360 environmental

Lower Vasse River, Busselton

Sediment Disposal and Reuse Options Assessment

Prepared for

City of Busselton

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people planet professional

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Disclaimer

Executive Summary

360 Environmental was commissioned by the City of Busselton (the City) to undertake an assessment of potential sediment disposal and reuse options in the Lower Vasse River, from the Butter Factory Museum to the Busselton Bypass, Busselton.

It is understood that the City is planning to remove a layer of nutrient-rich, fine organic sediments that has accumulated throughout the lower reach of the river with an average depth 450 mm as part of a Living Streams approach to future management of the Lower Vasse River. This sediment provides a significant internal source of nutrients that contributes to algal growth with the Lower Vasse River section located in the centre of town being plagued by severe seasonal algal blooms, which impact biodiversity and public amenity. It is estimated that a approximately 7,065 m^3 of dewatered sediments, dominated by fine silts and clay may need to be removed between the Butter Factory Museum and the Busselton Bypass and disposed and/or reused.

A sediment disposal and reuse options assessment of six options has been undertaken to determine requirements to safely dispose or preferably reuse sediments proposed to be removed to improve water quality in the Lower Vasse River, with the options defined as:

- **Option 1**: Disposal to Landfill
- **Option 2:** Onsite reuse for Wetland Rehabilitation
- **Option 3:** Reuse as infill by the City
- **Option 4:** Reuse by the City as daily landfill cover
- **Option 5**: Reuse as growing media
- **Option 6**: Reuse by a 3rd Party.

With all potential reuse/disposal options, removal of sediments at the site will result in a significant investment of time and resources to achieve the required outcomes. The qualitative benefit comparison aimed to identify the reuse/disposal options that best balances the impacts and influences of the triple bottom line of sustainability (i.e. environmental, societal and economic) while still protecting human health and the environment.

Based on the outcomes of the triple-bottom-line reuse/disposal options assessment, the following conclusions are drawn.

- **Option 4:** Reuse by the City as daily landfill cover is the preferred option on the basis that it best meets the triple-bottom-line objectives with all environment, social and economic indicators have been rated as having an overall high benefit, with comparison to the other options.
- **Option 5:** Reuse as a growing media is also considered a viable option as it allows for the reuse and transformation of the sediments into a product that is commercially viable

whilst also preserving the environment. It has however an overall moderate benefit due to the elevated cost and longer lag time prior to reuse.

- **Option 2:** Onsite reuse for wetland rehabilitation and **Option 3:** Reuse as infill by the City have an overall moderate benefit however based on the potential ecological impacts (groundwater and surface water) associated with moving sediments into a new environment, these options currently rate less favourably than **Option 4** and **Option 5**. Further analytical work, both of the sediments and at the receiving environment, would be required to prove the viability of these options.
- **Option 1** is not considered viable as landfill disposal is the most-costly option and does not align with the waste hierarchy.
- Although there is potential for the City to recover costs through the sale of treated sediments to a 3rd party, **Option 6:** Reuse by a 3rd party, rates as low as **Option 1** due to its potential environmental and reputational risks to the City as the end use is unknown. Further analytical work, both of the sediments and at the receiving environment, would be required to prove the viability of this option.

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1 Introduction

360 Environmental Pty Ltd (360 Environmental) was commissioned by the City of Busselton (the City) to undertake an assessment of potential disposal and reuse options for sediments proposed to be dredged from the Lower Vasse River, from the Butter Factory Museum to the Busselton Bypass, Busselton (herein referred to as the 'site'). to the site location is presented in **Figure 1**.

It is understood that the City is planning to remove a layer of nutrient-rich, fine organic sediments that has accumulated throughout the lower reach of the river with an average depth 450 mm as part of a Living Streams approach to future management of the Lower Vasse River. This sediment provides a significant internal source of nutrients that contributes to algal growth with the Lower Vasse River section located in the centre of town being plagued by severe seasonal algal blooms, which impact biodiversity and public amenity. The City developed the Lower Vasse River Waterway Management Plan in 2019 to improve the health of the lower section of the Vasse River, whereby the Plan recommends sediment removal as a management strategy.

It is estimated that approximately 7,065 m^3 of dewatered sediments, dominated by fine silts and clay may need to be removed from the Butter Factory Museum to the Busselton Bypass and disposed and/or reused. The City is however proposing to undertake the work in stages, with the first stage likely to extend from the Butter Factory Museum to the old boat ramp located upstream of the City Administration Building. The sediments are proposed to be removed via pumping into porous geotextile bags, which retain fine sediments while water is expelled and returned to the river. Once dewatered, the material will be transported offsite for disposal and/or reuse.

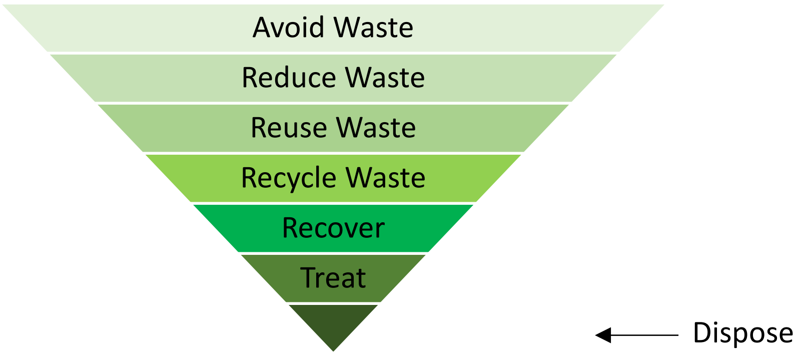
1.1 Regulatory Background

The suitability of soil/sediment management options are informed by different regulatory guidelines depending on whether the material is being reused, or alternatively, disposed. The determination of the ability for a soil/sediment to be reused within a property (or project area) is based on a risk assessment using the appropriate investigation levels for the land use as defined under the *Contaminated Sites Act 2003*, the Department of Water and Environment Regulations (DWER) (2014) *Assessment and Management of Contaminated Sites Guidelines* (AMCS) and the National Environmental Protection Council (2013) National Environmental Protection Measures (NEPM) (1999) Assessment and *Management of Contaminated Sites, Schedule B1*. If the soil/sediment is surplus, the material needs to undergo waste classification in accordance with DWER (2019) *Landfill Waste Classification and Waste Definitions 1996 (as amended 2019)*. To meet the definition of uncontaminated fill (UCF), neutralised acid sulfate soils (ASS) must meet the requirements for relevant metals, metalloids and sulfate guided by the *Environmental Protection Act 1986* (EP Act).

It is noted here that the project is likely to require State and Federal approval related to potential impacts on Carter's Freshwater Mussel, RAMSAR-listed Vasse-Wonnerup Wetland and ASS under Part IV, Section 38 of the EP Act, under the *Environmental Protection and Biodiversity Conservation Act 1999*, under the *Biodiversity Conservation Act 2016* and the *Contaminated Sites Act 2003*, however this will be assessed separately.

1.2 Waste Hierarchy

The waste hierarchy promotes a circular economy, supporting resource recovery and recycling, and reducing the generation of waste. The most preferable option being to avoid the generation of waste and the least preferable option being the disposal of waste. The aim of the City is therefore to try and reduce the amount of sediment requiring removal and reusing as far as possible the dredged sediments as per the waste hierarchy presented below.



The waste hierarchy that may be applicable to the removal of the sediment at the site in the order of preference would be as follows:

1. Elimination – Would involve no sediment removal but continued issues with algal blooms unless a suitable insitu methodology for the treatment of nutrients could be developed.
2. Reduce – Reduce the amount of sediments needing to be reused/disposed of by dewatering through the use of geotextile bags.
3. Reuse – Maximise the beneficial use of removed materials, for example in rehabilitation/habitat creation, backfilling or daily landfill cover.
4. Recycle – sort the sediment into various end uses (for which there are currently no identified viable options for this material).
5. Disposal – considered as a last resort, when options 1 to 4 have been exhausted or if the level of contamination of the sediments is too high.

1.3 Objective and Scope

This sediment disposal and reuse options assessment has been developed to determine requirements to safely dispose or preferably reuse sediments proposed to be dredged, to improve water quality in the Lower Vasse River.

The assessment has been prepared in general accordance with the following documents:

- DWER (2014) *AMSC*
- NEPC (2013) *NEPM*
- DWER (2019) *Landfill Waste Classification and Waste Definitions*
- DWER [formerly Department of Environment Regulation (DER)], 2015. *Acid Sulfate Soils Guideline Series – Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes*
- Department of Water and Environmental Regulation (formerly DER), 2015. *Acid Sulfate Soils Guideline Series – Treatment and Management of Soil and Water in Acid Sulfate Soils Landscapes.*

In order to meet the objectives, the following scope of work was undertaken:

- Desktop review including a review of existing report and tabulation of the results with a comparison to the nominated risk assessment criteria and waste classification guidelines
- Semi-qualitative evaluation of sediment management options including:
  - Viability of each option based on analytical results
  - Adherence to the waste management hierarchy
  - Costs and timing
  - Other limitations (e.g. geotechnical, spatial constraints, odour, dust)
  - Cost-benefit analysis of existing disposal and reuse options.
- Details of requirements and work instructions for the treatment and management of material onsite or for disposal offsite
- Review of risks and any requirements for on-going monitoring/treatment and close out reporting
- Details of surface water monitoring requirements post disposal/reuse
- Details of groundwater monitoring requirement post-disposal/reuse.

2 Site Details

2.1 Regional Environment Setting

The site regional environment setting is presented in **Table 1** with the aim of demonstrating the naturally occurring nature of the material and potential sources of contamination.

Table 1: Regional Environment Setting

Setting	Description
Acid Sulfate Soils	The site is located within area mapped as having high to moderate risk of ASS due to the presence of estuarine/riverine sediments.
Geology	As per the Geological Survey of Western Australia, 1999, the site is located on the southern portion of the Swan Coastal Plain, which is characterised by a low-lying coastal plain with undulating dunes at the coastal lakes/wetland systems, rising to older geological formations in the east. The geology of the area is characterized by the Quindalup dune system comprising calcareous sand (S13) made of pale and olive-yellow, medium to coarse-grained, sub-angular quartz, moderately sorted, underlain by estuarine silt (M6) which is made of brownish grey calcareous, some fine sand and shell debris with minor clay and by calcareous silt (Ma5) which are brown to mid-grey mottled blocky disseminated fine sands.
Hydrology	The Vasse River discharges into conservation category wetlands associated with the Vasse River Delta Wetlands and the Ramsar Listed Vasse-Wonnerup Wetland System. Water levels in the Vasse River are artificially controlled through the Vasse Diversion Drain penstock upstream and by a weir downstream of the site. Conservation Category (Estuary Waterbody) and Multiple Use (Estuary Peripheral) also extend within the site area. The Lower Vasse River has been dredged approximately 40 to 50 years ago and due to the controlled flows and altered bathymetry the Lower Vasse River functions hydrologically more like a lake than a natural river system. The major source of nutrients into the Lower Vasse River is from the Vasse River Diversion Drain, stormwater, groundwater intrusion, and general runoff.
Hydrogeology	Depth to groundwater is approximately 1 to 1.5 metres below ground level (mbgl) in direct correlation with the water level of Vasse River suggesting that the surface water and groundwater are interconnected with the river intersecting groundwater during the summer and autumn. Groundwater flow direction in the area is toward the Vasse River, which flows to the east towards Wonnerup.
Threatened Species	The Lower Vasse River is known to contain populations of Carter's Freshwater Mussel (Westralunio carteri). Mussels are generally confined to bank habitat areas and are not found in off-bank sampling locations.
Contaminated Sites	As per the Contaminated Sites online database, there are two lots reported as contaminated sites located less than 200m north of the site and one lot located less than 150m to the west of the site. It is noted here that the Contaminated Sites Database holds information on confirmed contaminated sites only (i.e., sites that have been classified as contaminated - remediation required, contaminated - restricted use and remediated for restricted use) and therefore lots that have been classified as 'possibly contaminated – investigation required' are not shown on the database: • 26 Albert St Busselton (Lot 11 on Diagram 74282) was classified as 'remediated for restricted use' in July 2020 due to the presence of hydrocarbons (such as from petrol and diesel) in soil at a depth of 2 mbgl in the north east and in groundwater as a plume beneath the north east portion of the site, extending off site to the east. This site was formerly used as a service station.

Setting	Description
	• 20 Albert St Busselton (Lot 200 On Diagram 92125) was classified as 'contaminated – restricted use' in January 2021 due to the presence of metals such as lead and zinc in fill material within subsurface soils beneath the site. Naphthalene and lead were present in groundwater in the north-western portion of the site at concentrations exceeding assessment levels for fresh waters, however the groundwater impact is presently in a localised area and was not found to be present at the downgradient boundary. • 34 Roe Tce Busselton (Lot 67 On Plan 222224) was classified as 'remediated for restricted use' in November 2014 due to the presence of asbestos-containing materials (ACM) in soils at the site. No potential contaminants were detected in groundwater beneath the site above health or ecological guideline. Based on the City's record, two lots have been reported as 'possibly contaminated – investigation required'. The reasons for the classifications are unknonw: • Rotary Park (Lot 42 on Plan 222224) is located directly south of the Lower Vasse River section between the old rail bridge and the causeway (i.e. Section 2) • 2 Southern Dr Busselton (Lot 68 on Diagram 18091) is located directly to the east of the lower Vasse River after the causeway (i.e. Section 3)

2.1.1 Naturally Occurring

The following material is considered to be naturally occurring at the site:

- Acid sulfate soils
- Estuarine silt which is made of brownish grey calcareous, some fine sand and shell debris with minor clay.

