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SuRF-UK bulletin

SuRF-UK bulletins provide examples of carrying out a sustainability assessment whilst undertaking a project.

Sustainability Assessment: Shell Terminal Facility, Madeira

SUSTAINABLE REMEDIATION OUTCOMES AND BENEFITS:

A sustainable remediation assessment was applied in this project coincident with removal of a short project completion timescale. The sustainability assessment, combined with a more flexible temporal project boundary generated the following outcomes.

Change of strategy from thermal desorption to enhanced bioremediation, based on a number of sustainability benefits associated with this change in strategy:

- A reduction in CO_2 emissions due to less intensive energy use;
- A reduction in costs;
- A reduction in fuel use;
- A reduction in neighbourhood disturbance caused by noise, which would have arisen from the operation of the thermal desorption plant; and
- Potential for local employment.

1. INTRODUCTION/NATURE OF ASSESSMENT

A sustainability assessment has been undertaken relating to remedial works at the Shell Terminal Facility on the island of Madeira. The site was selected for assessment following the suspension of the previous remedial action plan (RAP) due to the prevailing economic conditions on the island. The previous RAP identified excavation and on-site thermal treatment as the favoured remediation approach, driven in part by the available timescale for the remediation works. The time constraints associated with the previous remedial plan may no longer apply, and this presented the opportunity for review of alternative and potentially more sustainable remedial approaches.

This was a 'live' assessment undertaken at a decommissioned facility. It represents a 'Stage B' assessment, reviewing and comparing alternative remediation options. A number of alternative land use scenarios were also considered as part of the study. A programme of remediation and redevelopment planning has commenced and will be progressed dependent on identification of a buyer for the site.

2. SITE CONTEXT

Shell operated a facility on the island of Madeira terminal from 1962 to 2007 as a marine distribution terminal. The site ceased operations in 2007 and operational infrastructure (tanks, pipelines, etc.) was subsequently decommissioned and demolished between 2007 and 2008.

The site is located adjacent to the sea (to the south). To the east of the site there are a number of hotel complexes, and to the north there are residential properties. To the west, there is an area of undeveloped land (Figure 1).

Figure 1: Aerial photograph (top) (Image@2013 Digital Globe) and site plan (bottom) of the terminal facility, Madeira

Investigation data indicates that the geology beneath the site generally comprises a surface fill cover to approximately 0.3 to 0.4 metres below ground level (mbgl). This is underlain by a silty/clayey sand fill down to a depth of 1.2 - 1.8mbgl. This is underlain by natural soils comprising sandy gravels and cobbles. These are present to the maximum depth of the current investigation (4.0 - 4.5mbgl). Previous studies identify that the natural soils, comprising sandy gravels and cobbles, are present to 7mbgl. Basaltic rock is assumed to be present at depth (~10mbgl).

Groundwater is present at a depth of approximately 3 - 4mbgl, with flow generally towards the sea. Given the proximity of the site to the sea, groundwater levels are known to be tidally influenced.

A series of soil and groundwater investigations have been undertaken at the site since 1997. It is known that a number of product losses to the subsurface occurred, the most notable of which was a fuel oil spill in 2000. The quantity of product lost to the subsoil is unknown. The investigation data indicates that the soils beneath the site are impacted by heavy fuel oil (total petroleum hydrocarbons>C22, with moderate concentrations of polycyclic aromatic hydrocarbons) and, to a minor extent, middle distillate hydrocarbons (diesel and kerosene). It is likely that migration of hydrocarbon to the subsurface occurred predominantly through unpaved areas on the site. Lateral migration appears to have occurred at the interface between the fill and the natural soil material. Lateral spreading is also likely to have occurred at the groundwater surface, where a smear zone is evident as a result of the tidally influenced groundwater fluctuations. Hydrocarbon impact appears to be limited to the shallow soils, from ground level to a depth of 3 - 4mbgl.

The future end use of the site is uncertain. A number of alternative risk assessment scenarios have therefore been considered according to potential redevelopment options. An existing master plan for the site involves a mix of residential, commercial use (hotel) and parkland uses. An alternative (unrestricted) end use could comprise residential properties (with gardens). A potential human health inhalation risk (vapour intrusion into buildings) applies for all the potential scenarios considered. For the unrestricted end use scenario, a potential direct contact human health risk would also exist. No potential off-site risks have been identified (on account of the low solubility of the long-chain hydrocarbon compounds and relatively high potential dilution of the plume discharge to the sea). There is no evidence of non-aqueous phase liquid (NAPL) discharge to the sea.

The final extent of remedial works required would be determined on the basis of the proposed development plan and associated risk assessment. The required remediation standards vary according to the redevelopment scenario.

Shell wished to undertake an appropriate programme of remedial works which managed all unacceptable technical risks (to human health and the environment). The objective of this study was therefore to review a range of alternative remedial approaches, taking greater account of sustainability factors and to establish if an alternative approach to thermal treatment may have more favourable economic, environmental and social impacts.

It is acknowledged that further site investigations may be appropriate prior to the development of a detailed implementation plan for remedial works at the site. However, the existing data set was considered to be adequate for the completion of the sustainability assessment.

URS has developed a decision making tool to facilitate the integration of sustainable remediation concepts into the overall process of site investigation and remediation. This tool identifies stages of the process at which sustainability considerations can be incorporated. The URS tool has been developed with reference to, and generally aligns with, the sustainability appraisal framework developed by SuRF-UK (Framework for Assessing the Sustainability of Soil and Groundwater Remediation, March 2010). At the point of reviewing remedial options, an assessment may be undertaken to compare the sustainability of the alternative remedial options. Further information on the tool used is given in the subsequent sections of this document.

