EXECUTIVE SUMMARY

This Report describes a variety of potential remediation options available for the materials stockpiled at the Mifalei Plada Steel Works Site, Akko, Israel. Risk assessment studies have shown that potential risks to humans (receptors) arise principally from lead (Pb) concentrated in the fine fractions (<2mm) of the waste materials stockpiled in the Waste Mounds (source) via the inhalation and ingestion pathways.

A range of remediation options were considered and it has been concluded that the most economically viable option would be to reprofile the waste mounds at a suitable location on the Site followed by capping using clean crushed concrete or stone followed by a layer of top soil and grass. Subject to approval from the MoE, another technically and commercially viable remediation option would be the disposal of all the waste at a non-hazardous (construction) landfill (as the leachability of Pb from the wastes is negligible). Techniques such as soil washing, vitrification and metallurgical recycling were considered and rejected due to high costs.

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1. INTRODUCTION

1.1. INSTRUCTION

BAE Systems Environmental was appointed by Enosh Management and Engineering Systems (ENOSH) to conduct a Phase II Environmental Assessment, comprising an intrusive Site investigation, environmental risk assessment and remediation option study at the former Mifalei Plada Steel Works, Akko, Israel.

1.2. OBJECTIVES

The objectives of this study are to review remediation options and to formulate and recommend a remediation strategy based on the most practicable and economically feasible methods of reducing or eliminating risks identified by the environmental risk assessment.

1.3. SOURCES OF INFORMATION

Several sources of existing information have been referenced and consulted in compilation of this Report, the details of which are given below: -

- ‘Stage A Report – Historical Survey and Preparation of Sampling Program - Contamination Survey, Evaluation of Risk and the Assessment of Treatment Alternatives at the Acre Kiryat Haplada Site’, ENOSH Systems Co. Ltd, February 2003;

- ‘Factual Report for Site Pollution Investigation’, BAE Systems Environmental, Report No. A249-00-R2-D, December 2004;

- ‘Risk Assessment Report for Site Pollution Investigation, BAE Systems Environmental, Report No. A249-00-R3-E, December 2004.

1.4. DEFINITIONS

‘Soil’ is a generic term used to describe solid materials sampled from the Site, which includes gravel, sand and fine particles such as EAF dust.

The term ‘Site’ refers to the land occupied by the former Mifalei Plada Steel Works at Akko, Israel.

1.5. REPORTING CONDITIONS

The Report refers to the conditions present at the Site at the time of the study and BAE Systems Environmental can accept no liability for any future changes of Site conditions. It should be noted that BAE Systems Environmental has relied on the accuracy of the information contained in the documents consulted. Although we have taken reasonable steps to verify information and data, BAE Systems Environmental cannot accept responsibility for the accuracy of information or data not generated by ourselves.

This Report has been prepared without the benefit of knowing the intentions of third parties and therefore should not be used by such organisations without prior consultation with BAE Systems Environmental.

2. SITE DETAILS AND DESCRIPTION

2.1. SITE DETAILS

The Site is located about 4km south of the city of Akko (central coordination point 500, 200/754, 207). It is a former steel works dating back to 1954 with stockpiles of a variety of wastes surrounding the north, south and western boundaries of the Site.

The Site is located in an industrial area with paints manufacturing to the south, chemical manufacturing to the north, a rail line to the west and the local road network to the east.

For a detailed description of the Site history, refer to the Phase 1 referenced in Section 1.3.

2.2. FINDINGS OF THE SITE INVESTIGATION AND RISK ASSESSMENT

The information and data presented in the Factual Site Investigation and Risk Assessment Reports have been used to produce a conceptual Site model (CSM) that builds a geo-environmental ‘risk picture’ identifying possible source-pathway-receptor contaminant relationships.

The risk assessment found that the concentrations of Pb within the Waste Mounds are considered to present a significant risk to human health. As such, it was recommended that remedial action be undertaken to prevent exposure to Pb bearing materials in the Waste Mounds via the key pathways of inhalation and direct dermal contact.

Isolated hotspots of total petroleum hydrocarbon (TPH) contamination were discovered in the Made Ground.

3. SUMMARY OF THE SITE ENVIRONMENTAL SETTING

The Site occupies an area of approximately 27 hectares, and generally slopes downward from the south to the north. The naturally occurring soil materials on the Site are mainly granular in nature and possess relatively little cohesive strength or moisture storage capacity. No permanent watercourses are present on the Site. At the time of Site investigation conducted by BAE Systems Environmental, the groundwater table on the Site was detected at depths of between 1.5 and 2.2m below ground level (bgl), and sloped downward from the south to the north.

Buildings currently occupy a large portion of the Site. It is understood that no buildings have been designated for demolition. The Site is designated for further industrial use and some buildings are already partially occupied. It is understood that the Site will be in continuous operation and therefore remedial methods have been selected which will not cause any immediate or future danger to the operational facility.

3.1. GROUND CONDITIONS

Made Ground was identified over almost the entire property upto a maximum depth of 2.1m. The average depth has been understood to be 0.5m. The Made Ground was generally comprised of a thin layer of fine sand and ash, clinker, concrete gravel, slag fragments, sand and gravel. Underlying the Made Ground, natural sand strata were proved to a maximum exploration depth of 14m bgl. The sand was typically uniform with increasing frequency of shell fragments with depth.

The Waste Mounds present on the Site generally consisted of layers of ash (including EAF dust), slag, clinker, concrete and lime fragments. A third waste mound present in the centre of the Site adjacent to the former settlement lagoons appeared to consist of only black ash that probably relates to EAF dust.