2.1.2 Potential Source of Contamination

To help discern whether the sediment can or cannot be defined under the waste classification guidelines as a "clean fill" being raw excavated material that has not been subject to potentially contaminating land activities, understanding "sources of contamination" is therefore considered significant as part of this study. Based on the regional setting, the following potential sources of contamination have been identified:

- The Vasse River Diversion Drain, stormwater, groundwater intrusion, and general runoff are the source of elevated nutrients present in the sediment at the site with run-offs likely to carry heavy metal such as zinc, lead, copper, cadmium, nickel and chromium
- Petroleum hydrocarbon plume originating from 26 Albert Street, Busselton located hydraulically upgradient of the Lower Vasse River.

On this basis, the sediments from the Vasse River cannot be considered as meeting the definition of "clean fill".

2.2 Proposed Site Works

As part of the implementation of the Lower Vasse River Waterway Management Plan, the City of Busselton proposes to remove sediment in stages from Butter Factory Museum to the Busselton Bypass. The estimated sediment volume across the different river section (circa 2011) is presented in **Table 2**. The maximum volumes have been presented based on the volumes extrapolated from the survey undertaken by Apex in 2011 from 2 or 3 monitoring points per transect and using hydrologic shapefiles to calculate the surface area. Based on discussion between the City and sediment removal contractors, the amount of sediments to be removed has been reduced by 30% to reflect the over-estimated amount of sediments present as it is anticipated that there will be less sediment on the edges compared to the middle of the river and that not all sediments will be able to be removed. Sediments, which are mainly organic sediments (limited sand content) are expected to shrink by a further 50% during the dredging process and by a further 15% after a few weeks of dewatering.

Table 2: Estimated Sediment Volume

River Sections	Average Sediment Depth (mm)	River Area (m^2)	Maximum Volume (m^3)	Actual In-situ Volume (m^3) (less 30%)	50% reduction after dredging	15% reduction after dewatering
Section 1: Butter factory - Old rail bridge	463	4,679.455	2,168	1,518	759	493
Section 2: Old rail bridge to Causeway	565	6,815.483	3,851	2,696	1,348	876
Section 3: Causeway to New river	521	8,725.998	4,545	3,182	1,591	1,034
Section 4: New River to boat ramp	325	2,007.469	652	456	228	148
Section 5: Boat ramp to Strelly Street	454	18,080.28	8,208	5,746	2,873	1,867
Section 6: Strelly Street to bend (section 5A-CD)	525	7,401.458	3,886	2,720	1,360	884
Section 7: Bend to Bypass	467	16,588.77	7,741	5,419	2,709	1,761
TOTAL volume to transport and treat		**64,298.913**	**31,051**	**21,736**	**10,868**	**7,064**

3 Previous Environmental Investigations

A number of previous environmental investigation have been undertaken at and around the site as part of other projects. A summary of the findings is provided in **Table 3** whilst all historical results have been tabulated in relevant tables presented at the back of this document. Refer to **Figure 2** for the location of the sediment sampling locations.

Table 3: Summary of Previous Investigations

Study Name	Outcomes	Number of Samples Used in this Evaluation	Analytes
Sinclair Knight Merz, 1999 Vasse River Sediment Remediation Study	Based on the study conducted by SKM, the water and sediment quality of the Lower Vasse River were described as eutrophic and in urgent need of rehabilitation. The condition of the river was proposed to be remediated using draining and bulk removal of sediments. Lead and zinc were observed to be elevated in the top sediments of lower region of the river and are likely to be of anthropogenic origin. Nutrient data showed elevated nutrient and organic content in the surface sediments compared to the lower sandy sediments. A low soil particle density was observed for the sediments (between 2.22 g/cm3 and 2.43 g/cm3) whilst particle size distribution testing indicated that the majority of particle size are between 0.02mm and 0.055mm and are therefore very fine grained with a large pore water component which would contain nutrients under anoxic conditions. Disturbance of the sediments would therefore release nutrients in the water column.	6 Sediment samples (Top and Bottom depth) – A (Top and Bottom), B (Top and Bottom) and C (Top and Bottom) It is noted here that sample C is located outside of the study of interest	Heavy Metal (Ar, Cd, Cr, Cu, Hg, Pb, Ni, Zn) Total sulfur Acid Neutralization Capacity Net acid pH Total Phosphorus (TP) Total Kjeldahl Nitrogen (TKN) Atterberg Limits Leachate Analysis
City of Busselton, 2001 Lower Vasse River Cleanup Program	Dredging of the river was undertaken in 2001 as part of the Lower Vasse River Cleanup Program. The material from that project was disposed of at a gravel pit in Chapman Hill with no remediation and is still stored there. This material had a pH of 3.8 demonstrating that the sediments are potential acid sulfate soils. A trial remediation project was being undertaken in an attempt to create a useful material by mixing with compost and liquid brew. Although pH was reported to slightly increase following the spraying of calcium carbonate brew and mixing with loader, pH decreased back to its initial level. pH further decreased upon addition of compost and mulch. Concentrations of nutrients (total nitrogen and total phosphorus) and most heavy metals increased slightly between the 3 sampling events although only zinc was reported to be leachable.	3 samples – Sample 1, 2 and 3 (location unknown)	TP, total nitrogen (TN) Total organic carbon Heavy Metal (Ar, Cd, Cr, Cu, Hg, Pb, Ni, Zn) ASS CRS
Coffey Environments, 2010 Acid Sulfate Soil Investigation and Management Plan	An ASS investigation was undertaken on old spoil mounds which occur adjacent to an artificial wetland to allow reshaping of the banks of the New River Wetlands Demonstration site. A total of 64 soil samples were collected from the old spoil with net acidity exceeding the nominated ASS assessment criteria of 0.03%S. The acidity risk at this site was however considered low due to the inherent acid neutralising capacity of shelly materials found in the sediments and that most recorded pH_{KCl} and pHox are well above 6.5, indicating that the soils have sufficient acid buffering capacity with the exception of sandy clayey soils that may require some treatment It was concluded that onsite reuse of the untreated spoil could be done due to the low acidity risk given the natural buffering capacity of the shelly materials; and that treatment, removal and disposal offsite of sandy clayey soils without sufficient natural buffering capacity would be required. The liming rate for the layer from 1.25m to 3m BGL, where less than 1000m3 of ASS material is disturbed, is 70kg CaCO3 per tonne of soil whilst the liming rate for the layer from 3m to 4m BGL, where less than 1000m3 of ASS material is disturbed, is 116kg CaCO3 per tonne of soil. In the event of more than 1000m3 of ASS disturbed, the liming rate for the layer from 1.25m to 3m BGL is 139kg CaCO3 per tonne of soil whilst for the layer from 3m to 4m BGL it is 308kg CaCO3 per tonne of soil.	4 sampling locations (SB1-SB4) however sampling locations located outside the site's boundary	Field pH SPOCAS ANC Net Acidity
City of Busselton, 2012 Sediment Survey	A sediment investigation was undertaken by the City along 7 sections of the river to determine sediment depths and heavy metal concentrations. The depth of the top sediment was approximately 1735mm with an average thickness of 530mm. All heavy metals were detected above the LOR except Hg. The highest concentrations of As, Cd, Cr, Pb and Zn were reported at Section 1 whilst the lowest concentrations of heavy metals were reported along Section 5-7.	Section 1 – Butter Factory to Railway Bridge Section 2 – Railway Bridge – Causeway Road Section 3 – Causeway Road to Shire office Section 4 – Shire office to Strelly Steet Bridge Section 5 – Strelly St Bridge to River Bend Section 6 – River Bend to Fairlawn Road Section 7 – Fairlawn Rd to Busselton Bypass	pH Heavy metals (As, Cs, Cr, Fe, Hg, Pb, Zn)
Strategen, 2017 – Acid Sulfate Soil Investigation Report	As part of the local road's improvement in and around Busselton's urban area; known as Strategic Network Corridors project, two (2) of the proposed bridges, Eastern Link and Causeway Road involved river crossings in areas which were considered to potentially contain acid sulfate soils. An ASS investigation was undertaken to determine the nature and extent of the ASS risk near Eastern Link and Causeway Road. Four soil bores were drilled along the lower portion of the river. The results indicated that the average pHF of the samples tested was 8.0 pH units with pH varying between 7.4 and 8.8. pHFOX of less than 3 was recorded in a third of the samples with pH ranging between 1.2 and 2.2. All the samples showed a difference between pHF and the corresponding pHFOX greater than 1 indicating the potential presence of sulfides and acid generating potential. Samples submitted for the SPOCAS and Chromium Reducible Sulfur (CRS) suite indicated that the maximum liming rate would be 82 kg/tonne. Although ASS was reported to be present below the water table, groundwater quality did not indicate that acidification of potential acid sulfate soil (PASS) with a sulfate to chloride ratio of less than 0.5 in all cases. Groundwater was therefore generally considered to have adequate buffering to maintain an acceptable pH level in future. Sediment samples exhibited relatively low concentrations of heavy metals, with the exception of Cr and Zn at EL-N. Refer to **Table A** for the heavy metals results	4 sampling locations (EL-S, EL-N, CR-N, CR-S)	Field pH SPOCAS ANC Net Acidity Heavy Metal (Ar, Cd, Cr, Cu, Hg, Pb, Ni, Zn)

Study Name	Outcomes	Number of Samples Used in this Evaluation	Analytes
Strategen, 2018 - Acid Sulfate Soil and Dewatering Management Plan	Following on from the recommendations of the ASS investigation report and the likely requirement for dewatering for the construction of the two bridges, an ASSDMP was prepared to determine the ASS and dewatering management requirements. Additional investigation was also carried out at four locations across the lower portion of the river to determine the absence/presence of mono-sulfidic black ooze (MBO) in the Vasse River. The results indicated that ASS (but not MBO) is present in the riverbanks and sediments requiring dewatering. Based on the new investigation, the maximum lime dosing of the removed sediment would need to be at a rate of 142 kg per tonnes or 227 kg per m3.	None	---
City of Busselton, 2018 - Sediment Sampling	In March 2018, the City of Busselton undertook sediment sampling (9 sites) in the Lower Vasse River between the New River and the Butter Factory. Sediments were found not to be monosulfidic (indicated by low acid volatile sulfur) and therefore do not pose the risk of rapid acidification and associated deoxygenation of the water column with potential heavy metal release. However, sediments were sulfidic with high potential acidity. Concentrations of Pb and Zn were reported to be slightly elevated with the highest concentrations of Z, Pb and Cr reported in sample LVRS2P located near the City hall. BTEX, PAH, VOC, OCP/OPP, PCB and Phenols were not detected above the LORs in any of the samples collected. While the proposed method of removal using geotextile, bags mitigates the risk of exposure to air, and associated acidification, lime dosing would be required prior to disposal and/or reuse. Soil characteristics showed that dredged material could be disposed of at a Class I landfill facility. The City's main landfill site is the Vidler Road Waste Facility, classified as a Class II facility. However, the high nutrient and organic content of the material suggested potential for reuse of the material as a component of compost as composting can further dilute concentrations of pollutants.	8 sampling locations (LVRS1P, LVRS2P, LVRS3P, LVRS4P, LVRS5P, LVRS6P, LVRD1P, LVRD2P, LVRD3P	Heavy metals (Kr, As, Be, Cd, Cr, Cu, Fe, Pb, Hg, Mo, Ni, Ag, Zn) BTEXN TPH VOC PAH OPC/OPP PCB Phenol pH CRS Net Acidity Leachate Analysis
Bio Soil Solutions, 2020 – Soil Bioremediation	An assessment of the chemistry and biological aspect of approximately 50m³ of sediment removed from Lower Vasse River was undertaken to ultimately determine if the sediments are suitable for bioremediation. Based on the chemical analysis of nutrients, major ions and heavy metals, the sediments generally indicated the presence of nutrient/heavy metals outside desired level for efficient uptake by plants which may be antagonising other nutrients and/or minerals (i.e., calcium). Sulphur, nitrogen, aluminium, and total soluble salts were reported to be at 'toxic' levels. The biological analysis indicated that minimal fungi was present in the samples due to the low pH inhibiting the development of fungal species. Moreover, the low pH does not provide a suitable environment for the survival and function of most bacteria. Insufficient diversity in protozoa species was also reported in order to cater for efficient cycling of excess nutrient. Overall, the sample showed extremely high levels of nitrogen which is unable to be cycled. Consequently, the acidic soil and high level of sulfur is an unfavourable environment for microbial activity and growth which also limits he availability of phosphorus and potassium. In line with the Landfill Waste Classification and Waste Definitions 1996 (as amended 2019), the soil samples tested were concluded to meet the landfill criteria and may be considered for use in revegetation and daily cover. Although leaching of toxic nutrients/metals is prohibited by the sediment characteristic (high cation exchange capacity), it creates an anaerobic and compacted soil that is unfavourable for healthy plant growth. Although the sediments do not provide the most adequate environment for the growth of the microbiome, it was recommended to blend 50m³ course mulch for every 50m3 sediment pile to create immediate structure, provide a long-term food source for developing fungal hyphae and allow for improved aeration. The application of amended Bio+ Brew would also be required at the time of blending, with 3 monthly testing to establish whether organic soil amendments are required	Three samples – Sample 1, 2 and 3 (Location Unknown)	TP, total nitrogen (TN) Total organic carbon Heavy Metal (Ar, Cd, Cr, Cu, Hg, Pb, Ni, Zn) ASS CRS Leachate Analysis
Murdoch University, 2021 - Environmental Management Plan for Carter's Freshwater Mussel	A survey of Carter's Freshwater Mussel (Westralunio carteri) in three sections of the Lower Vasse River was undertaken to provide information for the planning of sediment removal in the river as the Carter's Freshwater Mussel is a listed threatened species under the Commonwealth Environmental Protection and Biodiversity Conservation Act (1999). The survey confirmed the presence of mussels in bank habitat throughout the lower section of the river. Overall densities in survey areas were 0.63 ± 0.10 mussels/m2 downstream of the Causeway and 1.73 ± 0.19 mussels/m2 upstream. No mussels were found in off-bank habitat. The numbers of W. carteri that would need to be relocated prior to the sediment removal between the Buttery Factory boards and old boat ramp was estimated to be ~3183 ±606and for the Strelly Street Bridge reach ~563 ±546. Although the restriction of mussels to the near-shore bank habitat meant there is potential to avoid direct disturbance during sediment removal from the riverbed, there remains a risk to the mussel population from potential negative effects on water quality and from smothering by resettling particulates. Further, the limitation on dredging close to riverbanks may reduce capacity to remove the maximum possible number of sediments, reducing the effectiveness of the sediment removal program. A management plan was therefore drafted to guide a relocation program during sediment removal work.	Not applicable	Not applicable