3. THE SUSTAINABILITY ASSESSMENT PROCESS

3.1 General

The sustainability assessment undertaken for the site included the following stages:

- Initial compilation of relevant site data to facilitate an initial workshop. This included summarising the business/site objectives, identifying stakeholders, compiling site investigation data and gathering other relevant documentation (remedial options assessment reports etc.);
- An initial workshop attended by the project team. This was undertaken to establish the context within which the assessment was to be undertaken, to agree the objectives and boundaries of the assessment, and to determine the nature (format and tier) of assessment to be completed;
- Collation of additional data required to complete the assessment;
- Completion of the assessment process; and
- Reporting of the assessment.

3.2 Objectives of sustainability assessment

The objective of the sustainability assessment was to identify a favoured remediation (soil treatment) option, which has greater focus on wider sustainability factors whilst still aligning with the overall business objectives for the site.

3.3 Parties involved

The following stakeholders were identified:

- Shell;
- Madeira Regional Environmental Agency (MREA)
- Chamber of the Municipality of Funchal (CMF) (local government);
- Surrounding neighbours (adjacent hotel to the east, beach users, some adjacent residents believed to be on Shell land to the north, and a number of food vendors to the west; and
- Buyer/developer (not identified at the present time).

The sustainability assessment was undertaken by Shell and URS; the wider stakeholders were not directly involved. These stakeholders have been consulted as part of the previous works and hence the assessment team was familiar with their views and opinions. These views have been considered within the process and are summarised below.

Madeira Regional Environmental Agency (MREA): The main interest of the MREA was to protect the environment and maintain the standards of public health in the area. They wanted to ensure full compliance with the regulatory environmental requirements and did not want any future issues arising from residual contamination.
Chamber of the Municipality of Funchal (CMF): The main interest of the CMF was to ensure development of the site is in full compliance with Portuguese and local regulations. The CMF wished to derive economic gain from the development due to tourism. They did not want any future responsibility for issues arising from residual contamination.
Surrounding neighbours: The surrounding neighbours (residential / recreational visitors) did not want to experience any significant disturbance or inconvenience from the remediation works, and that the site was left in a safe condition.
Buyer/developer (not identified at the present time): The main interest of the buyer is likely to be the need to ensure that there will not be any future issues from residual contamination, and that the site is left in a

state that is fit for the proposed future use. Reduced time scales may also be of interest but this depends on the buyer.

3.4 Scope

At the time the assessment was completed no purchaser of the site had been identified. In this context, there was no driver for completion of works within a defined or specific time period. Furthermore, whilst an existing master plan for the redevelopment of the site is in place, the potential exists for alternative development plans to be proposed. It was therefore evident that there were uncertainties relating to both the time that may be available for the completion of a remedial work programme and the remedial standards (soil treatment standards) that may apply. As part of the initial workshop, the project team therefore developed a number of scenarios to be considered within the assessment. These scenarios are summarised within Table 1.

Table 1: A summary of the scenarios considered within the assessment

		Duration of Remediation Programme	
		Short term programme (<18 months)	Long term programme (5 years)
End Use	In line with existing site master plan	Scenario 1	Scenario 2
	Unrestricted end use	Scenario 3	Scenario 4
	Updated site master plan	Scenario 5	Scenario 6

The existing master plan for the site involves a mix of residential, commercial use (hotel) and parkland uses. It is assumed that an unrestricted end use would comprise residential properties (with gardens). For the purposes of this assessment, it is assumed that an updated site master plan would seek to minimise the extent of remediation required at the site. The most likely scenario to achieve this would involve the use of the entire site for a commercial end use (hotel).

Remediation targets / soil treatment standards were derived for each of the above scenarios and the associated soil volume requiring treatment was estimated. As previously mentioned, applicable remediation standards would vary according to the redevelopment scenario.

3.5 Boundaries

The project team agreed upon the following boundaries for the assessment:

- **Time** - This was to be limited to the duration of the remedial works (which was defined as the timeline from the signing of a contract for the completion of the remedial works through to the demobilisation of equipment following the works).
- **Spatial** - The spatial boundary was to be limited to the island itself (the exception to this is greenhouse gas emissions which were acknowledged to have a global impact).
- **Lifecycle** - This was to be limited to the mobilisation and demobilisation of specialised equipment to the site, and would not include the manufacture / assembly of the plant.
- **Financial** - This was to be limited to the existing provision for remedial works on site (which had been developed for the previous development scenario).

3.6 Options considered

Following review, the project team agreed that the application of *in situ* technologies for remediation at the site was inappropriate. Potential *in situ* technologies considered included the application of concepts based on chemical oxidation, thermal and biological approaches. These options were discounted due to the nature of the contamination present, uncertainty in effectiveness and/or consideration of the feasibility of implementation in the site context; for example: (i) aliphatic long chained hydrocarbons are quite resistant to oxidation, and (ii) the high boiling point of the main impact (> 350°C) would require the treatment temperature to be increased well above the boiling point of water (i.e. completely drying out the treatment area), which seemed unrealistic at the site. Given the relatively shallow depth of the impacted soils (typically from ground surface to a depth of 3 - 4mbgl), it was considered that excavation of the soils may be achieved relatively easily by implementing an *ex situ* process, which would achieve greater certainty in treatment standards.

