
BH306A	4	7.7	1.94		Light/ dark grey, gravel and cobble sized, pockmarked, unprocessed SLAG with some scrap metal (5%) and or Light/ dark grey, granular unprocessed SLAG with occasional refractory bricks. 4.0m: Approx. 2.5m x 1.2m steel sheeting.	Dark brown very gravelly SAND or MADE GROUND dark brown sandy gravel of ash.
BH309	0.8-1.2	8	2		Light grey, unprocessed SLAG in granular and cobble form with broken refractory bricks (approx, <1%).	MADE GROUND grey slightly sandy gravel with cobbles or MADE GROUND grey sandy gravel.
BH310A	8	4.75	2.19		Unprocessed, angular SLAG with pockmarked cobbles. 6.9m - 8.3m: Water added to boring. 8.3m - 7.4m: Blowback. Redrilled. 7.8m - 7.9m: Shards of angular metal. And or Unprocessed, grey, angular, molten looking SLAG with small to medium sized, grey, pockmarked cobbles	MADE GROUND dark grey very sandy slightly silty gravel or MADE GROUND dark brown sandy gravel of ash.
BH311	1.6	10	1.89		Unprocessed SLAG in granular form with light brown/ dark grey refractory bricks (approx. <1%) and small, pockmarked pieces of slag.	Brown SAND & GRAVEL or MADE GROUND dark brown very sandy gravel.
BH312B	2	13	1.93		Mill Scale with some sand, gravel, occasional refactory bricks and a minute amount of household waste including textiles.	Brown very gravelly SAND or MADE GROUND dark brown very sandy gravel.
BH314	4.2	16.5	1.84		Demolition waste: Wood, glass, mass concrete, re-bar, glass bottles, red brick, oil filters, plastic sheeting and approximately 20% Sand and Gravel with approximately 10% raw steel materials in lenses (predominantly gravel sized, with occasional cobble sized pieces). 4.0m - 6.0m: Water is slightly iridescent. Occasional black slick in the water: run off from spoil heap.	Brown very gravelly slightly clayey SAND or MADE GROUND dark brown sandy silty gravel.
BH315	4	14.5	1.99		Light to dark grey, pockmarked, Unprocessed SLAG in granular and cobble form with approximately 5% waste steel.and or Light to dark grey, pockmarked, unprocessed SLAG in granular and cobble sized form with minor amounts of plastic.	Dark grey very gravelly slightly clayey SAND or MADE GROUND grey very sandy gravel.
	Ave	**9.4625**	**2.030833**			

Appendix D Site specific Kds

East Tip, Haulbowline

Site Specific Kd Calculations

loc	depth	Chromium Soil mg/kg	description	location	depth	Chromium Leachate ug/l		Kd	Average	Geomean	Minimum
BH303	3	3390	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	418	0.418	8110.047847			
BH305	4-4.5	302	slag with 20% refractory	BH305 E16	4.00-4.50	1.26	0.00126	239682.5397			
BH306A	7	3400	slag	BH306A E18	7.00-	0.438	0.000438	7762557.078			
BH310A E4	1.00-	2830	slag with 5% plastic and metals	BH310A E4	1.00-	429	0.429	6596.736597			
BH310B	5	4790	slag with 10% metal	BH310B E16	5.40-	4.51	0.00451	1062084.257			
BH311 E7	0.50-0.60	143	slag with 50% refractory waste	BH311 E7	0.50-0.60	192	0.192	744.7916667	1038640.21	105763.6398	744.7917
BH312a	3.6-3.8	415	sludge with HC	BH312A E14	4.00-4.10	0.538	0.000538	771375.4647			
BH312c	2.3	1470	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	36.8	0.0368	39945.65217			
BH316 E3	0.20-0.50	854	slag	BH316 E3	0.20-0.50	0.22	0.00022	3881818.182			
OP10 E2	0.8	592	millscale	OP10 E2	0.8	37.9	0.0379	15620.05277			
OP10 E4	2	3280	flue sludge	OP10 E4	2	8.74	0.00874	375286.0412			
OP10 E6	1.1	3880	slag	OP10 E6	1.1	18.4	0.0184	210869.5652			
OP14 E3	1.10-1.60	1140	millscale	OP14 E3	1.10-1.60	7.4	0.0074	154054.0541			
OP14 E6	1.7	369	slag	OP14 E6	1.7	30.2	0.0302	12218.54305			