Groundwater was encountered in borehole monitoring wells at depths between 1.51m and 2.55m bgl within the sand strata underlying the Made Ground. Groundwater was also encountered in many of the trial pits, typically between 1.7m and 2.3m bgl. The recorded groundwater levels indicate a hydraulic gradient towards the north with an average groundwater level of 2.00m bgl.

3.2. IDENTIFIED SOIL CONTAMINATION

Laboratory testing identified that the Waste Mounds contain high concentrations of Pb at an average concentration of 2750mg/kg. Human health risk assessment has shown that the Waste Mounds contain Pb at levels in excess of the UK Contaminated Land Exposure Assessment (CLEA) Soil Guideline Value (SGV) for industrial Site use of 750mg/kg that was used for assessment. Some isolated hotspots of TPH contamination were identified in the Made Ground at trials pits TP 01, TP04c and TP49 at maximum depths of 0.3m, 0.2m and 0.1m respectively.

Given the heterogeneous nature of the materials within the Waste Mounds, trials were conducted to separate the Waste Mound materials into differing particle sizes for laboratory analysis.

This was conducted to investigate the contamination distribution in the differing size particles of the mound materials. The results of this additional laboratory analysis are presented in Appendix 1 and determined that the majority of the Pb contamination is contained with the finer particle size material. ‘Soil’ fractions less than 2mm in size were found to contain Pb concentrations in excess of the CLEA SGV used for assessment, with a trend of increasing Pb concentration with increasingly finer particle size.

These results therefore confirmed that the significant Pb contamination is likely to be related to the presence of EAF dust within the Waste Mound materials.

3.3. GROUNDWATER CONTAMINATION

In terms of UK Drinking Water Quality Standards (WQS) or freshwater Environmental Quality Standards (EQS), the quality of groundwater encountered on the Property is poor. Concentrations of Al, Cu, Pb, Mn, Ni, V and hydrocarbons, all exceeded the guidance values used for assessment. It is understood there are no known drinking water abstraction points in the vicinity of the or down hydraulic gradient to the north of the Site, as such there are no complete pollutant linkages to potential receptors. Based on this it is considered that the Site poses a low risk to groundwater. A pollutant linkage may also exist between elevated levels of potential contaminants on the Site and nearby surface watercourses although the linkage is likely to be insignificant.

3.4. SOIL GAS

Based on the results of the gas monitoring, it was concluded that there is negligible risk to the Site use from the presence of soil gas.

3.5. GEOTECHNICAL & ENGINEERING CONDITIONS

Detailed analytical data for these conditions have been presented in the BAE Systems Environmental Factual Report for Site Pollution Investigation A249-00-R2-D.

3.5.1 Particle Size Distribution

The results presented in Table 16 of BAE Systems Environmental Risk Assessment report ref. A249-00-R3-E showed that the materials present in the Waste Mounds are predominantly granular comprising (on average): 8.1% of materials less than 63µm in size; 34.2% were between 63µm and 2mm in size; 47.7% of materials were greater than 2mm in size and less than 60mm; and 10% were greater than 60mm in size.

3.5.2 Natural Moisture Content

The moisture content of the “soil” (note: soil is a generic term for all fine materials found at the Site e.g., ash, sand etc) in the Waste Mounds ranged from 1.5 to 14% (w/w) with an average value of 5.5%. This low moisture content is due to the hot and dry local weather conditions and the predominantly granular nature of the waste mounds, as identified in the particle size distribution testing. Such soil and climatic conditions reduce the ability of soils to retain moisture within the soil matrix. Granular materials are highly permeable and are therefore unlikely to contain significant moisture levels.

3.5.3 Particle Density (Specific Gravity)

The recorded particle densities are much higher than those for typical soil material. The densities were in the range 3.25 – 3.55mg/m^3 compared with typical soil particle densities of about 2.6mg/m^3. This value of 2.65mg/m^3 is standard for use in laboratory testing to British Standard 1377:1990 in the absence of actual particle density test results. This value is commonly used when calculating results for compaction testing and is considered representative of common soil particle densities in a fully compacted sample that relates to the densest soil gradually encountered.