On this basis, all the remedial options taken forward for further assessment involved the initial excavation of the contaminated soils, with focus of the assessment on options for the treatment/disposal of excavated material. A total of five soil treatment/disposal options were identified as being potentially applicable for the treatment of soils at the Madeira site. These options and associated key activities are summarised as follows:

Thermal desorption

- Mobilisation, set up and commissioning of low temperature thermal desorption (LTTD) unit at the site;
- Excavation of soils and transfer to stockpiling location adjacent to LTTD unit;
- Treatment of soils (screening and processing with LTTD plant);
- Back fill and compaction of treated soils; and
- Demobilisation of plant and equipment and shipment.

Land farming

- Construction of treatment bed or series of treatment beds/cells;
- Excavation of soils, with transfer to, and placement, upon the treatment bed;
- Periodic turning/aeration of the bed using some form of agricultural tilling equipment;
- Back fill and compaction of treated soils once the required soil treatment standard has been achieved; and
- Removal of treatment beds and demobilisation of plant and equipment from the site.

Enhanced bioremediation

- Mobilisation, set up and commissioning of mixing plant (pug mill type) at the site;
- Excavation and stockpiling of soils adjacent to mixing plant. Excavated material would be screened (to remove coarse material) and placed upon separate stockpiles on the basis of the nature of the material. Each stockpile would be homogenised.
- Transfer of material from stockpiles on a batch basis and processing within mixing plant (with addition of amendments as appropriate);
- Monitoring of the stockpiles, with periodic turning and addition of amendments as required;
- Periodic return of soils to the mixing plant;
- Back fill and compaction of treated soils; and

- Demobilisation of mixing plant and other equipment from the site.

Soil washing

- Mobilisation, set up and commissioning of soil washing plant at the site;
- Excavation of soils and transfer to stockpiling location adjacent to treatment unit;
- Feed of soils to the soil washing unit and treatment (screening, scrubber and washer units and associated separation);
- Stockpiling of treated soils;
- Back fill and compaction of treated soils;
- Disposal of filter cake material; and
- Demobilisation of plant and equipment and shipment off the island.

Excavation and disposal

- Mobilisation of plant and equipment to the site (and establishment of stockpiling areas established at the port facility);
- Excavation of soils and direct loading onto off site waste haulage vehicles;
- Transfer of material from the site to the port facility;
- Stock piling of materials at port facility;
- Loading of soil material onto specialised vessels for shipment to specialised permitted disposal facility (likely central Europe);
- Import of clean backfill material to the site (assumed sourced on the island) and backfill and compaction of this material within excavation; and
- Demobilisation of equipment from site.

3.7 Assessment process

To facilitate the assessment, a conceptual outline remedial programme based upon each of the above soil treatment/disposal options was developed, and key sustainability considerations were highlighted. At this point in the assessment process, it became apparent that not all of the soil treatment/disposal options would be appropriate for all the scenarios identified. Certain options could be discounted either on the basis of time (i.e. unable to achieve risk-management goals in defined timeframe), treatment standard achievable (i.e. technical feasibility to meet risk-management objectives), or predicted cost (i.e. approaches that were considered to exceed the original estimated costs of thermal desorption were discounted). This is summarised in Table 2. Approaches in red or orange were not considered as they were deemed inappropriate or had uncertainties associated with them. Approaches highlighted green were considered in the sustainability assessment.

The project team agreed to make use of the URS tool for this assessment, and concluded that a Tier 1 semi quantitative approach (i.e. the simplest tier of appraisal) was appropriate. This approach involved the identification of relevant 'categories of indicators' (assessment criteria) for each of the three 'pillars' (themes) of sustainability (economic, environmental and social). The SuRF-UK Sustainable Remediation Indicators were used as the basis for this. As part of the initial workshop, the project team agreed upon the relevant assessment criteria and associated weightings. The conclusions reached in this process are summarised in Table 3, which provides rationale on the assigned weightings.

Table 2: Approaches and scenarios considered in the assessment

	Scenario					
	Existing site masterplan		Unrestricted end use		Updated site masterplan	
	<18 months	<5 years	<18 months	<5 years	<18 months	<5 years
	1	2	3	4	5	6
Remedial Option						
Thermal desorption	Y	Y	N	N	Y	Y
Land farming	Y	Y	N	P	Y	Y
Enhanced bioremediation	Y	Y	P	Y	Y	Y
Soil washing	Y	Y	N	N	Y	Y
Excavation and disposal	N	N	N	N	Y	Y
Key						
Y	Yes - Likely to be applicable					
P	Possible - Some uncertainty / constraints					
N	No - Not applicable					

Weightings are applied between 0 and 5, where 0 is considered not specifically relevant to the site, 1 reflects low importance and 5 indicates high importance. If an assessment criterion was considered to be equally relevant to all remedial options, it was also weighted as 0 and excluded from the assessment. For each relevant assessment criteria, the relevant indicators were identified and weightings applied.

Following the weighting process, the URS tool requires remedial options for each of the assessment criteria to be scored. The scores were applied on a relative basis, with reference to the relevant indicators shown in Table 3. The scores range between 1 and 5, where 1 represents the least favourable technique, and 5 is the most favourable. The scores were then multiplied by the assigned weighting. For each pillar a percentage score was then calculated (percentage of maximum possible score, reflecting the number of assessment criteria). This serves to illustrate those options that score high/low for a given pillar. The tool then combined (and normalised) the score for the three pillars, to provide a balanced overall score for the option.