4 Results Review

Sediments results from the City of Busselton 2012 Investigation including 7 samples from 7 different sections of the river and from the City of Busselton 2018 sediment and ASS investigation including 9 samples across the lower portion of the Vasse River between the Butter Museum and the Boat Ramp have been tabulated against relevant assessment criteria and are presented in **Table A - F**. The assessment criteria considered for this assessment are presented in Section 4.1 and a review and interpretation of the results is provided in Section 4.2.

4.1 Assessment Criteria Selection

This section provides discussion on the nominated human health and ecological risk assessment criteria for soil, ASS, sediment, and waste classification.

4.1.1 Soil Assessment Criteria

The sediments to be removed may have the potential to be reused and disposed to land after they have been dewatered and dried, therefore characterisation of the material and assessment of its compatibility with the receiving environment and associated land uses as a soil on a site-specific basis is required in accordance with guidance provided in Schedule B2 of the 2013 NEPM ASC. The selected guidelines are therefore for Public Open Space (i.e., Recreational and Area of Environmental Significance such as wetlands) and Industrial Areas (i.e., landfills or other use). The upper 95 percent confidence limit of the mean (95% UCL) is used to determine compliance with the screening levels.

The nominated soil assessment criteria, their description, use, and application are summarised in **Table 4**.

Table 4: Soil - Assessment Criteria, Description, Use, and Application

Investigation/Screening Levels		Site-Specific Considerations	Relevant Analytes
Human Health and Ecological	Description		
Human Health Investigation Level (HIL) – POS (C) and Commercial/ Industrial (D)	Values that have been developed for a broad range of metals. They apply for assessing human health risk via all relevant pathways of exposure. The HILs are generic to all soil types and apply generally to a depth of 3 m below the surface.	There are no criteria for total chromium. As Cr speciation is not undertaken, then the criterion for CrIII will be used for risk assessment purposes of Cr concentrations as a conservative measure.	Metals: As, Cd, Cu, Cr (VI), Hg, Pb, Ni, Zn Total PAH, OCP, PCB, Total Phenols
Human Health Screening Level (HSL-C and D) Direct Contact	Values that have been developed for selected petroleum compounds and fractions and are applicable to assessing human health risk via the direct contact pathway.	---	BTEXN

Investigation/Screening Levels		Site-Specific Considerations	Relevant Analytes
Human Health and Ecological	Description		
Ecological Investigation Level (EIL) – Area of Ecological Significance and commercial/ industrial	Values that have been developed for a broad range of metals and organic substances for ecological systems. EILs depend on land use scenarios and generally apply to the top 2 m of soil. EILs depend on specific soil physiochemical properties [i.e., pH, CEC, and % clay].	Site-specific EILs have not been calculated in the absence of site-specific soil characteristics (i.e., clay content, pH, and cation exchange capacity). As Cr speciation is not undertaken, then the criterion for CrIII will be used for risk assessment purposes of Cr concentrations as a conservative measure.	Metals: As, CrIII, Cu, Pb, Ni, Zn

4.1.2 ASS Assessment Criteria

The *Acid Sulfate Soil Guideline Series* (DER 2015) provides action criteria based on levels of oxidizable sulfur measured for broad categories of soil types. The ASS assessment criteria are detailed in **Table 5**. As most reuse options will require the sediments to be inert, these criteria are relevant for determining the level of treatment required prior to reuse.

Table 5: ASS Assessment Criteria

Criteria	Source	Description, Use and Application
Field Assessment Criteria	DER (2015a)	The presence of AASS or PASS are generally indicated as follows: • pHF <4 is indicative of AASS • pHF of 4 to 5.5 is an acid soil and may be indicative of an AASS presence • pHFOX <3 combined with a significant reaction is indicative of PASS • A large decrease between pHF to pHFOX (i.e., > 3) is indicative of PASS. Other indicators such as presence/absence of organic matter, fill, jarosite, etc., are used to aid in the interpretation of field results
Action Criteria	DER (2015a)	For disturbances of >1000 tonnes a net acidity action criterion of 0.03 %S is applicable for clay/silt, which was the main soil type encountered during the investigation

4.1.3 Sediment Assessment Criteria

The sediment assessment criteria are used to evaluate sediment quality and to indicate risks of unacceptable effects occurring as part of the sediment removal process to protect aquatic ecosystems. The sediment assessment criteria are detailed in **Table 6**.

Table 6: Sediment Assessment Criteria

Assessment Criteria	Source Guideline	Applicability to Site
DGVs and GV – High for sediment quality	ANZ Sediment Quality Guidelines (2018)	DGVs – assess potential impacts to aquatic ecosystems GV-high – applied as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems. The 95% UCL is used to determine compliance with the Screening Levels

4.1.4 Leachate Assessment Criteria

The leachate assessment criteria are intended to provide an assessment of whether any risk to surface water and/or groundwater could exist if the material was introduced to a new site. The leachate assessment criteria are detailed in **Table 7**.

Table 7: Leachate Assessment Criteria

Assessment Criteria	Source Guideline	Applicability to Site
Uncontaminated Fill	DWER (2019) Landfill Waste Classification and Waste Definitions 1996 (as amended 2019)	Leaching analyses are required to assess the quality of the fill material
Fresh Water	ANZ (2018). Australian and New Zealand Guidelines for Fresh Water and Marine Water Quality	Australian Standard water quality guideline most appropriate for the water conditions of the site and surrounding area (Wetland and Lower Vasse River)
Drinking Water	National Water Quality Management Strategy (NWQMS) (2018) Australian Drinking Water Guidelines (ADWG)	The ADWG apply to any water intended for drinking irrespective of the source (municipal supplies, rainwater tanks, bores, river)
Non-Potable Groundwater Use (NPUG)	Department of Health (DoH) (2014) Ground and surface water chemical screening guidelines	Uses include irrigation of gardens, parks, and reserves, growing vegetables, flushing toilets, dust suppression and other such non-potable uses

4.1.5 Waste Classification

Waste classification in Western Australia follows a two-tiered assessment approach as detailed in **Table 8** to determine whether materials are suitable for disposal to Class I, Class II, Class III or Class IV landfill. Acceptance of waste to landfill is determined based on the mean plus one standard deviation (mean+1SD) of all samples representative of the materials being disposed, not the individual sample exceedances.

Table 8: Waste Classification Assessment Criteria

Criteria	Assessment Level	Description, Use and Application
Contaminant Threshold (CT)	Level 1 Assessment	Initial screening of total concentrations to determine if landfill class acceptance and determination for further leachate testing. Total concentration results above CT require leachate testing. If concentrations are below the CT, the material is suitable for disposal to that landfill class without further leachate testing.
Contaminant Levels (CL)	Level 2 Assessment (Both CL and ASLP concentrations must be met for a material for it to be deemed suitable for a given landfill classification)	CLs to be used in conjunction with leachable concentrations to determine landfill acceptance.
Leachable Concentrations (ASLP)		Leachable concentration screening levels to be used to determine landfill acceptance. Leachate solution to be used is dependent upon CL level of the material.
Uncontaminated Fill	Level 1 and 2 Assessment (Both total and ASLP concentrations must be met for a material for it to be deemed suitable as uncontaminated fill)	Both total concentration and leaching analyses are required to assess the quality of the fill material unless no value exists for one of the parameters. The 95% UCL is used to determine compliance with the Screening Levels. Waste acid sulfate soils can be treated/neutralised before comparison against the thresholds.

4.2 Results Interpretation

4.2.1 ASS

Based on the ASS samples collected as part of the City of Busselton (2018) and Bio Solution (2020) investigations, no potential acidity was reported however the sediments displayed a very high potential acidity. Net acidity varied greatly, ranging from <0.01 %S to 4.4 %S (Section 5) with a mean value of 1.92 %S. Net acidity results were generally well above the ASS 'action criterion' of 0.03 %S fine texture materials in all samples.

Acid Neutralising Capacity (ANC) was reported to be low in comparison to acid generating potential indicating insufficient acid neutralising capacity present. Further, previous studies have indicated that ANC was dominantly present as shelly material which is not readily available to neutralise acidity. In accordance with the DWER guidelines, naturally occurring ANC must be excluded from the determination of the acid neutralising rate for ASS.

4.2.2 Nutrients

Nutrients in sediments were analysed as part of the SKM (1999), City of Busselton (2018) and BioSoil (2020) Investigation. No assessment criteria exist for the evaluation of risks from nutrients in sediments, however it is noted that elevated TN concentrations (ranging between 600 mg/kg and 10,200 mg/kg) and TP concentrations (ranging between 120 mg/kg and 860 mg/kg) were reported across the area sampled with the highest results reported in the sediments located near Strelly St Bridge (Section 5) and between the River Bend to Busselton

Bypass (Section 6 and 7). This is consistent with the high TOC and moisture content reported in the nine samples collected as part of the 2018 investigation and indicative of the high organic composition in these samples.

4.2.3 Heavy Metals

Based on the SKM (1999), City of Busselton (2012), Strategen (2017), City of Busselton (2018) and Bio Soil (2020) sediment results, antimony was not detected above the LOR in any of the samples collected as part of the study. The following exceedances were however reported:

- Copper ranged between 7 mg/kg and 33 mg/kg (LVRS2P), with concentration in sample LVRS2P located near the City of Busselton Town Hall (Section 4) exceeding the EIL for Areas of Ecological Significance. The 95% UCL was however below the EIL indicating that copper results are therefore compliant with the EIL screening value and are unlikely to represent a risk to terrestrial ecological receptor.
- Lead ranged between 9 mg/kg and 160 mg/kg (Section 1), with concentrations in sample Section 1, LVRS2P and LVRD3P exceeding the Sediment DVG only. Concentrations were below the DGV-high however the 95% UCL also exceeded the DGV-low indicating potential impacts to aquatic ecosystems from lead.
- Zinc ranged between 21 mg/kg and 390 mg/kg (Section 1), with concentrations in all 2018 samples exceeding the EIL for Areas of Ecological Significance, sample A-Top from 1999, samples from Section 1-4 from 2012 and sample EL-N also exceeding the EIL. Five of the 9 samples also exceeded the EIL for POS, whilst sample LVRS2P exceeded the EIL for commercial/industrial use and the Sediment DGV. The 95% UCL also exceeded the EIL for Areas of Ecological Significance and for POS, however remained below the sediment DVG indicating a potential risk to terrestrial ecosystems.

It is noted here that the most-conservative EILs have been used for Areas of Ecological Significant and Commercial/Industrial use in the absence of site-specific parameters (pH, CEC and clay content). Potential risks from zinc may therefore be overly conservative and should be re-assessed once soil characteristics are obtained.

Furthermore, although the metal contaminant concentrations may not exceed soil or sediment quality guideline values, significant risks may exist due to the presence of ASS and disturbance of the materials. For example, potentially hazardous concentrations of metal(loid)s may be released into the dissolved phase despite the particulate metal(loid) concentrations being below the sediment guidelines.

4.2.4 Organics

Benzene, toluene, ethylbenzene, and xylene (BTEX), and polycyclic aromatic hydrocarbon (PAH), organochlorine and organophosphorus pesticides (OCP/OPP), volatile organic compounds (VOC), polychlorinated biphenyls (PCB) and total phenols concentrations were below the laboratory limit of reporting (LOR) and hence compliant with relevant guidelines in all sediment samples, indicating absence of potential risks to the human health and ecological receptors.