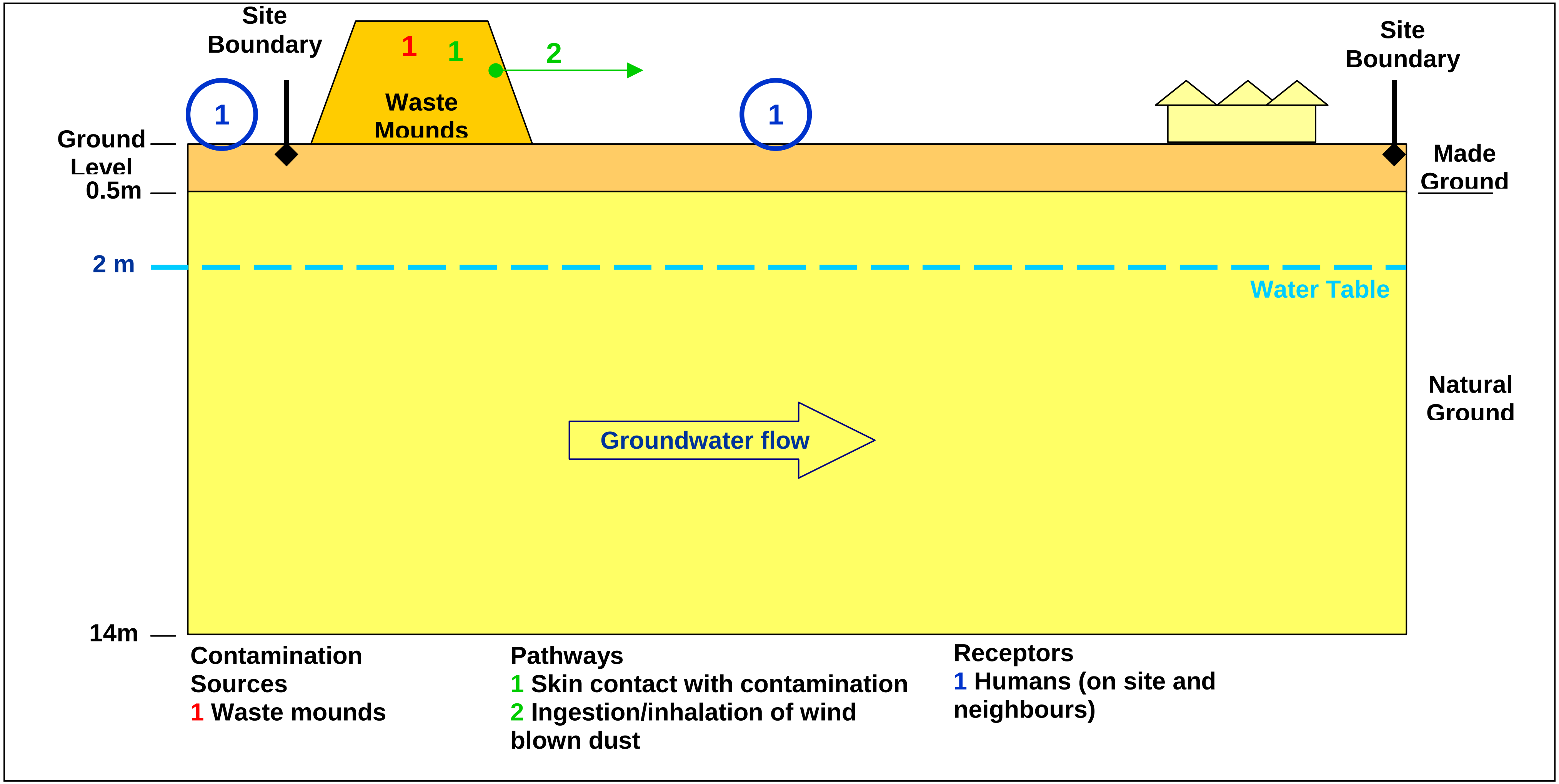

Figure 1: Conceptual site model based on the identified sources, pathways and receptors at the Akko Steel Works Site.

3.6. RISK ASSESSMENT

In light of the results detailed in BAE Systems Environmental Factual Report for Site Pollution Investigation Report A249-00-R2-D and Sections 3.2 to 3.5 of this Report, the conceptual Site model presented in the Risk Assessment report ref. A249-00-R3-E was updated as shown in Figure 1. The modifications to the sources, receptors and pathways are based on the assessments presented in the Risk Assessment report.

The principal sources of contamination are the Waste Mounds whilst the principal receptors of this contamination are expected to be Site workers and personnel working on the Site. The principal pathways for human exposure to contamination from the mounds are dermal contact and/or ingestion/inhalation of wind blown dust.

Leachability studies have shown that there is no significant risk of contamination to surface or groundwater. The Site Investigation data has also shown that a majority of the contaminants in the Waste Mounds may have been concentrated in the EAF dust.

The data presented in Appendix 1 show that the principal contaminant of concern is Pb. However, the data also shows that the concentration of Pb exceeded the CLEA derived SGV only in the fine fractions i.e., soil fractions <2mm in size. Therefore, based on particle size distribution analysis, it can be concluded that a majority of Pb in the waste mounds would be concentrated in approximately 42.3% of the total material volume.

In relation to the presence of TPH contamination in the Made Ground at TP01, TP04c and TP49, additional assessment could be conducted to further determine the level of risk. However, further assessment could be difficult due to the substances in TPH being present in the environment as complex mixtures containing many hundreds of individual compounds with differing toxicological properties. As such, it was advised that the timescales to conduct this work would be undesirable for such small hotspot occurrences of TPH and remediation would be the preferred option.

4. REMEDIATION OPTIONS

The principal contamination risks identified can be removed or mitigated by:

- Removal of the source (e.g., to an off-Site landfill);
- Treatment of the source to destroy the contamination or prevent it being available (e.g., stabilisation);
- Breakage of the pathway by which the contamination poses a risk to the receptor (e.g., capping or insertion of a barrier).

One of the primary requirements for any remediation scheme is an estimate of waste volumes, which are generally calculated on the basis of contaminant sequestration in various waste fractions. The volume of waste in the Waste Mounds was calculated as described below.

4.1. ESTIMATES OF CONTAMINATED MATERIAL VOLUMES IN THE WASTE MOUNDS

An estimate of the volume of material in the Waste Mounds has been made using a 3-d topographical model, which was produced using the software package Autodesk-revit.

West mound

Average cross sectional area	305 m^2
Length of the mound	216 m
Volume of the west mound	65880 m^3

North mound

Average cross sectional area	120.3 m^2
Length of the mound	133m
Volume of the west mound	16,000 m^3
Total sum	**83,100 m^3**

The volume of waste in the third waste mound in the middle of the Site (near the former settlement lagoons) was not estimated using Autodesk software. However, visual assessment suggests that the total volume of waste in third mound could be in the range 15,000 – 20,000m^3. Therefore the total gross volume of waste in all the Waste Mounds can be estimated to be approximately **100,000m^3**.