For a given option, this balanced overall score can be compared against the other options (within the same scenario) and is intended to assist in the identification of the most sustainable option. Further explanation of the calculation methodology is included within Appendix A. In the assessment for the Madeira site, the process was repeated for each of the scenarios identified (with the exception of Scenarios 3 and 4, for which Table 2 identifies that there are limited options). For a summary of the individual assessment results see the output tables from the tool in Tables 4, 5, 6 and 7 and Figures 2, 3, 4 and 5 (all of which are presented in Appendix B). Table 8 provides an overview of the results.

3.8 Uncertainties

It is acknowledged that there can be a substantial degree of subjectivity associated with the semi-quantitative approach adopted. To overcome this, the scoring process was undertaken independently by several members of the project team. As the tool requires justifications of the scores to be entered during the scoring process, the assessors were able to convene following the scoring and identify any notable differences in opinion. These were explored along with the sensitivity of the overall result to variation in the scoring. The scores were then agreed upon, with the associated justification identified. Independent assessment by multiple team members is considered to have removed the subjectivity associated with the applied approach.

Table 3: The assessment criteria and associated weightings

Theme	Assessment Criteria	Assigned Weighting	Key Relevant Indicators	Additional Notes/Justification
	Direct Economic Costs and Benefits	5	Direct financial benefits of remediation for organisation	- Key factors to Shell are the cost of the remediation works and the maximising sale value of the site.
	Indirect Economic Costs and Benefits	0	n/a	- Property value was relevant to Shell and the stakeholders, however this was considered to be a direct economic implication due to the impending sale of the land so indirect effects were excluded.
	Employment and Employment Capital	0	n/a	- Due to the duration of the works and the nature of the site, the potential for long-term employment and training is limited. This is the same across all options therefore has been excluded. - Potential for local labour during remediation project possible, subject to safety and competence assessment.
	Induced Economic Costs and Benefits	0	n/a	- It was concluded that the induced economic effects would not be dependent upon the type of remediation, therefore this was excluded.
	Project Lifespan and Flexibility	3	Ability of project to respond to changing circumstances (incl. discovery of additional contamination, different soil materials, different timescales)	- Focus within this criterion is the potential influence of changing circumstances upon overall cost (approaches with lower unit rates likely to be favoured) - For short remediation period scenarios (<18 months) there may be limited flexibility regardless of approach
	Impacts on Air	5	Greenhouse gases (CO_2, CH_4, N_2O) VOCs	- Note potential conflict of CO_2 emission and VOC emission (less intensive approach may have lower carbon footprint, however give rise to greater VOC emission) - Greenhouse gases arising from burning fossil fuels.
	Soil and Ground Conditions	0	n/a	- The suitability for likely construction on the land was discussed, however it was considered that this would be more dependent on the underlying rock, which will not be effected by the remedial works, therefore this category was excluded
	Groundwater and Surface Water	0	n/a	- Water management would be required regardless of soil treatment alternative. - Consideration needs to be given to proximity of bathing beach and activities on site need to be managed so that there is no runoff to groundwater and surface water but this would be the case of all remedial options assessed, therefore this category was excluded.
	Ecology	0	n/a	- A marine ecology assessment took place as part of the wider remedial investigation and it was deemed to be of no concern, so was excluded.
	Natural Resources and Waste	5	Impacts on waste resources (e.g. landfill space) Handling of materials on-site, off-site and waste disposal sources Use of fossil fuels	- Potential existence of suitable landfill facilities on the island - Energy use (in transport of plant to site from mainland Europe and remediation operation) potentially significant and varies between options.
	Human Health & Safety	5	Can unacceptable risks be mitigated? Extent of risks to site workers (from bio aerosols, allergens, particulate matter, etc.) Extent of risk to site workers (from operating machinery, traffic movements, evacuations etc.) Extent of risk to site neighbours (from operating machinery, traffic movements, evacuations etc.) Extent of risk to the public (from operating machinery, traffic movements, excavation etc.)	- Criteria relates specifically to site workers and intruders. If a risk to off-site receptors exists, then the approach will not be undertaken - The period of remedial works is important and lower duration alternatives will be favoured - Note that it is assumed that hydrocarbon vapour emissions may be controlled within acceptable limits with all options
	Ethics and Equality	0	n/a	- The ethics and equality were considered equal for all remedial options and as the "polluter paid" principle is being upheld under all options, this category was excluded. The length of remedial works has been considered as part of the Neighbourhood and Locality criteria.
	Neighbourhood and Locality	5	Impacts on local community: Dust Impacts on local community: Light Impacts on local community: Noise Impacts on local community: Odour Impacts on local community: Vibrations	- The period of remedial works is important and lower duration alternatives will be favoured. - Operations that have lesser potential for dust, odour, noise, vibration preferred. It was expected that any option would have to comply with local regulations to minimise neighbourhood disturbance, including working hours and mitigation measures.
	Communities and Community Involvement	0	n/a	- It was deemed that as all works will take place on private land, there will be no impact on public access. Works will be carried out in a transparent manner regardless of the option, therefore this category was excluded
	Compliance, Uncertainty and Evidence	1	Compliance of the work with local and national policies, regulatory standards and good practise Extent to which work is in line with industry working practices and expectations Quality of investigation, assessment and plans for implementation of remediation process Extent to which the remediation plans can cope with variation	- Shell will comply with policies, regulatory standards, etc. - Consider the extent to which the plans may cope with variation. Flexible options will be favoured - Consider potential consequences of a change in the current CSM identified through further investigation