Total petroleum hydrocarbons (TPH) were detected in all samples however are likely to reflect the elevated organic content of the sediments rather than from a petroleum source of impact. Silica-gel cleanup has however not been undertaken to confirm/refute this interpretation. All detected concentrations were below the relevant criteria (Sediment DGV and HSL-D for direct contact) indicating absence of potential risks to the human health and ecological receptors.

4.2.5 Leachability

As part of the SKM (1999), City of Busselton (2018) and the Bio Soil (2020) investigations, leachate testing was undertaken for arsenic, cadmium, chromium, copper, mercury, lead, nickel, and zinc. The following analytes were reported to be leachable:

- Lead (only analyte submitted for leachate analysis in 2018) was found to be leachable in 2 of the 12 samples collected with concentrations exceeding the UCF guideline value and the Fresh Water guideline.
- Zinc in 1999 was found to be leachable in 2 of the 4 samples collected with concentrations exceeding the UCF guideline value and the Fresh Water guideline. Zinc was also found to be leachable in the 3 samples collected as part of the 2020 trial with concentrations also exceeding the UCF guideline value and the Fresh Water Criteria.
- It is noted here that all other concentrations were reported below the LOR, however the LORs were reported above the UFC and Fresh Water guideline, and as such an accurate assessment cannot be made with regards to suitability as UCF and whether it poses a potential risk to freshwater ecosystems.

4.2.6 Waste Classification

Based on the anticipated volume of sediment to be removed (i.e., 7,065 m^3) and in accordance with the waste class guidelines (DWER 2019) if all the sediments are to be removed at once, then a minimum of 24 waste classification samples (if material is all dredged and disposed of collectively) should be collected to assess landfill class for disposal. If the sediment removal is undertaken per sections of the river then the minimum number of samples required per section is presented in **Table 9**.

Table 9: Minimum Waste Classification Samples Required Per Section

River Sections	Estimated Volume (m^3)	Minimum No of Samples
Section 1: Butter factory - Old Rail Bridge	493	6
Section 2: Old Tail Bridge to Causeway	876	8
Section 3: Causeway to New River	1,034	11
Section 4: New River to Boat Ramp	148	4
Section 5: Boat Ramp to Strelly Street	1,867	11
Section 6: Strelly Street to Bend (section 5A-CD)	884	8
Section 7: Bend to Bypass	1,761	11

River Sections	Estimated Volume (m^3)	Minimum No of Samples
	TOTAL	59

Based on the current number of sediment samples collected (24 samples in total), sufficient samples have been collected for the characterization of the volume of material required to go to landfill as a whole, if required. Following assessment of the existing sediment data from within the proposed sediment removal area against the waste class guidelines (DWER 2019) the following concentrations exceeded the CT criteria:

- Lead (Pb) was reported to exceed the CT1 and/or CT3 criterion in 22 of the 24 samples with the mean plus one standard deviation (mean+1SD) also exceeding the CT1 criterion
- Cadmium (Cd) exceeded the CT1 criterion in five of the 24 samples with the mean+1SD also exceeding the CT1 criterion
- Chromium (Cr) exceeded the CT1 criterion in nine of the 24 samples with the mean+1SD also exceeding the CT1 criterion
- Nickel (Ni) exceeded the CT1 criterion for Class I/II landfills in one of the 24 samples only with the mean+1SD below the CT1 criterion.

These results therefore trigger the need for further leachate testing to determine the leachability of Cd, Cr and Pb. Leachate analysis using deionised (DI) water was undertaken as part of the SKM (1999) investigation for all heavy metals including Pb, Cd, Cr and Ni and as part of the City of Busselton (2018) investigation for lead only.

Results indicated that Pb, Cd, Cr and Ni were not leachable as part of the 1999 investigation but Pb was reported to be leachable in 2 of the 12 samples collected as part of the 2018 investigation (LVRS1P and LVRS2P), however concentrations were all below the ALSP1 criteria with sediment concentrations also all below the CL1 criteria. It is noted here that leachate analysis using DI water (pH 7 solution) is intended to simulate leachability of the material that would encounter rainwater. The results are not intended to simulate leachate associated with the burial of sediments within a lined landfill.

Leachate testing was not undertaken for cadmium and chromium as concentrations were only marginally exceeding the CT1 criteria as part of the 2018 investigation. This is considered a small data gap, however given that similar or higher total concentrations of Cd and Cr were reported in the sediments in 1999 and these were not reported to be leachable, the absence of leachate data in 2018 it is considered that this data gap is unlikely to result in a change to the interpreted Class 1 landfill classification of the sediments.

4.2.7 Summary

The results to date provide limited site-specific data per section of the river, indicating slight to moderate changes in sediment quality within the different river sections. A summary of the maximum results per section of the river is presented in **Table 10**. As per the table, Sections 4, 5 and 6 are the ones presenting the highest net acidity and will require the most lime dosing.

The highest nutrients were observed at Section 1, 4, 5, 6 and 7 whilst the highest heavy metal concentrations were reported in Section 1 and 4.

Table 10: Maximum Concentrations

River Section	Net Acidity (%S)	Total Nitrogen (mg/kg)	Total Phosphorus (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Section 1 – Butter Factory to Railway Bridge	2.2	3,700	550	160	390
Section 2 – Railway Bridge – Causeway Road	1.9	2,500	280	35	83
Section 3 – Causeway Road to Shire office	2.2	3,400	470	32	79
Section 4 – City office to Strelly Steet Bridge	2.7	4,800	540	94	210
Section 5 – Strelly St Bridge to River Bend	4.4	4,800	540	7.9	29
Section 6 – River Bend to Fairlawn Road	2.7	8,800	860	9	32
Section 7 – Fairlawn Rd to Busselton Bypass	---	10,200	1,310	3.4	18

5 Sediment Disposal/Reuse Options Evaluation

The potential beneficial reuse of spoil depends largely upon its physical and chemical characteristics, as well as costs and time required to process the material into a form that can be used effectively for environmental benefit. Transportation costs will generally limit beneficial reuse to occur at locations that are long distances from the dredging operations. As land disposal is often expensive where risks are identified due to contamination (including ASS), disposal within similar environments is often the preferred option where this results in lower or similar levels of environmental risks.

Organic-rich water retaining silts usually provide opportunities for backfilling or beneficial conditioning of agricultural lands or ecological improvement. The options currently being investigated for reuse and disposal, and their waste definition are summarised in **Table 11** below. DWER’s guidance on the determination of whether a material is a waste or resource is provided as **Appendix A**, and includes the following considerations:

- Point of view of the source/provider: whether material that is received at premises is waste or not must be assessed from the perspective of the person who is the source/producer of the material and not the receiver of the material.
- Nature of the material: There is no requirement that material must be environmentally harmful in order to be waste. The nature/composition of material is not determinative of whether it is waste.
- Concept of being “unwanted”: Even if material is left over from, or a by-product of, a particular project and not wanted by its source/producer for that project, it may still be wanted by them for use for some other project (on the same site or a different site) or for sale to a third party.
- Payments relating to the materials: Whether or not a third party pays for material or is paid to receive material from its producer/source, is a relevant consideration in assessing whether the material is waste.
- Substantially transformed: Material that is waste at a certain point in time may stop being waste if it is re-used in certain ways, sufficiently processed or is recycled.

Table 11: Waste Definition

Disposal/Reuse Option	Waste Definition	Applicable Evaluation Criteria
Option 1: Landfill Disposal	Waste however, as the waste is located outside the Perth Metropolitan area, the landfill levy does not apply.	Class I Landfill Waste Classification Guidelines
Option 2: Reuse onsite as part of restoration of the off-stream treatment wetland	Not Applicable	Ecological and Human Health Protection Criteria

Disposal/Reuse Option	Waste Definition	Applicable Evaluation Criteria
Option 3: Fill material for man-made ponds at 131 (part of Lot 27) Rendezvous Road, Vasse	Resource - If material is left over from, or a by-product of, a particular project and not wanted by its source/producer for that project, it may still be wanted for use for some other project (on the same site or a different site). Material wanted by its producer/source for use in some other project is not considered to be waste	Ecological and Human Health Protection Criteria
Option 4: Growing media for rehabilitation of the City's Piggot Road gravel pit (110, Lot 4134 Piggot Road).		Ecological and Human Health Protection Criteria
Option 5: Daily cover for the Dunsborough Landfill site at 48 (Lot 8) Western Cape Drive, Naturaliste	Resource – if the landfill needs day cover and pays for its receipt	Class I Landfill Waste Classification Guidelines Ecological and Human Health Protection Criteria
Option 6: Reuse by a 3rd Party	Waste - If material is unwanted or excess to requirements, viewed from the perspective of its source/producer, the material is considered waste. The source/producer of material that is excavated at one site and taken to another will be the owner of the material at its source, however, as the waste is located outside the Perth Metropolitan area the landfill levy does not apply.	UCF Guidelines

It is noted here that all of the land-based options, whether buried or unburied, will require some form of application of neutralization materials (for example lime) to reduce the acidity. An ASSMP should therefore be prepared for the entire site (i.e Butter Factory Museum to Busselton Bypass) based on recently obtained ASS data and minimum number of sample locations required for based on the area to be targeted for each sediment removal stages. Neutralisation of the removed sediment, post dewatering, will need to be undertaken on an appropriately constructed limestone pad by mechanical application to achieve uniform blending of the neutralising material and the acid-generating soils. The neutralising material will need to be thoroughly mixed into each soil layer by scarification with suitably equipped earthmoving plant (or other suitable method). Each completed layer of neutralised soils will be subject to validation testing. Excavated material will need to be neutralised using a suitable neutralising agent with the amount of neutralising agent required based on the highest percent sulfur concentration calculated for each of the different sediment removal stages.

As per the DWER guidelines, untreated ASS will preferentially be treated onsite to limit the potential for acidification. Where excavated dewatered sediment volumes are equal or greater to 1,000 tonnes/annum, offsite ASS treatment should only occur at facilities that are licensed under Category 67a of the Environmental Protection Regulations and have a DWER approved ASS management plan.

Table 12 summarises the potential actions for material management and their suitability based on the sediments results to date and residual data gaps to support confirmation of the suitability of the option.

Table 12: Sediment Reuse/Disposal Assessment

<table>
<tr><th>Use/Disposal</th><th>Relevant Guideline</th><th>Evaluation</th><th>Data Gaps/Recommendations</th></tr>
<tr><td>Option 1: Landfill Disposal</td><td>• Waste classification guidelines (DWER, 2019);
○ CT
○ CL
○ ASLP.
• ASS Guidelines (DWER, 2015).</td><td>• Based on the waste classification and leachate results available, CLs and ASLP concentrations were generally compliant with Class I landfill criteria
• The sediments have a high acid generating potential and will require treatment to render them inert prior to being able to be received by the landfill.

The sediments are considered suitable for disposal at a Class I /II landfill, if required. Post-neutralisation of the material would also be considered inert and may be suitable for day cover.</td><td>• An insufficient number of samples has been analysed to support disposal of the full volume of material to landfill. Additional waste classification samples would need to be collected based on the volume of sediment to be disposed of for each section of the river [refer to Table 9], if landfill disposal is chosen as a suitable option by the City.
• Additional leachate analysis would also likely be required for analytes based on the results to confirm leachability meets the ASLP1 criteria. It would be recommended to undertake the testing in line with the proposed sediment removal stages.
• ASS treatment will be required prior to disposal.</td></tr>
<tr><td>Option 2: Onsite reuse for Wetland Rehabilitation</td><td>• NEPM (NEPC, 2013):
○ EIL – Area of Ecological Significance
○ 95% UCL
• ANZECC/ARMCANZ, 2000:
○ DVG.
• Leachate Assessment criteria:
○ FW.
• ASS Guidelines (DWER, 2015).</td><td>• To develop wetland habitat, dredged material would generally be used to fill areas to promote colonization by wetland vegetation.
• Based on the sediment results for the Lower Vasse River portion, lead exceeded the DVG and may represent a potential risk to aquatic ecosystems, whilst zinc exceeded the DVG and EIL presenting a potential risk to both aquatic and terrestrial ecosystems. It is noted however that the most conservative EILs were used in this assessment in the absence of site-specific EIL.
• Leachable concentrations of zinc also exceeded the Fresh Water criteria indicating potential impact to surface water and degradation of the water quality.
• Elevated phosphorus and nitrogen may also increase the risk of excess phosphorus and nitrogen in the water column and connecting waterbodies, resulting in degraded water quality.
• The sediments have a high acid generating potential, however liming treatments will reduce the acidity of the sediment and may be sufficient to result in a reduced trend of heavy metals availability, with the strongest effect likely to be seen on the most acidic sediments and sediments with the highest initial concentrations of heavy metals.
• The sediments have a low soil particle density and are very fine grained with a large pore water component which would contain nutrients under anoxic conditions. Disturbance of the sediments is therefore likely to release nutrients in the water column resulting in degraded water quality.