The gross volume of potentially contaminated material stockpiled in the Waste Mounds has been calculated to be 100,000m^3. Geotechnical and contamination distribution testing has shown that the <2mm soil fraction (EAF dust + sand+ fines) contains the contamination in concentrations which may require remedial action, whilst the particle fraction >2mm does not require remedial action. Therefore, most potential remediation methods would benefit from separation of the <2mm fraction from the other (relatively uncontaminated) waste materials. If the separation of the <2mm fraction can be sufficiently effective to lower the Pb concentrations in the remaining volume to less than the CLEA derived guidance threshold, this remaining volume can be considered uncontaminated, and may be usable as clean cover above the main ground or if surplus to requirements on Site, subject to approval of the regulator, removed to a non-hazardous waste landfill Site.

Table 1 below presents an estimated breakdown of the % and volumes of the materials stockpiled in the North and West Waste Mounds. This breakdown has been achieved using the laboratory particle size distribution data. The data shows that the total volume of waste requiring treatment is approximately 42,300m^3.

	Waste Mounds	
	%	m^3
Fines + Silt + Sand + EAF dust (<2mm fraction)	42.3(of 100,000m^3)	42300
Gravel size + Oversize fraction (>2mm in particle diameter)	57.7 (of 100,000m^3)	57700

Table 1: Breakdown of waste in the Mounds based on particle size.

<u>Volume of TPH Contaminated Soil in the Made Ground</u>

The total volume of TPH contaminated soil around the three identified trials pits (TP 01, TP04c and TP49) was calculated using a 25m^2 sampling grid to a maximum depth of 0.5m. Therefore, the gross volume of TPH contaminated soil has been estimated to be approximately 37.5m^3.

4.2. GENERIC REMEDIATION PROCEDURES RELEVANT TO THE SITE

The procedures described below can be used to prevent human exposure to contamination from the Waste Mounds. These procedures can be used in isolation or in combination, although on most Sites they are used to complement each other. Most of these remediation options should also treat TPH contaminated material. Techniques such as soils washing, vitrification and recycling by metallurgical means have been deliberately ignored, as these are very costly. A summary of the reasons for their rejection is given in Appendix 1.

(a) Cover Solutions

Containment is the most widely used strategy for the remediation of contaminated land due to its effectiveness in eliminating potential linkages or pathways between contamination source and receptor. The principal receptors present on the Site are on-site personnel, who could be exposed via the inhalation and ingestion pathways. Capping the waste materials using locally won sands or soils, as clean cover material will break these pathways. The addition of engineered capping layers such as geotextiles and geomembranes comprised of HDPE liners, concrete and asphalt can achieve additional groundwater protection. The provision of a basal liner to protect the underside of the contaminated material from contact with groundwater will not be necessary. The specific circumstances on this Site do not require a total containment strategy by virtue of the fact that from the risk assessment, the groundwater does not require protection from the Waste Mound material. Therefore, the installation of additional basal HDPE liners will not be beneficial.

However, a drawback of cover solutions is that it is difficult to achieve stable capped mounds, which are resistant to erosion, without significant reprofiling of the waste. Regrading the materials into various size fractions using wet or dry sieving followed by compaction and capping of the waste materials using slopes designed to provide stability can result in increased slope stability. Appropriate profiling of the capped waste mounds will reduce the maintenance required to prevent their erosion. Landscaping the mounds can follow capping, such that a layer of grass or other appropriate vegetation is used to further reduce erosion. Unsorted (by segregation) waste mounds will have relatively larger footprints, thereby limiting the development area of the Site.

(b) Segregation of Contamination followed by On-Site Capping and/or Landfilling

This would involve separation of the most contaminated soil fractions, i.e. the fine fractions and sand (which would also include EAF dust), from the bulk uncontaminated soil mass, i.e. gravel or oversize, using dry sieving. Segregation can also be achieved using wet techniques such as soil washing, but these tend to be costly and require specialist equipment and are therefore only used in instances where segregation of the contaminated fraction is difficult. Trials on Waste Mound material have shown that adequate segregation of material >2mm from material <2mm can be achieved using dry sieving via power screening equipment. Waste segregation would result in significant waste volume reductions and therefore, the overall costs of treatment or disposal may be lower than those for treating the entire waste in the Mounds.

The contaminated fine fractions in the soil can be sent to a hazardous waste landfill (probably at Ramat Hovav) for disposal or placed on Site and capped. Any contaminated oversize can also be sent to a landfill or placed on-Site and capped. Other materials such as gravel and uncontaminated oversize, which are generally expected to be uncontaminated, can be reused as clean fill either on-site or off-site. Segregation also removes scrap metal fractions, which prevent proper compaction of the waste materials and can be sold-off as scrap.

Segregation of waste is only viable if it can be sufficiently shown that the contamination can be segregated efficiently into one soil/waste fraction. It has been clearly demonstrated that nearly all the Pb exceeding the CLEA derived SGV is concentrated in the <2mm fraction of the waste materials in the Waste Mounds. Segregation of wastes provides additional options for decision making on the optimal locations where the contaminated materials can be placed on-site and/or the nature of the landfills the materials can be sent to i.e., whether hazardous or non-hazardous landfills. Since segregation causes waste volume reductions, this also has the potential to increase the development area of the Site.

(c) Stabilisation and Solidification

Converting the Pb in the Waste Mounds to more insoluble forms can eliminate their mobility and bioavailability, thereby rendering the dust non-hazardous. Portland cement or lime can be used to stabilise the metal contaminants and chemically bind the fine fractions (including EAF dust) to form solid agglomerated lumps. Pozzolans such as fly ash, react with the heavy metals in the fine fractions, forming complex aluminosilicates, that harden to form concrete like materials which have not been found to be susceptible to acid leaching.