East Tip, Haulbowline

Site Specific Kd Calculations

loc	depth	Copper Soil mg/kg	description	location	depth	Copper Leachate ug/l		Kd	Average	Geomean	Minimum
BH303	3	498	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	0.177	0.000177	2813559.322			
BH305	4-4.5	28.9	slag with 20% refractory	BH305 E16	4.00-4.50	0.101	0.000101	286138.6139			
BH306A	7	869	slag	BH306A E18	7.00-	0.06	0.00006	14483333.33	12589459.1	5977160.315	284713.4
BH310A E4	1.00-	592	slag with 5% plastic and metals	BH310A E4	1.00-	0.171	0.000171	3461988.304			
BH310B	5	667	slag with 10% metal	BH310B E16	5.40-	0.06	0.00006	11116666.67			
BH311 E7	0.50-0.60	44.7	slag with 50% refractory waste	BH311 E7	0.50-0.60	0.157	0.000157	284713.3758			
BH312a	3.6-3.8	718	sludge with HC	BH312A E14	4.00-4.10	0.06	0.00006	11966666.67			
BH312c	2.3	1300	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	0.06	0.00006	21666666.67			
BH316 E3	0.20-0.50	1390	slag	BH316 E3	0.20-0.50	0.071	0.000071	19577464.79			
OP10 E2	0.8	1510	millscale	OP10 E2	0.8	0.06	0.00006	25166666.67			
OP10 E4	2	3460	flue sludge	OP10 E4	2	0.117	0.000117	29572649.57			
OP10 E6	1.1	287	slag	OP10 E6	1.1	0.06	0.00006	4783333.333			
OP14 E3	1.10-1.60	1800	millscale	OP14 E3	1.10-1.60	0.06	0.00006	30000000			
OP14 E6	1.7	66.5	slag	OP14 E6	1.7	0.062	0.000062	1072580.645			

East Tip, Haulbowline

Site Specific Kd Calculations

loc	**depth**	**Nickel Soil mg/kg**	**description**	**location**	**depth**	**Nickel Leachate ug/l**		**Kd**	Average	Geomean	Minimum
BH303	3	156	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	0.549	0.000549	284153.0055			
BH305	4-4.5	10.4	slag with 20% refractory	BH305 E16	4.00-4.50	1.18	0.00118	8813.559322			
BH306A	7	307	slag	BH306A E18	7.00-	0.49	0.00049	626530.6122	685371.695	273682.2406	8813.559
BH310A E4	1.00-	217	slag with 5% plastic and metals	BH310A E4	1.00-	0.566	0.000566	383392.2261			
BH310B	5	174	slag with 10% metal	BH310B E16	5.40-	0.572	0.000572	304195.8042			
BH311 E7	0.50-0.60	10.3	slag with 50% refractory waste	BH311 E7	0.50-0.60	1.11	0.00111	9279.279279			
BH312a	3.6-3.8	211	sludge with HC	BH312A E14	4.00-4.10	0.427	0.000427	494145.1991			
BH312c	2.3	410	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	0.794	0.000794	516372.796			
BH316 E3	0.20-0.50	379	slag	BH316 E3	0.20-0.50	0.1	0.0001	3790000			
OP10 E2	0.8	505	millscale	OP10 E2	0.8	0.487	0.000487	1036960.986			
OP10 E4	2	236	flue sludge	OP10 E4	2	1.35	0.00135	174814.8148			
OP10 E6	1.1	72.2	slag	OP10 E6	1.1	0.55	0.00055	131272.7273			
OP14 E3	1.10-1.60	537	millscale	OP14 E3	1.10-1.60	0.33	0.00033	1627272.727			
OP14 E6	1.7	20.8	slag	OP14 E6	1.7	0.1	0.0001	208000			

East Tip, Haulbowline

Site Specific Kd Calculations

loc	depth	manganese Soil mg/kg	description	location	depth	Manganese Leachate ug/l		Kd	Average	Geomean	Minimum
BH303 E10	3.00-	39400	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	0.098	0.000098	402040816.3			
BH305 E16	4.00-4.50	11400	slag with 20% refractory	BH305 E16	4.00-4.50	0.433	0.000433	26327944.57			
BH306A E18	7.00-	21100	slag	BH306A E18	7.00-	0.104	0.000104	202884615.4			
BH310A E4	1.00-	28900	slag with 5% plastic and metals	BH310A E4	1.00-	0.187	0.000187	154545454.5			
BH310B E16	5	25100	slag with 10% metal	BH310B E16	5.40-	0.136	0.000136	184558823.5			
BH311 E7	0.50-0.60	1780	slag with 50% refractory waste	BH311 E7	0.50-0.60	0.724	0.000724	2458563.536	373383458	75949437.74	2208696
BH312A E14	3.6-3.8	2540	sludge with HC	BH312A E14	4.00-4.10	1.15	0.00115	2208695.652			
BH312C E7	2.3	18300	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	0.097	0.000097	188659793.8			
OP10 E2	0.8	5560	millscale	OP10 E2	0.8	0.3	0.0003	18533333.33			
OP10 E4	2	46200	flue sludge	OP10 E4	2	0.04	0.00004	1155000000			
OP10 E6	1.1	70800	slag	OP10 E6	1.1	0.04	0.00004	1770000000			