Sediments currently appear inappropriate for wetland habitat restoration due to the elevated nutrient concentrations, presence of lead and zinc at concentrations potentially causing a risk to aquatic and terrestrial ecological receptors and leachable heavy metals. However, based on the results of the recommended investigation/test, this option may subsequently be deemed viable.</td><td>• ASS treatment would be required prior to reuse. It is recommended to undertake a liming treatment trial on the sediments and reassess sediment metal and nutrient concentrations and leachability following the completion of the trial.
• A comparison against site-specific EILs for zinc post-treatment would need to be undertaken to assess actual risks to aquatic and terrestrial ecological receptors.
• To assess the potential impacts on water quality of the wetland during rehabilitation works, leachate analysis for nutrients (nitrogen and phosphorus) and elutriate tests would need to be undertaken to investigate the desorption of contaminants from sediment particulates to water.
• Recent leachate analysis from samples collected along the entire portion of the river to be dredged would also be required to confirm/refute leachability of heavy metals. It would be recommended to undertake the testing in line with the proposed sediment removal stages.
• A physical properties study would also need to be undertaken to assess the existing soil physical properties such as sediment type and characteristics, and potential for consolidation and instability. This would include parameters (DMP 2016) including:
○ Cation exchange capacity (CEC) – measures the capacity of soils to hold cations
○ Organic carbon – an indicator of soil nutrient store
○ Available P (Colwell) – a measure of the phosphorus that is available for plant uptake
○ Available K (Colwell) - a measure of the potassium that is available for plant uptake
○ Available S (KCL 40 test) - a measure of the sulfur that is available for plant uptake.</td></tr>
<tr><td>Option 3: Reuse as infill by the City</td><td>• NEPM (NEPC, 2013):
○ EIL – Commercial/Industrial
○ HIL-D
○ HSL-D for Direct Contact
○ 95% UCL.
• Leachate Assessment criteria:
○ FW
○ ADWG
○ NPUG.
• ASS Guidelines (DWER, 2015).</td><td>• Based on the sediment results, zinc and the 95% UCL exceeded the EIL for commercial and industrial land use presenting a potential risk to terrestrial ecosystems. It is noted however that the most conservative EIL for zinc was used in this assessment in the absence of site-specific EIL.
• Similarly, zinc and the 95% UCL exceeded the UCF Maximum allowed concentration and leachate guideline value indicating that the material would not be deemed suitable to be moved between project areas. It is noted however that the leachate analysis for heavy metals were undertaken on samples used as part of the bio-remediation trial for which the samples may have been exposed to air, oxidised, and contributed to the release of metalloids in the dissolved phase.
• Leachable concentrations were below the drinking water criteria and NPUG criteria indicating that if groundwater is abstracted for drinking water purposes near the man-made ponds located at 131 (part of Lot 27) Rendezvous Road, Vasse, groundwater will be suitable for its beneficial use.
• All other detected concentrations of heavy metals and TPH were below the EIL, HIL-D, HSL-D for direct contact and UCF guideline.
• The sediments have a high acid generating potential, however liming treatments will reduce the acidity of the sediment and will result in trend of heavy metals availability decrement, with the strongest effect likely to be seen on the most acidic sediment and sediment with the highest initial concentrations of heavy metals.

Sediments currently appear inappropriate for reuse as infill due to elevated nutrient concentrations, presence of lead and zinc at concentrations potentially causing a risk to terrestrial ecological receptors</td><td>• ASS treatment would be required prior to reuse. It is recommended to undertake a liming treatment trial on the sediment and a reassessment of sediment concentrations and leachability following the completion of the trial.
• A comparison against site-specific EILs for zinc would need to be undertaken to assess actual risks to terrestrial ecological receptors.
• Leachate testing of all metals, total nitrogen, sulfate, total phosphorus has not been undertaken and as such, confirmation of the suitability of the material as 'Uncontaminated Fill' cannot be substantiated.
• Recent leachate analysis from samples collected along the entire portion of the river to be dredged would also be required to confirm/refute leachability of zinc and other heavy metals. It would be recommended to undertake the testing in line with the proposed sediment removal stages.</td></tr>
</table>

Use/Disposal	Relevant Guideline	Evaluation	Data Gaps/Recommendations
		and leachable heavy metals. However, based on the results of the recommended investigation/test, this option may be viable.	
Option 4: Reuse by the City as daily landfill cover	• Waste classification guidelines (DWER, 2019) – Inert Waste ○ CT1 ○ CL1 ○ ASLP1 • NEPM (NEPC, 2013) ○ EIL – Commercial/Industrial ○ HIL-D ○ HSL-D for Direct Contact ○ 95% UCL • ASS Guidelines (DWER, 2015)	• Based on the sediment results the materials look likely to meet Class I landfill criteria for Inert Waste Type 1. • Risks to groundwater are considered negligible as groundwater at landfill sites is not usually abstracted for any other purposes than for dust suppression. • The sediments have a high acid generating potential and will require treatment to render them inert prior to being able to be received by the landfill. **Sediments appear suitable for reuse as daily landfill cover and are likely to act as a buffer to the acid runoff and the infiltration of water to allow for the growth of grass.**	• ASS treatment would be required prior to reuse. It is recommended to undertake a liming treatment trial on the sediment and a reassessment of sediment concentrations and leachability following the completion of the trial.
Option 5: Reuse as growing media	---	• Based on the bioremediation trial undertaken by the City in 2020, the sediments generally indicated the presence of nutrient/heavy metals outside desired level for efficient uptake by plants, insufficient levels of fungi species and bacteria to provide an adequate media for plant growth. **Sediment may be suitable for reuse as growing media, however mixing with mulch and products would be required to achieve a suitable medium.**	• ASS treatment would be required prior to reuse. It is recommended to undertake a liming treatment trial on the sediment and a reassessment of sediment concentrations and leachability following the completion of the trial. • Blending of course mulch through the sediment on a 1:1 ratio would be required to create immediate structure, provide a long-term food source for developing fungal hyphae and to allow for improved aeration • The application of amended Bio+ Brew would also be required at the time of blending, with 3 monthly testing to establish whether organic soil amendments are required.
Option 6: Reuse by a Third-Party	• Waste classification guidelines (DWER, 2019) ○ Uncontaminated Fill – Soil and leachate ○ 95% UCL • Leachate Assessment criteria ○ FW ○ ADWG ○ NPUG • ASS Guidelines (DWER, 2015)	• Zinc and the 95% UCL exceeded the UCF Maximum allowed concentration and leachate guideline value indicating that the material would not be deemed suitable to be moved between project areas. It is noted however that the leachate analysis for heavy metals were undertaken on samples used as part of the bio-remediation trial for which the samples may have been exposed to air, oxidised, and contributed to the release of metalloids in the dissolved phase. • Leachable concentrations were below the drinking water criteria and NPUG criteria indicating that if groundwater is abstracted for drinking water purposes, groundwater will be suitable for its beneficial use. • All other detected concentrations of heavy metals and TPH were below the EIL, HIL-D, HSL-D for direct contact and UCF guideline. • The sediments have a high acid generating potential, however liming treatments will reduce the acidity of the sediment and will result in trend of heavy metals availability decrement, with the strongest effect likely to be seen on the most acidic sediment and sediment with the highest initial concentrations of heavy metals. **Sediments currently appear inappropriate for reuse by a 3d party due to the presence of lead and zinc above the UCF guidelines. However, based on the results of the recommended investigation/test, this option may be viable.**	• ASS treatment would be required prior to reuse. It is recommended to undertake a liming treatment trial on the sediment and a reassessment of sediment concentrations and leachability following the completion of the trial. • A comparison against site-specific EILs for zinc would need to be undertaken to assess actual risks to terrestrial ecological receptors. • Leachate testing of total nitrogen, sulfate, total phosphorus has not been undertaken and as such, confirmation of the suitability of the material as 'Uncontaminated Fill' cannot be substantiated. • Recent leachate analysis from samples collected along the entire portion of the river to be dredged would also be required to confirm/refute leachability of zinc and other heavy metals. It would be recommended to undertake the testing in line with the proposed sediment removal stages.

6 Risk Assessment

A number of risks associated with the implementation of the different options have been identified pre- and post-disposal and are presented in **Table 16** and **Table 17**. The potential consequences (**Table 13**) and likelihood (**Table 14**) associated with each risk were used as a basis for allocating a "risk classification" to each hazard (**Table 15**).

Table 13: Consequence Matrix Table

ASPECT	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
Reputational	Internal Only: Damage to reputation or values of reputation of work area within a work area or team	Internal Only: Damage to reputation or values of several work areas or team for a single issue on one project	Damage to reputation (professionalism, trust). One off public exposure in local media, word of mouth or local mythologies	Criticism which impacts credibility with clients/government and other stakeholders. Minor exposure in local media	Criticism which impacts credibility with clients, government, and other stakeholders. Impacts key stakeholders/clients and has a long-term effect on
Conformance/ Compliance	Non-conformance with internal procedure with low potential for impact	Non-compliance with external standard, contract, or procedure with low potential for impact - Root Cause Analysis may be	Non-compliance with moderate potential for impact e.g., one-off noncompliance with licence; fine for breach of	Breach of licences, legislation, regulation, or repeated non-compliance with high potential for prosecution. Non-	Legal dispute directly attributable to professional negligence
Environment	Temporary, readily reversible impact; localised event location of little environmental value. No impact or disruption to project	Temporary change to the environmental conditions of an area or system; isolated and localised environmental impact requiring some work to reverse; Minor,	Direct or indirect environmental impacts to an area or system; stakeholder concern over environmental nuisance. Reportable to regulators.	Actual or potential environmental harm either temporary or permanent, requiring immediate attention; Moderate environmental impact.	Serious environmental harm causing actual or potential environmental impacts that are irreversible; of high impact or widespread.
Financial	Up to $1,000 loss or less than 0.25% impact on revenue	Up to $5,000 loss or up to 5% impact on revenue	Up to $50,000 loss or between 5-10% impact on revenue	Up to $500,000 loss or between 10-25% impact on revenue	Greater than $500,000 loss or more than 25% impact on revenue

Table 14: Likelihood

Likelihood	Likelihood Description	Frequency	Probability
ALMOST CERTAIN	Is expected to occur in most circumstances	Occurs more than twice per year	>1 in 10
LIKELY	Will probably occur	Typically occurs once or twice per year	1 in 10-100
POSSIBLE	Might occur at some time in the future	Typically occurs in 1-10 years	1 in 100-1,000
UNLIKELY	Could occur but doubtful	Typically occurs in 10-100 years	1 in 1,000 -10,000
RARE	May occur but only in exceptional circumstances	Greater than 100-year event	1 in 10,000-100,000

Table 15: Risk Rating

Likelihood	Consequence					Risk Acceptance Threshold
	Insignificant	Minor	Moderate	Major	Catastrophic	
Almost Certain	M	H	H	E	E	L – Risks are below risk acceptance threshold; do not require active management
Likely	M	M	H	H	E	M – Risks lie on the risk acceptance threshold; require active monitoring
Possible	L	M	M	H	E	H – Risks exceed risk acceptance threshold; require active management
Unlikely	L	L	M	M	H	E – Risks significantly exceed risk acceptance threshold; need urgent and immediate attention
Rare	L	L	M	M	H	

Table 16: Risk Assessment – Prior to Disposal

Option	Hazard	Likelihood	Consequence	Risk Rating
All Options	Insufficient mixing of liming material with removed sediments resulting in sediments not being approved for disposal.	Possible	Minor	L
Option 1: Landfill Disposal	Insufficient number of waste classification samples collected based on the volume of sediment to be disposed resulting in sediments not being approved for disposal.	Possible	Minor	L
	Leachate analysis confirm the presence of leachable analytes resulting in a higher landfill class required for disposal.	Unlikely	Moderate	M
Option 2: Onsite reuse for Wetland Rehabilitation	Heavy metals present in elevated concentrations and actual risks to aquatic and terrestrial ecological receptors resulting in sediments not being able to be reused.	Unlikely	Moderate	M
	Leachable nutrients and metals and desorption of contaminants from sediment particulates to water are too high resulting in sediments not being able to be reused.	Possible	Moderate	M
	The physicochemical sediment properties are not suitable for reuse.	Likely	Moderate	H
Option 3: Reuse as infill by the City	Heavy metals present in elevated concentrations and actual risks to aquatic and terrestrial ecological receptors resulting in sediments not being able to be reused.	Unlikely	Minor	L
Option 4: Reuse by the City as daily landfill cover	Heavy metals present in elevated concentrations and do not meet Waste Classification guidelines as Inert Waste 1.	Unlikely	Moderate	M
Option 5: Reuse as growing media	Insufficient mulch blended through the sediment to create a suitable growing media.	Possible	Moderate	M
	Mixing of liming material with removed sediments results in sediments not being suitable for reuse as growing media.	Possible	Moderate	M
Option 6: Reuse by a Third-Party	Heavy metals present in elevated concentrations and actual risks to aquatic and/or terrestrial ecological receptors resulting in sediments not being able to be reused.	Possible	Moderate	M
	Total nitrogen, sulfate, total phosphorus and heavy metals leachate results do not meet the UCF guideline resulting in sediments not being able to be reused.	Likely	Moderate	H

Table 17: Risk Assessment – Post-Disposal

Option	Hazard	Likelihood	Consequence	Risk Rating
Option 1: Landfill Disposal	None	---	---	---
Option 2: Onsite reuse for Wetland Rehabilitation	Adverse effects on the existing water quality of the wetland	Possible	Major	H
	Adverse effects on groundwater quality	Possible	Major	H
Option 3: Reuse as infill by the City	Adverse effects on the existing water quality of the downgradient water bodies	Possible	Moderate	M
	Adverse effects on groundwater quality	Possible	Moderate	M
Option 4: Reuse by the City as daily landfill cover	None	---	---	---
Option 5: Reuse as growing media	Chemical and biological test indicate that the sediment/mulch blend is not appropriate to produce a suitable growing media	Possible	Moderate	M
Option 6: Reuse by a Third-Party	Adverse effects on the existing water quality of the downgradient water bodies	Possible	Moderate	M
	Adverse effects on groundwater quality	Possible	Moderate	M

7 Monitoring and Reporting

The selection of disposal/reuse option will lead to the development of a management plan to minimise environmental risks during disposal/reuse of dredged material within waters or on land. Additionally, an appropriate ASSMP should be prepared prior to the removal of the sediments. The monitoring and reporting requirement post disposal/reuse is presented in **Table 18**.