The following solutions are available for the stabilised and solidified materials:

i. On-site stockpiling of all the materials at a suitable location;

ii. Use on-site as engineering fill;

iii. Use off-site as engineering fill;

iv. Disposal off-site at a construction waste landfill.

It is advisable that specific leachability trials be performed on stabilised & solidified materials designated for use on-site or off-site as engineering fill. These trials should provide information on the long-term impact of these solidified materials on the groundwater at sites where they could be used as engineering fill.

(d) Disposing all the Waste Mound Materials to a <u>Non-Hazardous</u> Landfill (without segregation)

Leachability testing data described in the risk assessment report A249-00-R3-E and the Site Pollution Investigation Report A249-00-R2-D has shown that the risk to groundwater as a result of leachability of lead from the wastes stockpiled in the Waste Mounds is minimal. Consequently, although the wastes are potentially hazardous to human health, they do not pose a risk to the groundwater. Therefore, subject to approval from the Ministry of Environment (MoE), the wastes could possibly be disposed of in a non-hazardous (construction) landfill. This would result in significant increase in the development area at the site in addition to large cost-savings (compared to disposal of all or part of the waste to a hazardous landfill).

(e) Off-Site Disposal to a Landfill of all Waste Materials to a <u>Hazardous</u> Landfill (without Segregation)

This procedure completely removes the contaminated materials from the Site. The materials sent to a landfill (probably the one at Ramat Hovav) will generally depend on their physical and chemical properties, based on which decisions on their hazard potential can be made. All the materials stockpiled in the Waste Mounds could be disposed of in a hazardous waste landfill. The entire volume of soil in areas of the Made Ground where TPH contamination was identified can also be disposed of at a hazardous waste landfill.

5. FACTORS AFFECTING REMEDIATION OBJECTIVES AND CHOICE OF REMEDIATION OPTIONS

i) Identification of suitable landfills for the disposal of waste materials from the Site.

ii) Costs of transport and disposal of the waste.

iii) Any pre-treatment requirements prior to transport and disposal of the waste.

iv) Availability of appropriate equipment and personnel for waste segregation, capping and stabilisation and the ability to control the emission of contaminated dusts.

v) Regulatory and Site requirements for the segregation and/or capping of waste on-Site.

vi) The prevalence of adverse weather conditions where the remediation work is to be conducted.

vii) Regulations governing the transport of hazardous waste.

viii) Cost of waste segregation versus the cost savings in capping or landfilling.

ix) The benefits derived from maximising the Site land available for development or use by existing on-Site operations

x) Any collateral benefits such as improved groundwater protection

xi) Durability of the remediation option

xii) Regulatory interpretation of the hazard potential of the stockpiled wastes.

6. RECOMMENDED OPTIONS

The following assumptions (based on the risk assessment) have been made with regards to the nature of the materials at the Site prior to the choice of suitable remediation techniques – (i) all the contaminated materials are stockpiled in the Waste Mounds; (ii) the principal contaminant is Pb; (iii) nearly all the Pb is concentrated in the fine (<2mm) fractions.

The available remediation options can be broadly divided into two categories: (i) Off-site (ii) On-site. Off-site procedures include landfilling at hazardous and/or non-hazardous construction landfills and/or off-site reuse of treated or untreated waste fractions. On-site procedures include capping all the materials on-site using various cover materials. Figure 2 is a conceptual diagram of the available techniques for the remediation of the materials stockpiled in the Waste mounds. All these options are discussed further in Sections 6.1 – 6.2.