4. THE SUSTAINABILITY ASSESSMENT OUTCOMES

Table 8: An overview of the scores for each remediation option and scenario

	Overall Scores for each Remedial Option				
	Thermal Desorption	Land Farming	Enhanced Bioremediation	Soil Washing	Excavation with off-site disposal
Scenario 1	55%	60%	63%	56%	Not assessed
Scenario 2	55%	66%	64%	56%	Not assessed
Scenario 5	63%	65%	68%	66%	35%
Scenario 6	63%	66%	68%	66%	35%

On the basis of this sustainability assessment, it is considered that an enhanced bioremediation approach is likely to represent the most sustainable and appropriate remedial solution for the site. This applies to all the scenarios considered, with the exception of Scenario 2, in which land farming also scores highly due to the relaxed time constraints. Given this consistent result, the 'risk' associated with proceeding with a remedial programme based upon an enhanced bioremediation approach would appear to be low (i.e. the favoured approach upon the eventual development scenario at the site).

The adoption of an enhanced bioremediation approach for the treatment of the soils would represent a change of the original strategy for the site, which proposed the use of a thermal desorption approach. This previous selection had been driven primarily by time constraints associated with the previous redevelopment plan and associated programme. The assessment undertaken has illustrated that if the original time constraints applied to the project are no longer relevant or appropriate, then an alternative approach (enhanced bioremediation) is likely to have a better sustainability outcome (economic, environmental, social).

The assessment indicates that the application of an enhanced bioremediation approach will have better sustainability outcomes at the site, with high scores for the environmental and economic pillars (see Tables 4-7 in Appendix B).

Whilst enhanced bioremediation was identified as a favourable option, the assessment also highlighted a number of indicators for which this approach may be less favourable. These aspects should be considered and addressed in detail as the programme is progressed and the detailed action plan developed. For instance, 'average' scores have been applied for a number of the social indicators, including 'Neighbourhood and Locality' on account of potential dust and odour issues. The detailed implementation plan should therefore identify measures to minimise and mitigate these potential concerns.

A simple Tier 1 semi-quantitative approach is considered to have been appropriate for the assessment. Whilst a Tier 2 assessment could be undertaken for selected indicators, it was considered that the completion of this would bring limited added benefit.

5. CONCLUSION

Prior to the sustainability assessment, the preferred remedial option was thermal desorption. As a result of assessment enhanced bioremediation was chosen as the strategy to take forward. There are a number of benefits associated with this change in strategy:

- A reduction in CO_2 emissions due to less intensive energy use;
- A reduction in costs;
- A reduction in fuel use;
- A reduction in neighbourhood disturbance caused by noise, which would have arisen from the operation of the thermal plant; and
- Potential for local employment.

6. LESSONS LEARNED

During the progression of this assessment the following aspects have become evident:

- A key element of the works is to define and develop the remedial options to an appropriate degree before proceeding with the sustainability assessment. A conceptual design for each approach needs to be developed in order that adequate information is available to base the assessment.

- The context within which the assessment is to be undertaken should be discussed at an early stage between the project team, to ensure the assessment is properly 'framed'. There are evident advantages to doing this in the form of a face to face meeting, as this allows the relevant aspects to be explored in greater detail. Specific aspects that require discussion include, for example, the overall business objectives, the background to the site, site soil and groundwater data and associated conceptual model, risk assessment and risk-mitigation requirements and identification of the key stakeholders.

- It is acknowledged that stakeholder involvement in the completion of this assessment has been limited. Engagement with other stakeholders (i.e., representatives of MREA, CMF and neighbours) has been undertaken in the course of the project, and the likely views of these stakeholders have been considered within this assessment. Whilst different indicators may be more important to other parties (for instance the bias of the regulating authorities may be towards environmental factors, while social factors may be the focus of local neighbour and community groups), it is considered that a reasonably balanced assessment has been undertaken. Despite this, benefit would have been gained from further discussion with stakeholders to help to clarify and develop understanding of the 'average' scores given to the social aspects, as in the sustainability assessment outcomes section.

- The assessments undertaken illustrate that whilst a given option may score significantly differently on specific indicators or categories of indicators, the overall scores typically illustrate a more balanced picture, with fewer differences between the options.

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APPENDIX A - A Worked Example of the Assessment Process

Example (for Scenario 1, Economic, Direct Costs and Benefits):
• A weighting of 5 was assigned to Direct Economic Costs and Benefits

• Each option was then scored
 - Thermal Desorption scored 2, as it is likely the higher cost option
 - Land Farming scored 5, as it is likely to represent the lowest cost option
 - Enhanced Bioremediation scored 3, as the estimated costs are likely fall between the other options.
 - Soil Washing scored 2, as the cost is likely to be similar to that of Thermal Desorption

• The scores were then multiplied by the assigned weighting to determine the weighted scores for this criterion:
 - Thermal Desorption 10
 - Land Farming 25
 - Enhanced Bioremediation 15
 - Soil Washing 10

• This process was repeated for each relevant assessment criteria within the Economic pillar

• By following the process above for Project Lifespan and Flexibility (which is the only other relevant assessment criterion in the Economic pillar in Scenario 1, weighted as 3), the weighted scores were as follows:
 - Thermal Desorption 12
 - Land Farming 3
 - Enhanced Bioremediation 9
 - Soil Washing 9