Table 18: Monitoring Requirement Post-Disposal/Reuse

Option	Monitoring	Reporting
Option 1: Landfill Disposal	---	• The landfill operator will maintain acceptance records in accordance with the Operational Licence

Option 2: Onsite reuse for Wetland Rehabilitation	• Surface water monitoring of the wetland weekly, as required until results are compliant with the ANZG (2018) 90% species protection levels, or baseline and pH results are > 6.5, total acidity (TA) is <40 mg/L and DO is > 6 mg/L
	• Testing should include:
	  ○ Turbidity, DO and pH
	  ○ TA
	  ○ Nutrients
	  ○ Major ions and metals.
		• The contractor/city will prepare a log and maintain a log of the weekly water quality testing
		• The environmental consultant will review the water quality results and prepare a closure report.

Option 3: Reuse as infill by the City	Depending upon where the sediment will be reused, the monitoring may include surface water and groundwater monitoring:
	• Surface water monitoring of the adjacent/downgradient surface water body and groundwater wells present at the site on a three-monthly basis as required and until the results are compliant with the nominated groundwater assessment criteria based on the beneficial use of groundwater in the area
	• Testing should include:
	  ○ pH
	  ○ TA
	  ○ Nutrients
	  ○ Chloride and sulfate
	  ○ Metals
	  ○ TPH/TRH and BTEX[1].
		• The environmental consultant will undertake the groundwater and surface water sampling, review the surface water/ groundwater quality results and advise on surface water/groundwater monitoring regime
		• The environmental consultant will prepare three-monthly groundwater/surface water monitoring event (GME) reports and an Annual GME report.

[1] TPH/TRH included in the list of analytes due to the presence of a hydrocarbon plume hydraulically upgradient of the site

Option	Monitoring	Reporting
Option 4: Reuse by the City as daily landfill cover	---	• The landfill operator will maintain acceptance records in accordance with the Operational Licence.
Option 5: Reuse as growing media	• Monthly visual inspections by the contractor to monitor progress of the compost • Full chemistry analysis and biological assessment to be undertaken by the contractor after three months to track progress and apply organic soil amendments and practices where required.	• The contractor will prepare a log and maintain a log of the quantity of mulch used and quantity of sediment blended • The contractor will prepare a report following receipt of the chemical and biological testing.
Option 6: Reuse by a Third-Party	Not considered to be the responsibility of the City as the decision whether or not to monitor would be up to the purchasing party.	

8 Cost Analysis

A cost analysis of the different options is summarized in **Table 19** with a detailed breakdown of the cost estimate derivation provided in **Appendix** 2. It is noted here that these costs are estimates only in order to provide an indication of the total cost likely to be incurred for the sediments from the Butter Factory to the Busselton Bypass. These costs should be further refined once the stages of works are determined. The following rate assumptions are built into the cost estimation:

- Untreated volume of sediments is 7,065 m^3 post dewatering and is equivalent to 12,720 tonnes of sediment
- Average ASS treatment rate of 200 kg aglime/tonne of ASS assuming an 80% effective neutralizing value (ENV) of the Aglime.
- Limestone treatment pad capable of treating ASS in 200 m^2 lifts requiring 100 m^3 of crushed limestone for construction.
- Transport of material using an 18 m3 truck at a rate of $95/hour.
- With the exception of Options 1 and 4, onsite treatment is undertaken at the source.
- Cost for obtaining a licence for the receiving facility to treat the material has not been included.
- Costs for earthworks undertaken by the City are covered by the City.

Table 19: Cost Analysis

Option	Approximative Rates (+/- 30%)	Estimated Cost for 7,065 m^3 (12,720 tonnes)	Cost plus 30%
Option 1: Landfill Disposal	Transport of Untreated ASS	$27,000	$35,100
	Treatment of ASS at Landfill	$74,929	$97,410
	Disposal of Treated ASS	$809,700	$1,052,610
	Total (excl GST)	**$911,629**	**$1,185,120**
Option 2: Onsite reuse for Wetland Rehabilitation	Onsite treatment of ASS	$105,265	$136,850
	Transport of Treated ASS to Wetland	$78,300	$101,790
	Wetland Rehabilitation	$100,000	$130,000
	Monitoring and Reporting (1 year)	$70,000	$91,000
	Total (excl GST)	**$353,565**	**$459,640**
Option 3: Reuse as infill by the City	Onsite treatment of ASS	$105,265	$136,850
	Transport of Treated ASS to Offsite Location	$91,350	$118,760
	Pond Infill Works (covered by City)	$0	$0
	Monitoring and Reporting	$90,000	$117,000
	Total (excl GST)	**$286,615**	**$372,610**

Option	Approximative Rates (+/- 30%)	Estimated Cost for 7,065 m^3 (12,720 tonnes)	Cost plus 30%
Option 4: Reuse by the City as daily landfill cover	Transport of Untreated ASS	$54,000	$70,200
	Treatment of ASS at Landfill	$76,990	$100,090
	Disposal Fees	$0	$0
	Total (excl GST)	**$130,990**	**$170,290**
Option 5: Reuse as growing media	Onsite treatment of ASS	$105,265	$136,850
	Transport of Treated ASS to Offsite Location	$21,520	$37,980
	Bioremediation	$973,338	$1,265,340
	Monitoring (first year)	$20,000	$26,000
	Total (excl GST)	**$1,120,123**	**$1,456,170**
Option 6: Reuse by a Third-Party	Onsite treatment of ASS	$105,265	$136,850
	Transport of Treated ASS to 3rd Party	$134,140	$174,380
	Sale of Treated ASS to 3rd Party (cost to be negotiated – estimated at $15/tonne)	-$202,425	-$263,150
	Monitoring and Reporting (responsibility of 3rd Party)	$0	$0
	Total (excl GST)	**$239,405**	**$311,230**
	Total (with resale at $15/tonne)	**$36,980**	**$48,080**

9 Qualitative Benefit Comparison

With all potential reuse/disposal options, removal of sediments at the site will result in a significant investment of time and resources to achieve the required outcomes. As such, a qualitative benefit comparison has been undertaken for this site. For the purpose of this evaluation, the qualitative benefit comparison aims to identify the reuse/disposal options that best balances the impacts and influences of the triple bottom line of sustainability (i.e. environmental, societal and economic) while still protecting human health and the environment. Decision-making regarding reuse/disposal should preferentially support those options which demonstrate the most sustainable outcomes for the project. **Table 20** defines the sustainable environmental, social and economic indicators adopted for this evaluation.

Table 20: Sustainability Indicators

Environment	Social	Economic
Soil and ground conditions	Community Benefit	End land use/value
Groundwater/Surface Water		Direct economic costs
Surface Water	Licenced Facility	Project lifespan and flexibility
Ecological Receptors		Material reuse

Table 21 presents the qualitative (low – medium - high) benefit comparison of the potentially appropriate reuse/disposal options as determined in **Table 12** and to each indicator with a discussion of benefits and risks. A "High" ranking is considered the best option.

Table 21: Qualitative Assessment

Sustainable Remediation Indicator	Option 1: Landfill Disposal		Option 2: Onsite reuse for Wetland Rehabilitation		Option 3: Reuse as infill by the City		Option 4: Reuse by the City as daily landfill cover		Option 5: Reuse as growing media		Option 6: Reuse by a Third-Party	
	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison
Environmental Indicators												
Soil and ground conditions	• No apparent soil and ground impacts • No apparent human health and ecological risks associated with contaminants.	High (3)	• Potential ecological risks associated with contaminants.	Low (1)	• Potential ecological risks associated with contaminants.	Low (1)	• No apparent soil and ground impacts • No apparent human health and ecological risks associated with contaminants.	High (3)	• No apparent soil and ground impacts • No apparent human health and ecological risks associated with contaminants.	High (3)	• Uncontaminated fill guidelines pertaining to materials coming onsite may make achieving targets for material reuse difficult.	Moderate (2)
Groundwater/ Surface Water	• Materials capable of leaching contaminants into groundwater and surface water is unlikely.	High (3)	• Materials capable of leaching contaminants into groundwater and surface water • Potential negative effects on surface water quality of the wetland • Potential negative effects on groundwater.	Low (1)	• Materials capable of leaching contaminants into groundwater • Potential negative effects on groundwater.	Low (1)	• Materials capable of leaching contaminants into groundwater and surface water is unlikely.	High (3)	• Materials capable of leaching contaminants into groundwater and surface water is unlikely.	High (3)	• Materials capable of leaching contaminants into groundwater and surface water • Potential negative effects on surface water quality of the wetland • Potential negative effects on groundwater.	Low (1)
Ecological Receptors	• Long-term uncertainty will remain with respect to risks to ecological receptors as no landfill materials will be removed from site.	Moderate (2)	• Potential ecological risks associated with contaminants • Materials capable of leaching contaminants into groundwater and surface water.	Low (1)	• Potential ecological risks associated with contaminants • Materials capable of leaching contaminants into groundwater and surface water.	Low (1)	• Long-term uncertainty will remain with respect to risks to ecological receptors as no landfill materials will be removed from site.	Moderate (2)	• Ecological risks are unlikely.	High (3)	• Potential ecological risks associated with contaminants • Materials capable of leaching contaminants into groundwater and surface water.	Low (1)
Social Indicators												
Community benefit	• Short duration disposal timeframe compared to other options • Does not align with the Waste Hierarchy.	Low (1)	• Reuse endpoint aligns with City Lower Vasse River Waterway Management Plan • Aligns with the Waste Hierarchy.	Moderate (2)	• Reuse endpoint aligns with City Lower Vasse River Waterway Management Plan • Aligns with the Waste Hierarchy.	Moderate (2)	• Reuse endpoint aligns with City Lower Vasse River Waterway Management Plan • Aligns with the Waste Hierarchy.	Moderate (2)	• Moderate duration to achieve suitable mix • Reuse endpoint aligns with City Lower Vasse River Waterway Management Plan • Aligns with the Waste Hierarchy.	Moderate (2)	• Unknown as it depends on where the material will be reused. • Risks of reputational damage to the City if the material is misused or mismanaged by a 3rd party	Low (1)

Sustainable Remediation Indicator	Option 1: Landfill Disposal		Option 2: Onsite reuse for Wetland Rehabilitation		Option 3: Reuse as infill by the City		Option 4: Reuse by the City as daily landfill cover		Option 5: Reuse as growing media		Option 6: Reuse by a Third-Party	
	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison	Considerations	Qualitative Benefit Comparison
Licence Facility	• Untreated ASS can be taken up to the landfill directly as the landfill is licensed under the EP Act 1984	High (3)	• ASS can be treated onsite for future reuse as part of the Wetland Rehabilitation	High (3)	• ASS will have to be treated onsite or at a licensed soil treatment facilities prior to offsite reuse	Moderate (2)	• Untreated ASS can be taken up to the landfill directly as the landfill is licensed under the EP Act 1984	High (3)	• ASS will have to be treated onsite or at a licensed soil treatment facilities prior to offsite reuse	Moderate (2)	• Untreated ASS should not be sold to a 3rd Party • If untreated ASS is sold, the receiving entity will require a licence.	Low (1)
Economic Indicators												
End land use/value	• Land use endpoint will not create economic benefits for the land.	Low (1)	• Rehabilitation of Wetland • Ecological value recognized for the land.	High (3)	• Land use endpoint will create economic benefits for the land • The need to purchase additional fill material is removed.	High (3)	• The need to purchase additional fill material is removed • Land use endpoint will not create economic benefits for the land.	Moderate (2)	• Ecological value recognized for the land to which the growing media will be applied.	Moderate (2)	• Unknown as it depends on where the material will be reused.	Low (1)
Direct economic costs	• Cost of reuse is high compared to the other options	Low (1)	• Cost of reuse is moderate.	Moderate (2)	• Cost of reuse is relatively low compared to the other options.	Moderate (2)	• Cost of reuse is relatively low compared to the other options.	High (3)	• Cost of reuse is high compared to the other options	Low (1)	• Cost of reuse is relatively low compared to the other options.	High (3)
Project lifespan and flexibility	-----	Low (1)	• Project duration may extend beyond expected timelines but in general should be able to be managed • Material treatment timelines may not align with reuse timelines causing project delays.	Moderate (2)	• Project duration may extend beyond expected timelines but in general should be able to be managed • Material treatment timelines may not align with reuse timelines causing project delays.	Moderate (2)	• Material treatment timelines may not align with reuse timelines causing project delays.	Moderate (2)	• Bioremediation process may extend over a longer timeline to achieve the correct mix and right growing media.	Low (1)	• Material treatment timelines may not align with reuse timelines causing project delays.	Moderate (2)
Material reuse	• No material reuse. Does not align with the Waste Hierarchy.	Low (1)	• Beneficial reuse of sediments for wetland restoration if the sediments are geotechnically suitable • Recycling of materials reduces burden on landfills • Aligns with the Waste Hierarchy.	High (3)	• Beneficial reuse of sediments for filling pits • Recycling of materials reduces burden on landfills • Aligns with the Waste Hierarchy.	High (3)	• Beneficial reuse of sediments as capping material post treatment • Recycling of materials reduces burden on landfills • Aligns with the Waste Hierarchy.	High (3)	• Beneficial reuse of sediments • Sediment/mulch blend may not be appropriate to produce a suitable growing media • Materials processing will create a revenue stream.	Moderate (2)	• Beneficial reuse of sediments • Recycling of materials reduces burden on landfills • Aligns with the Waste Hierarchy.	High (3)
TOTAL Rating	16		18		17		23		19		15	

10 Conclusions

Based on the outcomes of the triple-bottom-line reuse/disposal options assessment, the following conclusions are drawn.