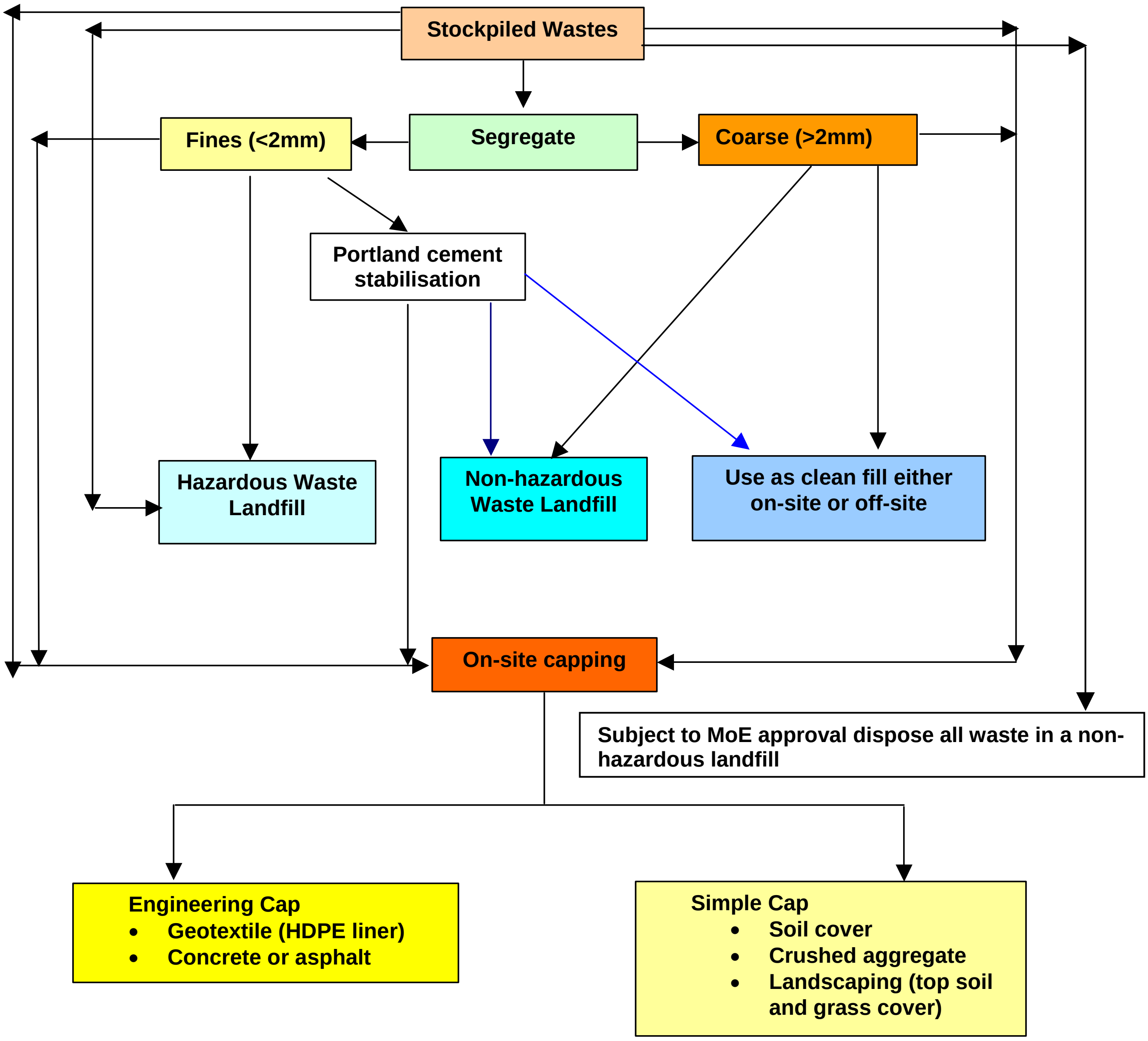

Figure 2: Conceptual diagram of the available remediation options and their inter-relationships.

6.1. OFF-SITE REMEDIATION

1) Landfilling all the stockpiled wastes at a hazardous landfill: All the materials in the Waste Mounds could be disposed of at a hazardous waste landfill with minimal processing after excavation, thereby removing the source of contamination completely from the Site. This clears up a large section of the Site for future redevelopment. The cost of disposal of the entire waste volume i.e. 100000m^3, at the Ramat Hovav landfill is calculated to be US$30.4m.

2) Landfilling segregated waste: Segregating the waste materials into fine (<2mm) and coarse fractions (>2mm) by dry screening can reduce the cost of landfilling. The fine fractions can be disposed in a hazardous waste landfill while the non-hazardous coarse fractions can be disposed of in a construction landfill. The cost of disposal of the hazardous fraction of the waste materials (<2mm fraction; 42,300m^3) has been calculated to be US$12.92m, while the disposal costs for the non-hazardous fraction (>2mm fraction; 57,700m^3) has been calculated to be US$1.85m.

3) Landfilling all the stockpiled wastes at a non-hazardous landfill: As the leachability of Pb from the wastes is low and does not pose a risk to groundwater at the site, all the stockpiled wastes could be sent to a non-hazardous landfill for disposal. The total cost of disposal of approximately 100,000m^3 at a non-hazardous landfill has been calculated to be US$3.13m.

4) Landfilling TPH contaminated waste: The cost of disposal of the entire volume (37.5m^3) of soil in areas of the Made Ground where TPH contamination was identified has been estimated to be US$11,250.

6.2. ON-SITE REMEDIATION – COVER SOLUTIONS

This involves the on-site capping of all the stockpiled materials using crushed concrete, stone with the optional addition of a HDPE liner within the capping design. The provision of a strong, durable cover liner can be expected to account for a large component of the cost of capping. For this reason it may be financially beneficial accumulate all waste materials on the Site into a single location, in order to minimise the surface area of cover liner required.

Calculations show that the maximum volume of 100,000 m^3 of waste material on the Site can be placed above ground level in a bund of 80 x 60 m^2 with side-slopes and coned-end-slopes of 1:2 (maximum height of the reprofiled compacted mound being 25m). The total inclined surface area of such a mound is approximately 20,000m^2 (see Appendix 3 for a drawing of the Waste Mounds).

The areas of the Site within which the estimated volume of waste materials could be housed appear to be along the southern and the western boundaries. However, the size and shape of capped mounds need to be discussed with the landowner to agree best locations and shape of capped mounds in order to balance the cost of capping with the cost of loss of useable development area.

6.2.1 Applicable Capping Solutions

(i) Reprofiling of the Waste Mounds followed by capping using a mixture of clean soil and crushed concrete or stone. A layer of topsoil and selected grass/vegetation cover of sufficient sward density, root penetration and percent coverage to resist erosion is advisable. This procedure suffers from disadvantages such as a need for regular maintenance of the cover layer in addition to taking out a significant area from potential developmental use at the Site.

(ii) Re-profiling of the Waste Mounds followed by capping using a mixture of clean soil and crushed concrete or stone followed by a HDPE liner to prevent contaminant migration to groundwater by leaching. A grass or other suitable vegetation cover could be laid on top of the capped stockpiles to strengthen the slopes and also for aesthetic purposes. The total footprint area of the waste mounds needing covering with a HDPE liner would be 60m x 80m = 4800m^2 or approximately 5000m^2 plus an additional 1000m^2 for bunding and contingency resulting in a total area of 6000m^2. It is noteworthy that the installation of a HDPE liner as an additional capping layer is not a necessity, as the risk to groundwater is minimal. Furthermore, the quality of groundwater encountered at the Site is fairly poor for any future leaching of contaminants from the stockpiled materials to have any significant impact.