East Tip, Haulbowline

Site Specific Kd Calculations

loc	depth	Zinc Soil mg/kg	description	location	depth	Zinc Leachate ug/l		Kd	Average	Geomean	Minimum
BH303	3	1500	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	6.18	0.00618	242718.4466			
BH305	4-4.5	592	slag with 20% refractory	BH305 E16	4.00-4.50	2.89	0.00289	204844.2907			
BH306A	7	1070	slag	BH306A E18	7.00-	0.41	0.00041	2609756.098	1164794.27	537085.7595	111807.7
BH310A E4	1.00-	2160	slag with 5% plastic and metals	BH310A E4	1.00-	5.3	0.0053	407547.1698			
BH310B	5	591	slag with 10% metal	BH310B E16	5.40-	0.41	0.00041	1441463.415			
BH311 E7	0.50-0.60	1070	slag with 50% refractory waste	BH311 E7	0.50-0.60	9.57	0.00957	111807.7325			
BH312c	2.3	2250	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	19.4	0.0194	115979.3814			
BH316 E3	0.20-0.50	2460	slag	BH316 E3	0.20-0.50	0.41	0.00041	6000000			
OP10 E2	0.8	4410	millscale	OP10 E2	0.8	4.35	0.00435	1013793.103			
OP10 E4	2	189000	flue sludge	OP10 E4	2	124	0.124	1524193.548			
OP10 E6	1.1	1090	slag	OP10 E6	1.1	6.89	0.00689	158200.2903			
OP14 E3	1.10-1.60	562	millscale	OP14 E3	1.10-1.60	0.501	0.000501	1121756.487			
OP14 E6	1.7	215	slag	OP14 E6	1.7	1.13	0.00113	190265.4867			

Chromium VI

loc	depth	Chromium VI Soil mg/kg	description	location	depth	Chromium VI Leachate ug/l		Kd	Average	Geomean	Minimum
BH303	1	1.49	slag and 1% plsatic, 5% waste steel in construction form and occasional red brick	BH303 E16	0.20-	30	0.03	49.66666667			
BH303	3	0.1	slag with 10% waste steel and 5% refractory	BH303 E10	3.00-	442	0.442	0.226244344			
BH306A	7	0.1	slag	BH306A E18	7.00-	34	0.034	2.941176471	42.8749014	11.23789219	0.226244
BH310A E4	1.00-	9.32	slag with 5% plastic and metals	BH310A E4	1.00-	457	0.457	20.39387309			
BH310B	5	1.55	slag with 10% metal	BH310B E16	5.40-	30	0.03	51.66666667			
BH311 E7	0.50-0.60	2.55	slag with 50% refractory waste	BH311 E7	0.50-0.60	221	0.221	11.53846154			
BH312c	2.3	0.1	slag with 5% steel, 2.5% refractories and 0.5% wate plastic	BH312C E7	2.60-	44	0.044	2.272727273			
OP10 E2	0.8	0.835	millscale	OP10 E2	0.8	39	0.039	21.41025641			
OP10 E4	2	8.6	flue sludge	OP10 E4	2	30	0.03	286.6666667			
OP10 E6	1.1	0.657	slag	OP10 E6	1.1	30	0.03	21.9			
OP14 E6	1.7	0.1	slag	OP14 E6	1.7	34	0.034	2.941176471			

Appendix E RTM spreadsheets

Environment Agency

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**East Tip, Haulbowline**			
Site Address:				
Completed by:	**Yvonne Buchanan**			
Date:	**30-Sep-12**		**Version:**	**x.xx**
Contaminant	**Manganese**			
Target Concentration (C_T)	**1**	**mg/l**	**Origin of C_T:**	**WFD**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Copper Area A**	
Target concentration	C_T	**1**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.93E-01	fraction	calculated site specific
Air filled soil porosity	θa	7.00E-02	fraction	calculated site specific
Bulk density of soil zone material	ρ	2.03E+00	g/cm^3	site specific
Henry's Law constant	H		dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.26E+07	l/kg	*calculated site specific*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.26E+07**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.26E+07**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	1	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	haulbowline
Completed by:	Yvonne Buchanan
Date:	30-Sep-12
Version:	x.xx

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Chromium**		
Target concentration	C_T	**1**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.93E-01	fraction	calculated site specific
Air filled soil porosity	θa	7.00E-02	fraction	calculated site specific
Bulk density of soil zone material	ρ	2.03E+00	g/cm^3	site specific
Henry's Law constant	H		dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.06E+05	l/kg	*calculated site specific*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.06E+05**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.06E+05**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	1	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	East Tip, Haulbowline
Completed by:	Yvonne Buchanan
Date:	30-Sep-12
Version:	x.xx

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**East Tip, Haulbowline**			
Site Address:				
Completed by:	**Yvonne Buchanan**			
Date:	**30-Sep-12**		**Version:**	**x.xx**
Contaminant	**Chromium VI**			
Target Concentration (C_T)	**1**	**mg/l**	**Origin of C_T:**	**WFD**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Zinc	
Target concentration	C_T	1	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.93E-01	fraction	calculated site specific
Air filled soil porosity	θa	7.00E-02	fraction	calculated site specific
Bulk density of soil zone material	ρ	2.03E+00	g/cm^3	site specific
Henry's Law constant	H		dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.16E+06	l/kg	*calculated site specific*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.16E+06**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.16E+06**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	1	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	East Tip, Haulbowline
Completed by:	Yvonne Buchanan
Date:	30-Sep-12
Version:	x.xx

Appendix F Geochemical Modelling

Please see CD