- **Option 4:** Reuse by the City as daily landfill cover is the preferred option on the basis that it best meets the triple-bottom-line objectives with all environment, social and economic indicators have been rated as having an overall high benefit, with comparison to the other options.
- **Option 5:** Reuse as a growing media is also considered a viable option as it allows for the reuse and transformation of the sediments into a product that is commercially viable whilst also preserving the environment. It has however an overall moderate benefit due to the elevated cost and longer lag time prior to reuse.
- **Option 2:** Onsite reuse for wetland rehabilitation and **Option 3:** Reuse as infill by the City have an overall moderate benefit however based on the potential ecological impacts (groundwater and surface water) associated with moving sediments into a new environment, these options currently rate less favourably than **Option 4** and **Option 5**. Further analytical work, both of the sediments and at the receiving environment, would be required to prove the viability of these options.
- **Option 1** is not considered viable as landfill disposal is the most-costly option and does not align with the waste hierarchy.
- Although there is potential for the City to recover costs through the sale of treated sediments to a 3rd party, **Option 6:** Reuse by a 3rd party, rates as low as **Option 1** due to its potential environmental and reputational risks to the City as the end use is unknown. Further analytical work, both of the sediments and at the receiving environment, would be required to prove the viability of this option.

11 Limitations

This report is produced strictly in accordance with the scope of services set out in the contract or otherwise agreed in accordance with the contract. 360 Environmental makes no representations or warranties in relation to the nature and quality of soil and water other than the visual observation and analytical data in this report.

In the preparation of this report, 360 Environmental has relied upon documents, information, data, and analyses ("client's information") provided by the client and other individuals and entities. In most cases where client's information has been relied upon, such reliance has been indicated in this report. Unless expressly set out in this report, 360 Environmental has not verified that the client's information is accurate, exhaustive, or current and the validity and accuracy of any aspect of the report including, or based upon, any part of the client's information is contingent upon the accuracy, exhaustiveness, and currency of the client's information. 360 Environmental shall not be liable to the client or any other person in connection with any invalid or inaccurate aspect of this report where that invalidity or inaccuracy arose because the client's information was not accurate, exhaustive, and current or arose because of any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to 360 Environmental.

Aspects of this report, including the opinions, conclusions, and recommendations it contains, are based on the results of the investigation, sampling and testing set out in the contract and otherwise in accordance with normal practices and standards. The investigation, sampling and testing are designed to produce results that represent a reasonable interpretation of the general conditions of the site that is the subject of this report. However, due to the characteristics of the site, including natural variations in site conditions, the results of the investigation, sampling and testing may not accurately represent the actual state of the whole site at all points.

It is important to recognise that site conditions, including the extent and concentration of contaminants, can change with time. This is particularly relevant if this report, including the data, opinions, conclusions, and recommendations it contains, are to be used a considerable time after it was prepared. In these circumstances, further investigation of the site may be necessary.

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12 References

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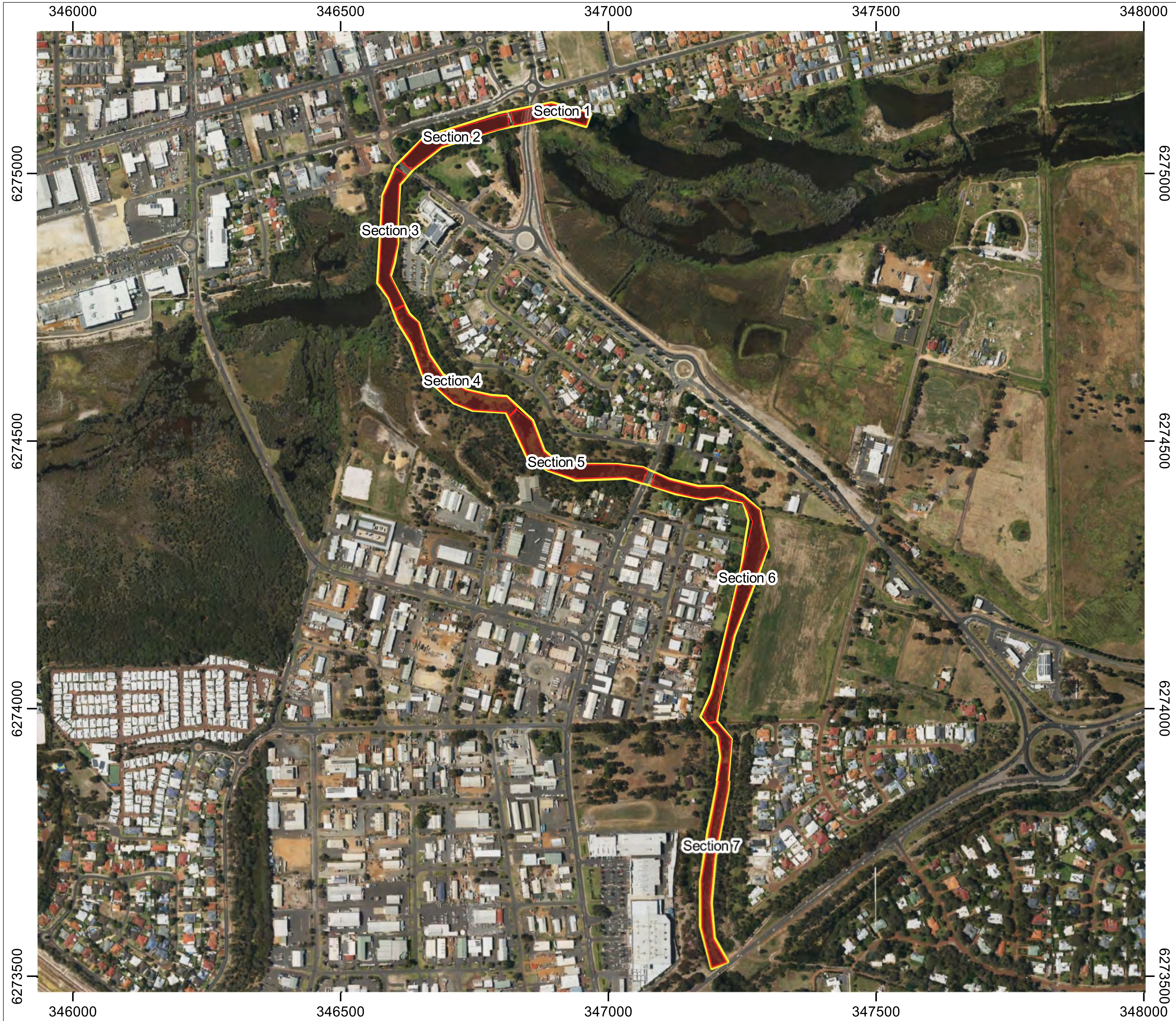
Figure



Legend

Site Boundary

River Sections

River Sections
Section 1: Butter factory - Old rail bridge
Section 2: Old rail bridge to Causeway
Section 3: Causeway to New river
Section 4: New River to boat ramp
Section 5: Boat ramp to Strelly Street
Section 6: Strelly Street to bend
Section 7: Bend to Bypass

- CADASTRAL BOUNDARY SOURCED FROM LANDGATE 2020
- AERIAL PHOTOGRAPHY SOURCED FROM LANDGATE 2020
- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

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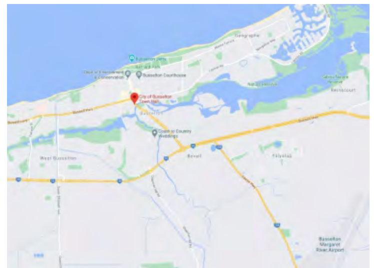
0 150 300 450 m
Meters

LOCALITY MAP



PROJECT NO	DATE	REVISION
4418	22/03/2021	0
CREATED	CHECKED	APPROVED
VM	JP	JP

City of Busselton, Lower Vasse River

Sediment Disposal and Reuse Options Assessment

Figure 1

Site Location

Legend

Site Boundary

Sampling Locations

Sediment Sampling Locations

Soil Bores

- CADASTRAL BOUNDARY SOURCED FROM LANDGATE 2020
- AERIAL PHOTOGRAPHY SOURCED FROM LANDGATE 2020
- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

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LOCALITY MAP

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4418	22/03/2021	0
CREATED	CHECKED	APPROVED
VM	JP	JP

City of Busselton, Lower Vasse River

Sediment Disposal and Reuse Options Assessment

Figure 2

Historical Sediment Sampling Locations

Tables

Table A - 2012 Sediment Results

Analyte	LOR	Units	DGV	DGV - High	EIL Areas of Ecological Significance	HIL-C Recreational	EIL Urban Residential/ Public Open Space	HIL-D	EIL (Commercial/industrial)
Inorganics									
pH	0.1	---	--	--	---	---	---	---	---
Sulfate	10	mg/kg	--	--	---	---	---	---	---
Metals (NEPM 8)									
Arsenic	0.2	mg/kg	20	70	**40**	300	**100**	3000	**160**
Cadmium	0.05	mg/kg	1.5	10	---	90	---	900	---
Total Chromium	0.05	mg/kg	80	370	**60**[b]	----	**190**[b]	3600	**310**[b]
Iron	5	mg/kg	43766*		---	---	---	---	---
Mercury	0.02	mg/kg	0.15	1	---	80	---	730	---
Lead	0.5	mg/kg	50	220	**470**	600	**1100**	1500	**1800**
Zinc	5	mg/kg	200	410	**50**[b]	30,000	**70**[b]	400000	**110**[b]

Investigation	SKM (1999) – Vasse River Sediment Remediation Study				City of Busselton (2012) Sediment Survey							Strategen (2017) Acid Sulfate Soil Investigation Report				
Sample ID	A-Top	A-Botttom	B-Top	B-Bottom	Section-1	Section-2	Section-3	Section-4	Section-5	Section-6	Section-7	CR-S	CR-N	EL-N	EL-S	95% UCL (EILs)
Laboratory Sample No.	43174-1	43174-2	43174-3	43174-4	12E0777/001	12E0777/002	12E0777/003	12E0777/004	12E0777/005	12E0777/006	12E0777/007	17-10372-B16	17-10372-B24	17-10372-B46	17-10372-B54	
Laboratory	Australian Environmental Laboratories				ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre					
Date Sampled	16/12/1998	16/12/1998	16/12/1998	16/12/1998	18/10/2012	18/10/2012	18/10/2012	19/10/2012	19/10/2012	19/10/2012	19/10/2012	05/07/2017	05/07/2017	05/07/2017	05/07/2017	
Inorganics																
pH					7.4	7.6	7.5	6.7	6.5	6.3	6.4	--	--	--	--	--
Sulfate					2900	12000	4600	8800	2300	2500	1500	--	--	--	--	--
Metals (NEPM 8)																
Arsenic	<0.5	1.7	<0.5	0.8	4	1.9	2.5	2.5	0.6	0.8	0.4	<5	<5	10	<5	**---**
Cadmium	<0.5	<0.5	0.6	<0.5	0.43	<0.05	<0.05	0.31	<0.05	0.14	0.1	0.6	0.8	<0.1	0.4	1
Total Chromium	21	10	26	7	25	12	17	17	6.1	9.2	4	4	5	51	9	24
Iron	---	---	---	---	29000	20000	32000	30000	11000	15000	7900	<1	<1	5	8	25325
Mercury	<0.05	0.12	<0.05	0.11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	--
Lead	30	2	16	1	**160**	35	32	20	7.9	9	3.4	5	6	15	3	52
Zinc	220	**5**	36	3	390	**83**	**79**	**100**	29	32	18	13	6	140	4	156

Acronyms:

LOR = limits of reporting
mg/kg = milligrams per kilogram
''---'' = criteria have not been derived for these chemical constituents/compounds.
* Indicates that the Nova Scotia EQS for FreshWater sediments and soil have been used in the absence of Australian criteria

Font and Cell :

- Coloured cells indicate exceedence of relevant assessment criteria
- Bolded analytical data indicates detection above LOR

Assessment of potential sediment disposal and reuse options
Lower Vasse River, Busselton
City of Busselton