(iii) Segregation of fine fractions, sand and oversize in the waste by dry sieving followed by placement of the <2 mm particle fraction in a landscaped area and capping with crushed concrete or stone and soil similar to that described in (i) above. Segregation of wastes prior to reprofiling and capping will result in significant hazardous waste volume reductions and increased development area at the Site. The total volume of the segregated fine fractions (<2mm) is expected to be approximately 42,300m^3, while the volume of that of the coarse (>2mm) and oversize fraction is expected to be approximately 57,700m^3. The separated fine fractions could be stockpiled at a suitable location on-site and capped. The separated coarse fractions could be used as 'clean' engineering fill either on-site or off-site or else disposed of in a construction landfill.

(iv) As option (iii), but with an additional HDPE liner.

It should be noted that the cover solutions discussed above have specifically not included any below ground excavation, other than to retrieve contaminated materials that have previously been used as infill.

6.3. STABILISATION AND SOLIDIFICATION

Stabilisation of contaminated fines and sand using Portland cement forms a hard concrete like material. This procedure immobilises the Pb in the waste fractions as insoluble sulfates and results in a geotechnically solid material, which can be used as engineering fill on-site or off-site (or otherwise stockpiled on-site or disposed of at a construction landfill). The total volume of material that can be potentially treated using stabilisation will be approximately 42,300m^3.

6.4. BUDGETARY COST- ESTIMATES

Table 2 below gives a budgetary estimate of the unit costs of various activities which form part of the remediation techniques discussed above.

It is clear from Table 3 below that the cost of landfilling hazardous materials from the Waste Mounds outweighs any potential environmental benefits. The total cost of Landfilling hazardous waste at Ramat Hovav has been calculated to be in the range US$12.92m – 30.4m, while the cost of on-site capping has been calculated to be in the range US$0.82 – 1.67m. The negligible leachability of Pb in the fine fractions means that simple on-site capping should be sufficient to eliminate the source receptor pathway.

Activity	Cost (US$)	Per unit
Excavate, transport and disposal at Ramat Hovav	300	m^3
Reprofile	4	m^3
Reprofile area to cover	0.53	m^2
Crushed cap + Soil Layer	15	m^2
HDPE liner cost	3	m^2
Dry screen including excavation and backfill	10	m^3
Portland cement stabilisation	20	m^3
Construction landfill (excavate, transport and dispose)	30	m^3

Table 2: Breakdown of unit costs of various activities which form part of the remediation techniques discussed above.

Remediation Method	Cost (US$M)
1) Landfilling at Ramat Hovav (unsegregated)	30.4
2(a) Landfilling at Ramat Hovav (segregated; fine fractions 42,300m^3)	12.92
2(b) Landfilling segregated coarse fractions (>2mm)	1.85
2(c) Landfilling all waste at a construction landfill (100,000m^3)	3.13
2(d) Landfilling TPH contaminated soil from the Made Ground	0.011
3) Reprofiling of Waste mounds followed by capping using clean soil + crushed concrete or stone.	0.82
4) Reprofiling of Waste mounds followed by capping using a mixture of clean soil + crushed concrete or stone + HDPE liner.	0.88
5(a) Segregation of <2mm (fine) fractions followed by capping using clean soil + crushed concrete or stone.	1.61
5(b) As option 3, but with additional HDPE liner.	1.67
6(a) Dry sieving, contaminated fines + sand, cement stabilised + used on-site or off-site as engineering fill.	2.48
6(b) Dry sieving, contaminated fines + sand, cement stabilised + disposed of at a construction landfill.	5.70

Table 3: Total costs for the application of the various remediation procedures discussed above (detailed breakdown in Appendix 2).

6.5. COST-BENEFIT ANALYSIS OF THE CHEAPER SOLUTIONS

Table 4 below is a cost-benefit analysis of the application of the remediation solutions excluding the hazardous waste landfilling options. These options are offered to the Ministry for the Environment for evaluation as potential remediation solutions as each can provide sufficient contamination risk reduction, are financially feasible and provide options for continued use or increased industrial/commercial use of the Site.

The least technically challenging and a relatively cheap solution (US$3.13) for the stockpiled materials would be to dispose of all materials at a non-hazardous waste landfill **(Option 2(c))**. However, this is only possible if the MoE can be convinced of the case for the material being classed as non-hazardous, due to the very low leachability of Pb from the wastes. The cheapest (at US0.82M) solution for the waste materials is excavation followed by stockpiling at a suitable location on Site **(Option 3)**. Reprofiling, compaction and capping using clean crushed concrete or stone can follow this. A layer of topsoil and grass or other suitable vegetation will provide additional stability to the capped mounds. The entire operation can be completed in a relatively short period of time with minimal impact on the existing Site activities and the local environment. Additional groundwater protection can be achieved by the installation of an additional HDPE liner on top of the crushed concrete or stone cover **(Option 4)**. The cost of installation of a HDPE liner covering an area of 20,000m^2 is expected to be approximately US$60,000.

As most materials in the Waste Mounds greater than 2mm in diameter are not deemed to be hazardous, these can be separated from the fine fractions by dry sieving **(Option 5(a))**. Although dry sieving increases the overall costs by approximately US$1.0M, it results in several benefits, which are – an increased developmental area of the Site, a decrease in the area required for stockpiling, reprofiling and capping the regarded materials, increased particle homogeneity which makes compaction easier, which in turn results in increased slope stability. The coarse materials can be used as ‘clean’ infill either on-site or off-site. Additional groundwater protection can be achieved through the installation of a HDPE liner **(Option 5(b))**. Appropriate dust suppression measures will be required during dry sieving of materials, as this procedure without such measures will generate large quantities of dust, which could be a nuisance for the current occupiers of the Site and spread contaminated material onto neighbouring land.