• For the Economic pillar the percentage of the maximum score is then calculated as follows:
 - The total number of assessment criteria scored within the pillar was identified (i.e. those that received a weighting between 1 and 5). For Economic in Scenario 1, this was 2
 - The maximum possible unweighted score for each option within the pillar was then calculated. As each assessment criteria could have scored a maximum of 5, the maximum possible unweighted score for each option was 10
 - The maximum possible weighted score for each option was then calculated:

$$\text{Maximum Possible Weighted Score} = \frac{\text{Max. possible unweighted score} * (\Sigma \text{ the weightings})}{\text{Number of relevant assessment criteria within the pillar}}$$

and divided by 3. The overall score was normalised for the differing numbers of assessment criteria within each pillar. For the Economic pillar this gave:
(10 * (3 + 5)) / 2 = 40

• The actual score for each option was then calculated as a percentage of 40 (the maximum possible weighted score for the Economic pillar in Scenario 1). This meant that the overall score was normalised to account for the differing numbers of assessment criteria within each pillar:
 - Thermal Desorption ((10 + 12) / 40) * 100 = 55%
 - Land Farming ((25 + 3) / 40) * 100 = 70%
 - Enhanced Bioremediation ((15 + 9) / 40) * 100 = 60%
 - Soil Washing ((10 + 9) / 40) * 100 = 48%

• This process was repeated for the Environmental and Social pillars

• The scores for each pillar are then combined and divided by 3 to determine an overall score. This overall score is 'normalised', i.e. each pillar represents 33% of the total score.

APPENDIX B - Tables 4-7 and Figure 2-5 showing summary of scoring from 4 scenarios in the sustainability assessment

Table 4: Summary of Scoring for Scenario 1: Existing Masterplan (17,500 tonnes) in less than 18 months

Theme	Assessment Criteria	Weight	Remediation Option*				Justification of Scores
			1	2	3	4	
Economic	**Direct Economic Costs and Benefits**	5	2	5	3	2	- Based upon cost estimates
	Indirect Economic Costs and Benefits	0	0	0	0	0	
	Employment and Employment Capital	0	0	0	0	0	
	Induced Economic Costs and Benefits	0	0	0	0	0	
	Project Lifespan and Flexibility	3	4	1	3	3	- Rates for thermal and soil washing are broadly similar and both are flexible for changing quantities. As volumes increase, costs will increase. Thermal is the most flexible - Some uncertainty is associated with bio option and higher quantities - Limited flexibility for land farming option given short period available for remediation
Environmental	**Impacts on Air**	5	1	4	3	2	- Highest CO2 footprint likely to be associated with thermal approach (followed by soil washing) - Whilst lowest footprint is likely to be associated with land farming, it is likely to give rise to greatest VOC emissions but the overall impact of this is likely to be less than the impact of enhanced bio and soil washing
	Impacts on Soil and Ground Conditions	0	0	0	0	0	
	Impacts on Groundwater and Surface Water	0	0	0	0	0	
	Impacts on Ecology	0	0	0	0	0	
	Use of Natural Resources and Waste Generation	5	1	5	4	2	- Thermal approach involves high energy consumption - Land farming requires minimal consumption of fuel and fuel consumption for enhanced bio is also low - Soil washing involves relatively high water and power consumption and generates filtercake which is assumed to go for off site/off island disposal
Social	**Impacts on Human Health and Safety**	5	5	1	3	4	- Safety of thermal process can be managed with associated process control. thermal approach also minimises time on site so on this basis scores highly - Bio approaches (particularly land farming) involve longer period of works on site, so workers are potentially exposed to higher risk - Safety of soil washing unit can be managed through process control and operating procedures
	Ethics and Equality	0	0	0	0	0	
	Neighbourhood and Locality	5	4	1	3	4	- Dust impacts are likely to be greatest for land farming and (to a lesser extent) enhanced bio approach - Potential odour issue is likely to be greatest with land farming and (to a lesser extent) enhanced bio as a result of large stockpile and bio bed - Daily operations associated with all approaches to be restricted, however thermal and soil washing will have overall shorter programme duration (minimising potential dust, light, noise, vibration issues)
	Communities and Community Involvement	0	0	0	0	0	
	Compliance, Uncertainty and Evidence	1	5	1	3	4	- All scenarios expected to be reasonably flexible to changes in extent - Land farming is the least flexible option given uncertainties of achieving treatment standards within limited available period - Thermal approach most able to deal with changes in contaminant levels

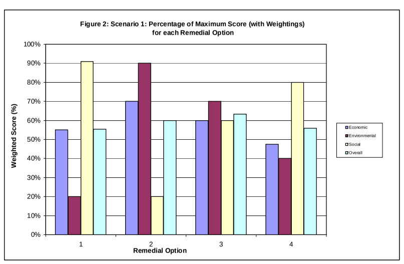


Figure 2: Scenario 1: Percentage of Maximum Score (with Weightings) for each Remedial Option

* **Remedial options**
1.- Thermal desorption
2.- Land farming
3.- Enhanced bioremediation
4.- Soil washing

Table 5: Summary of Scoring for Scenario 2: Existing Master plan (17,500 tonnes) in 5 years