Stabilisation and Solidification using Portland cement should convert most of the hazardous fraction in the soil into inert, non-hazardous material **(Option 6(a))**. The solidified materials can then be stockpiled on-site, or used on-site or off-site as clean engineering fill or disposed to a construction landfill. The cost of stabilisation followed by use on-site or off-site as engineering fill has been calculated to be approximately US$2.47M (this figure does not include the income that can be generated through the sale of the stabilised material, although this is believed to be negligible within the Israeli market). If the stabilised material is disposed of at a construction landfill instead of being used as engineering fill, the overall remediation total costs have been calculated to be US$5.70M **(Option 6(b))**.

All the options discussed here are commercially and technically viable. It is important that the Ministry for the Environment is convinced of the benefits of several of the suggested options and approval for the use of most of the options is obtained so that there are several options available for landowner to assess with other benefits and constraints on Site use.

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Option	Remediation Method	Cost (US$M)	Maximise useful development area	Groundwater Protection	Technical simplicity	Min. disruption to current Site activities	Min. environmental impact	Lifetime and durability
2(c)	Dispose all waste at a non-hazardous landfill	**3.13**	✓	✓	✓	✓	✓	✓
3	Reprofile waste mounds, clean + crushed concrete or stone capping.	**0.82**			✓	✓	✓	✓
4	Reprofile waste mounds, HDPE capping liner + crushed concrete or stone and soil capping.	**0.88**		✓		✓	✓	✓
5(a)	Dry sieving, contaminated fines + sand and oversize placed in landscaped area and capped with crushed concrete or stone and soil.	**1.60**	✓		✓			✓
5(b)	As option 3, but with additional HDPE capping liner.	**1.67**	✓	✓				✓
6(a)	Dry sieving, contaminated fines + sand, cement stabilised and placed on Site + oversize, used as engineering fill on-site or off-site.	**2.48**	✓	✓				✓
6(b)	Dry sieving, contaminated fines + sand, cement stabilised and placed on Site + oversize, disposed of in a construction landfill.	**5.70**	✓	✓				✓

Table 4: Cost-benefit analysis of application of various techniques for the remediation of the Waste Mounds.

7. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

The principal conclusions that can be drawn from this Report are as follows:

a. The high costs associated with soil washing, vitrification and metallurgical recycling have ruled them out as commercially viable remediation techniques.

b. Landfilling all or even part of the waste stockpiled in the Waste Mounds at a hazardous waste landfill is prohibitively expensive.

c. Landfilling all the waste at a non-hazardous landfill is a potentially viable option provided approval is gained from the MoE.

d. There are several other cheaper options available for remediating the materials stockpiled in the Waste Mounds. These options eliminate the identified risks completely and also allow the reclamation of large areas of the site for redevelopment.

e. These options include on-site capping of wastes and off-site disposal at hazardous or non-hazardous landfills.

f. The entire waste in the Waste Mounds can be capped on-site at a suitable location.

g. Significant waste volume reductions and increased development area can be achieved if the wastes are segregated into contaminated (fine fractions) and uncontaminated fractions (coarse fractions) by dry sieving.

h. The contaminated fractions can be either capped on-site or pre-treated with Portland cement prior to disposal at a non-hazardous landfill or reused on-site or off-site as ‘clean’ construction fill.

i. Suitable areas on the Site have to be identified that can house the amalgamated, reprofiled, capped wastes from the waste mounds.

j. The next step is to recommend to the regulators at the MoE that they accept several or all of the lower cost remediation options.

k. This will enable the landowner to choose a remediation option based on factors such as: loss of developable land due to the presence of waste stockpiles on-site; area of land required for development; financial constraints limiting cement stabilisation and off-site disposal.

l. In order to develop a specification for tendering the remediation work, estimates of the timescales required to implement the various remediation options have to be worked out.

m. Dust suppression procedures suitable for this site have to be identified and built into the remediation tender specification.

REFERENCES

Reference has been made to the following sources of information:

1) Stage A Report – Historical Survey and Preparation of Sampling Program – Contamination Survey, Evaluation of Risk and Assessment of Treatment Alternatives at the Acre Kiryat Haplazda Site. ENOSH Systems Co. Ltd., February 2003.

2) 'Factual Report for Site Pollution Investigation', BAE Systems Environmental, Report No. A249-00-R2-D, December 2004.

3) 'Risk Assessment Report for Site Pollution Investigation, BAE Systems Environmental, Report No. A249-00-R3-E, December 2004.

4) Youcai, Z., Stanforth, R. (2000). Integrated hydrometallurgical process for production of zinc from electric arc furnace dust in alkaline medium. J. Hazardous Materials. B80, 223-240.

5) Brooks, C. S. (1991). Metals recovery from industrial waste. Lewis Publishers, Michigan, USA. 33-141.

6) Barrett, E. C., Nenniger, E. H., Dziewinski, J. (1992). A hydrometallurgical process to treat carbon steel electric arc furnance dust. Hydrometallurgy, 30, 59-68.

7) Elgersma, F., Kamst, G. F., Witkamp, G. M., Van Rosmalen, G. M. (1992). Acidic dissolution of zinc ferrite. Hydrometallurgy, 29, 173-189.

8) Gill, C. B. (1981). Non-ferrous Extractive Metallurgy. Wiley, New York, pp. 18-279.

9) EPA 542-R-98-001a (1998). Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater. NATO CCMS Pilot Study.