Theme	Assessment Criteria	Weight	Remediation Option*				Justification of Scores
			1	2	3	4	
Economic	**Direct Economic Costs and Benefits**	5	2	5	3	2	- Based upon cost estimates
	Indirect Economic Costs and Benefits	0	0	0	0	0	
	Employment and Employment Capital	0	0	0	0	0	
	Induced Economic Costs and Benefits	0	0	0	0	0	
	Project Lifespan and Flexibility	3	4	3	3	3	- Rates for thermal and soil washing are broadly similar and both are flexible for changing quantities. Longer time period for remediation increases flexibility of bio options - Increased volumes become more realistic for land farming option given longer period for remediation
Environmental	**Impacts on Air**	5	1	4	3	2	- Highest CO2 footprint likely to be associated with thermal approach (followed by soil washing) - Whilst lowest footprint is likely to be associated with land farming, it is likely to give rise to greatest VOC emission but the overall impact of this is likely to be less than the impact of enhanced bio and soil washing
	Impacts on Soil and Ground Conditions	0	0	0	0	0	
	Impacts on Groundwater and Surface Water	0	0	0	0	0	
	Impacts on Ecology	0	0	0	0	0	
	Use of Natural Resources and Waste Generation	5	1	5	4	2	- Thermal approach involves high energy consumption - Land farming requires minimal consumption of fuel - Soil washing involves relatively high water and power consumption and generates filtercake which is assumed to go for off site/off island disposal - Overall use of resources associated with bio option is less than soil washing
Social	**Impacts on Human Health and Safety**	5	5	1	3	4	- Safety of thermal process can be managed with associated process control. Thermal approach also minimises time on site so on this basis scores highly - Bio approaches (particularly land farming) involve longer period of works on site, so workers will be exposed to higher risk - Safety of soil washing unit can be managed through process control and operating procedures
	Ethics and Equality	0	0	0	0	0	
	Neighbourhood and Locality	5	4	1	3	4	- Dust impacts likely to be greatest for land farming and (to a lesser extent) enhanced bio approach - Potential odour issue likely greatest with land farm and (to a lesser extent) enhanced bio as a result of large stockpile and bio bed - Daily operations associated with all approaches to be restricted, however thermal and soil washing will have overall shorter programme duration (minimising potential dust, light, noise, vibration issues)
	Communities and Community Involvement	0	0	0	0	0	
	Compliance, Uncertainty and Evidence	1	5	3	4	4	- All scenarios expected to be reasonably flexible to changes in extent - Land farming least flexible option given uncertainties of achieving treatment standards (however improved by increased period of remediation) - Thermal approach most able to deal with changes in contaminant levels

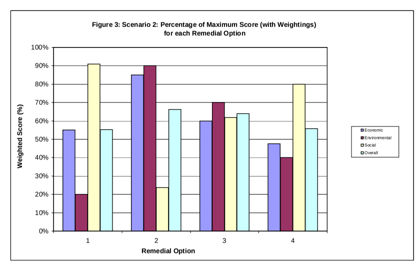
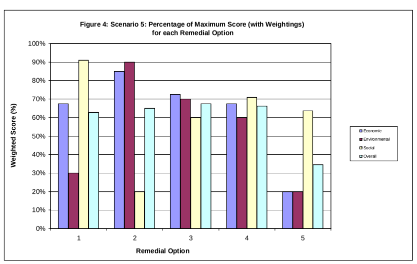


Figure 3: Scenario 2: Percentage of Maximum Score (with Weightings) for each Remedial Option

* **Remedial options**
1.- Thermal desorption
2.- Land farming
3.- Enhanced bioremediation
4.- Soil washing

Table 6: Summary of Scoring for Scenario 5: Updated site masterplan (9,000 tonnes) in less than 18 months

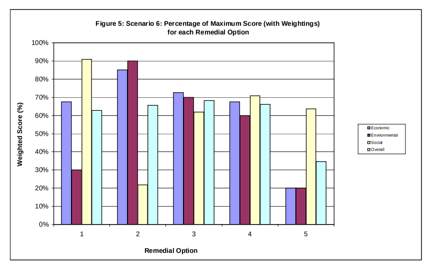
Theme	Assessment Criteria	Weight	Remediation Option *					Justification of Scores
			1	2	3	4	5	
Economic	**Direct Economic Costs and Benefits**	5	3	5	4	3	1	- Based upon cost estimates
	Indirect Economic Costs and Benefits	0	0	0	0	0	0	
	Employment and Employment Capital	0	0	0	0	0	0	
	Induced Economic Costs and Benefits	0	0	0	0	0	0	
	Project Lifespan and Flexibility	3	4	3	3	4	1	- Focus is on project cost changes - Rates for thermal and soil washing are broadly similar and both are flexible for changing volumes/quantities - Short time period for remediation reduces flexibility of bio options. Although required soils treatment standard less onerous for this option, any significantly increased volumes unlikely to be realistic for land farming option. - Unit rates for off site disposal are highest and hence changing circumstances will have greatest impact
Environmental	**Impacts on Air**	5	1	4	3	3	1	- Highest CO2 footprint likely to be associated with thermal approach and excavation approach - Whilst lowest footprint is likely to be associated with land farming, it is likely to give rise to greatest VOC emission (and hence maximum score not allocated) - Enhanced bio and soil washing assumed to be similar
	Impacts on Soil and Ground Conditions	0	0	0	0	0	0	
	Impacts on Groundwater and Surface Water	0	0	0	0	0	0	
	Impacts on Ecology	0	0	0	0	0	0	
	Use of Natural Resources and Waste Generation	5	2	5	4	3	1	- Off island disposal requires high fuel consumption and use of landfill facility (assuming landfill disposal) - Thermal approach involves high energy consumption - Soil washing involves relatively high water and power consumption and generates filter cake which is assumed to go for off site/off island disposal - Land farming requires minimal consumption of fuel - Overall use of resources associated with bio option is less than soil washing
Social	**Impacts on Human Health and Safety**	5	4	1	3	3	4	- Safety of thermal process can be managed with associated process control. Thermal approach also minimises time on site so scores highly. There may be a perception issue associated with operation of the plant - Safety of off site disposal process can be managed through working procedures and this approach minimises time on site. Inherent risk associated with greater off site vehicle movements - Safety of soil washing unit can be managed through process control and associated operating procedures
	Ethics and Equality	0	0	0	0	0	0	
	Neighbourhood and Locality	5	5	1	3	4	2	- Dust impacts likely to be greatest for land farming and (to a lesser extent) enhanced bio approach - Potential odour issue likely greatest with land farm and (to a lesser extent) enhanced bio as a result of large stockpile and bio bed - Daily operations associated with all approaches to be restricted, however thermal, soil washing and off site/off island disposal will have overall shorter programme duration (minimising duration of dust light, noise, vibration nuisance) - Potential vibration nuisance associated with off site transport to port facility for excavation option - Note: Potential perception issue associated with thermal desorption however this is not reflected in the score for this assessment
	Communities and Community Involvement	0	0	0	0	0	0	
	Compliance, Uncertainty and Evidence	1	5	1	3	4	5	- All scenarios expected to be reasonably flexible to changes in extent (less so with land farming option given short period) - Land farming least flexible option given uncertainties of achieving treatment standards (although treatment standards lower for this scenario) - Thermal and off site disposal approaches most able to deal with changes in contaminant levels, volumes etc



* **Remedial options**
1.- Thermal desorption
2.- Land farming
3.- Enhanced bioremediation
4.- Soil washing
5.- Excavation and disposal (off the island)

Table 7: Summary of Scoring for Scenario 6: Updated site master plan (9,000 tonnes) in 5 years

Theme	Assessment Criteria	Weight	Remediation Option *					Justification of Scores
			1	2	3	4	5	
Economic	**Direct Economic Costs and Benefits**	5	3	5	4	3	1	- Based upon cost estimates
	Indirect Economic Costs and Benefits	0	0	0	0	0	0	
	Employment and Employment Capital	0	0	0	0	0	0	
	Induced Economic Costs and Benefits	0	0	0	0	0	0	
	Project Lifespan and Flexibility	3	4	3	3	4	1	- Focus is on project cost changes - Rates for thermal and soil washing are broadly similar and both are flexible for changing volumes/quantities. Longer time period for remediation increases flexibility of bio options - Increased volumes become more realistic for land farming option given longer period for remediation (and required standard for this scenario is less onerous) - Unit rates for off site disposal are highest and hence changing circumstances will have greatest impact
Environmental	**Impacts on Air**	5	1	4	3	3	1	- Highest CO2 footprint likely to be associated with thermal approach and excavation approach - Whilst lowest footprint is likely to be associated with land farming, it is likely to give rise to greatest VOC emission (and hence maximum score not allocated) - Enhanced bio and soil washing assumed to be similar
	Impacts on Soil and Ground Conditions	0	0	0	0	0	0	
	Impacts on Groundwater and Surface Water	0	0	0	0	0	0	
	Impacts on Ecology	0	0	0	0	0	0	
	Use of Natural Resources and Waste Generation	5	2	5	4	3	1	- Off island disposal requires high fuel consumption and use of landfill facility (assuming landfill disposal) - Thermal approach involves high energy consumption - Soil washing relatively high water and power consumption and generates filter cake which is assumed to go for off site/off island disposal - Land farming requires minimal consumption of fuel - Overall use of resources associated with bio option is lower than soil washing
Social	**Impacts on Human Health and Safety**	5	4	1	3	3	4	- Safety of thermal process can be managed with associated process control . Thermal approach also minimises time on site so scores highly. There may be a perception issue associated with the operation of the plant - Safety of off site disposal process can be managed through working procedures. Disposal approach also minimises time on site. There is however inherent risk associated with greater off site vehicle movements - Safety of soil washing unit can be managed through process control and associated operating procedures
	Ethics and Equality	0	0	0	0	0	0	
	Neighbourhood and Locality	5	5	1	3	4	2	- Dust impacts likely to be greatest for land farming and (to a lesser extent) enhanced bio approach - Potential odour issue likely greatest with land farm and (to a lesser extent) enhanced bio as a result of large stockpile and bio bed - Daily operations associated with all approaches to be restricted, however thermal, soil washing and off site/off island disposal will have overall shorter programme duration (minimising duration of dust light, noise, vibration nuisance) - Potential vibration nuisance associated with off site transport to port facility - Potential perception issue associated with thermal desorption
	Communities and Community Involvement	0	0	0	0	0	0	
	Compliance, Uncertainty and Evidence	1	5	2	4	4	5	- All scenarios considered to have reasonable flexibility to address changes in site conditions. Off site/off island disposal, thermal and soil washing likely to have greatest flexibility - Land farming and enhanced bio options have a greater degree of flexibility under this scenario because of longer time period and lower target concentrations



* **Remedial options**
1.- Thermal desorption
2.- Land farming
3.- Enhanced bioremediation
4.- Soil washing
5.- Excavation and disposal (off the island)