Table B - 2018 Sediment Results

											Investigation	City of Busselton (2018) Sediment Sampling									95% UCL (EILs)	Bio Soil (2020) Bioremediation		
											Sample ID	LVRS1P	LVRS2P	LVRS3P	LVRS4P	LVRS5P	LVRS6P	LVRD1P	LVRD2P	LVRD3P		Sediment 1	Sediment 2	Sediment 3
											Laboratory	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL		ARL	ARL	ARL
											Date Sampled	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018		26/10/2018	26/10/2018	26/10/2018
Analyte	**LOR**	**Units**	**Default guideline values (DVG)**	**DVG - High**	**EIL: Areas of Ecological Significance**	**HIL-C: Recreational and Public Open Space**	**EIL: Urban Residential and Public Open Space**	**HSL-C: Direct Contact**	**HIL-D: Commercial and Industrial**	**EIL: Commercial and Industrial**	**HSL-D: Direct Contact**													
Inorganics																								
Total Nitrogen	10	mg/kg	---	---	---	---	---	---	---	---	---	3200	2800	2900	3000	3000	3100	2900	3000	2600	3058	5900	5500	6200
NOx-N	1	mg/kg	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	---	18	2	<1
Total Phosphorus	1	mg/kg	---	---	---	---	---	---	---	---	---	280	170	200	210	250	150	280	250	200	251	560	610	630
TOC	0.1	%	---	---	---	---	---	---	---	---	---	1.5	1.5	1.7	1.8	1.7	1.7	1.6	1.6	1.5	1.7	5.2	5.2	5.1
Fluoride	40	mg/kg	---	---	---	---	---	---	---	---	---	140	130	130	120	150	130	150	140	140	143	---	---	---
Cyanide - Total	1	mg/kg	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	---	---	---	---
Cyanide - Free*	1	mg/kg	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	---	---	---	---
Metals (NEPM 8)																								
Antimony	2	mg/kg	2	25	---	---	---	---	198000 [a]	---	---	<2	<2	<2	<2	<2	<2	<2	<2	<2	---	---	---	---
Arsenic	5	mg/kg	20	70	**40**	300	**100**	---	3000	**160**	---	<5	<5	<5	<5	<5	<5	<5	<5	<5	---	<5	<5	<5
Berylium	0.1	mg/kg	---	---	---	90	---	---	500	---	---	<0.1	<0.1	0.2	0.1	0.2	0.2	<0.1	<0.1	<0.1	---	---	---	---
Cadmium	0.1	mg/kg	1.5	10	---	90	---	---	900	---	---	0.3	0.7	0.3	0.2	0.2	0.3	0.4	0.3	0.4	0.4	<0.1	<0.1	<0.1
Total Chromium	1	mg/kg	80	370	**60 [b]**	---	**190 [b]**	---	6700 [a]	**310 [b]**	---	6	13	7	4	5	5	6	6	7	8	21	17	18
Copper	1	mg/kg	65	270	**20 [b]**	17000	**60 [b]**	---	240000	**85 [b]**	---	16	**33**	19	8	7	9	14	10	13	20	20	26	29
Iron	1	mg/kg	---	---	---	---	---	---	---	---	---	10000	19000	14000	9000	9800	9400	8600	6600	8300	12971	---	---	---
Lead	1	mg/kg	50	220	**470**	600	**1100**	---	1500	**1800**	---	37	**94**	31	14	9	12	39	15	**61**	**53**	23	26	**31**
Mercury	0.02	mg/kg	0.15	1	---	80	---	---	730	---	---	0.04	0.08	0.03	0.02	<0.02	0.02	0.04	0.03	0.05	0.05	0.15	0.13	0.18
Molybdnenum	2	mg/kg	---	---	---	---	---	---	1200 [a]	---	---	<2	2	<2	<2	<2	<2	<2	<2	<2	---	---	---	---
Nickel	1	mg/kg	21	52	**5 [b]**	1200	**30 [b]**	---	6000	**55 [b]**	---	2	3	3	2	2	2	2	1	1	2	3	3	4
Silver	1	mg/kg	1	3.7	---	---	---	---	---	---	---	<1	1	<1	<1	<1	<1	<1	1	<1	---	---	---	---
Zinc	1	mg/kg	200	410	**15 [b]**	30000	**70 [b]**	---	400000	**110 [b]**	---	**90**	210	**62**	**25**	**21**	**28**	**91**	**110**	**110**	**122**	**17**	**26**	**31**
BTEXN (2013 NEPM)																								
Benzene	0.2	mg/kg	---	---	---	---	---	120	---	---	430	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Toluene	0.5	mg/kg	---	---	---	---	---	18000	---	---	99000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Ethylbenzene	0.5	mg/kg	---	---	---	---	---	5300	---	---	27000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Total Xylenes	0.5	mg/kg	---	---	---	---	---	15000	---	---	81000	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Total Petroleum Hydrocarbon (TPH)																								
TPH C6-C9	0.2	mg/kg	280	550	---	---	---	---	---	---	47000 [a]	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
TPH C10-C14	0.2	mg/kg			---	---	---	---	---	---		1.3	0.9	2.7	2.8	2.1	1.6	3.7	6.8	5.4	4.3	---	---	---
TPH C15-C28	0.4	mg/kg			---	---	---	---	---	---		24	39	30	22	7.1	36	16	51	46	39	---	---	---
TPH C29-C36	0.4	mg/kg			---	---	---	---	---	---		25	53	36	20	5.6	34	17	41	51	42	---	---	---
TPH >C36	0.4	mg/kg			---	---	---		---	---		10	23	16	8.8	3.1	14	8.2	15	23	18	---	---	---
Volatile Organic Carbon																								
Styrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,3,5-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,2,4-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Carbon tetrachloride	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Chlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
DCM	10	mg/kg	---	---	---	---	---	---	---	---	---	<10	<10	<10	<10	<10	<10	<10	<10	<10	---	---	---	---
Hexachlorobutadiene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Methyl tert butyl ether	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Perchloroethene (PCE)	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Trichloroethylene(TCE)	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Vinyl Chloride	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
1,1-Dichloroethane	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
1,2-Dichloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,1-Dichloroethene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
cis-1,2-Dichloroethene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
trans-1,2-Dichloroethene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
1,1,1-Trichloroethane	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
1,1,1,2-Tetrachloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,1,2,2-Tetrachloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,2-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,3-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,4-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
1,2,3-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
2-Methylnaphthalene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
PAH																								
Naphthalene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Acenaphthylene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Acenaphthene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Fluorene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Phenanthrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Anthracene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Fluoranthene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Pyrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Benz(a)anthracene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Chrysene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Benzo(b)fluoranthene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Benzo(k)fluoranthene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Benzo(a)pyrene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Dibenz(a,h)anthracene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Benzo(ghi)perylene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Carcinogenic PAHs (as BaP TEQ) (LOR) [c]	0.2	mg/kg	---	---	---	3	---	---	40	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Sum of polycyclic aromatic hydrocarbons	0.1	mg/kg	10000	50000	---	300	---	---	4000	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
OCP																								
Aldrin	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
alpha-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
beta-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
delta-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Hexachlorobenzene (HCB)	0.01	mg/kg	---	---	---	10	---	---	80	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Heptachlor	0.01	mg/kg	---	---	---	10	---	---	50	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Heptachlor epoxide	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Bifenthin	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Total Chlordane	0.01	mg/kg	4.5	9	---	70	---	---	530	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Chlorpyrifos	0.02	mg/kg	---	---	---	---	---	---	---	---	---	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	---	---	---	---
alpha-Endosulfan	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
beta-Endosulfan	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Endosulfan sulfate	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Endosulfan (sum)	0.01	mg/kg	---	---	---	340	---	---	2000	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
BromophosEthyl	0.05	mg/kg	---	---	---	---	---	---	---	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	---
Dieldrin	0.01	mg/kg	2.8	7	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
4.4`-DDE	0.01	mg/kg	1.4	7	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Endrin	0.01	mg/kg	2.7	60	---	20	---	---	100	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
4.4`-DDD	0.01	mg/kg	3.5	9	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
4.4`-DDT	0.01	mg/kg	1.2	5	3	---	180	---	---	640	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Sum of DDD + DDE + DDT	0.01	mg/kg	---	---	---	400	---	---	3600	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Lindane	0.01	mg/kg	0.32	1	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Methoxychlor	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Sum of Aldrin + Dieldrin	0.01	mg/kg	---	---	---	10	---	---	45	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
Oxychlordnae	0.01	mg/kg	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	---
OPP																								
Diazinon	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Ethion	0.05	mg/kg	---	---	---	---	---	---	---	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	---
Fenitrothion	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Malathion	0.1	mg/kg	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	---
Trifluralin	0.2	mg/kg	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Polychlorinated Biphenyls (PCB)																								
PCB (Total)	0.2	mg/kg	34	280	---	1	---	---	7	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	---
Phenolic Compounds																								
Phenol	0.05	mg/kg	---	---	---	40000	---	---	240000	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	---

Acronyms:

mbgl = metres below ground level
LOR = Limit of Reporting
mg/kg = milligrams per kilogram
ug/kg = micrograms per kilogram
NA= Samples were not analysed for this specific analyte.
NL = Vapour concentration reach saturation point and cannot increase to a point which would result in an unacceptable health risk.
F1 to F4 = Four carbon chain fractions based on fractions adopted in the Canada-wide standard for petroleum hydrocarbons (PHC) in soil. For comparison to assessment criteria, only F1, F2, F3 and F4 are applied.
'---" = Criteria have not been derived for these chemical constituents/compounds.
[a] In the absence of HIL values, the soil standards for the protection of human health from Canada (Nova Scotia) have been adopted.
[b] In the absence of site specific soil parameters, the most conservative EILs have been adopted.
[c] Carcinogenic PAHs TEQ have been calculated using the 8 carcinogenic PAH TEFs.

Font and Cell :

- Bolded analytical data indicates detection above LOR.
- Coloured cells indicate exceedence of relevant assessment criteria.
- Coloured and underlined cells indicate exceedence of multiple assessment criteria.

Assessment of potential sediment disposal and reuse options
Lower Vasse River, Busselton
City of Busselton

Table C - Uncontaminated Fill Results

			Investigation	Sinclair Knight Merz (1999) – Vasse River Sediment Remediation Study				City of Busselton (2012) Sediment Survey							Strategen (2017) Acid Sulfate Soil Investigation Report				City of Busselton - 2018 Sediment Investigation									Bio Soil, 2020 - Bioremediation			95% UCL
			Sample ID	A-Top	A-Botttom	B-Top	B-Bottom	Section-1	Section-2	Section-3	Section-4	Section-5	Section-6	Section-7	CR-S	CR-N	EL-N	EL-S	LVRS1P	LVRS2P	LVRS3P	LVRS4P	LVRS5P	LVRS6P	LVRD1P	LVRD2P	LVRD3P	Sediment 1	Sediment 2	Sediment 3	
			Laboratory	Australian Environmental Laboratories				ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre	ChemCentre	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	
			Date Sampled	16/12/1998	16/12/1998	16/12/1998	16/12/1998	18/10/2012	18/10/2012	18/10/2012	19/10/2012	19/10/2012	19/10/2012	19/10/2012	05/07/2017	05/07/2017	05/07/2017	05/07/2017	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	26/10/2018	26/10/2018	26/10/2018	
Analyte	LOR	Units	Uncontaminated Fill - Maximum concentration																												
Inorganics																															
Total Nitrogen	10	mg/kg	---	10200	1900	5500	600	---	---	---	---	---	---	---	---	---	---	---	3200	2800	2900	3000	3000	3100	2900	3000	2600	5900	5500	6200	--
NOx-N	1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	18	2	<1	--
Total Phosphorus	1	mg/kg	---	860	220	770	120	---	---	---	---	---	---	---	---	---	---	---	280	170	200	210	250	150	280	250	200	560	610	630	--
TOC	0.1	%	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.5	1.5	1.7	1.8	1.7	1.7	1.6	1.6	1.5	5.2	5.2	5.1	--
Fluoride	40	mg/kg	400	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	140	130	130	120	150	130	150	140	140	---	---	---	--
Cyanide - Total	1	mg/kg	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	---	---	---	--
Cyanide - Free*	1	mg/kg	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<1	<1	<1	<1	<1	<1	<1	<1	<1	---	---	---	--
Metals (NEPM 8)																															
Antimony	2	mg/kg	20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<2	<2	<2	<2	<2	<2	<2	<2	<2	---	---	---	--
Arsenic	5	mg/kg	100	<0.5	1.7	<0.5	0.8	4	1.9	2.5	2.5	0.6	0.8	0.4	<5	<5	10	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	--
Berylium	0.1	mg/kg	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	0.2	0.1	0.2	0.2	<0.1	<0.1	<0.1	---	---	---	--
Cadmium	0.1	mg/kg	1	<0.5	<0.5	0.6	<0.5	0.43	<0.05	<0.05	0.31	<0.05	0.14	0.1	0.6	0.8	<0.1	0.4	0.3	0.7	0.3	0.2	0.2	0.3	0.4	0.3	0.4	<0.1	<0.1	<0.1	1
Total Chromium	1	mg/kg	160	21	10	26	7	25	12	17	17	6.1	9.2	4	4	5	51	9	6	13	7	4	5	5	6	6	7	21	17	18	19
Copper	1	mg/kg	50	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	16	33	19	8	7	9	14	10	13	20	26	29	23
Iron	1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	10000	19000	14000	9000	9800	9400	8600	6600	8300	---	---	---	12971
Lead	1	mg/kg	300	30	2	16	1	160	35	32	20	7.9	9	3.4	5	6	15	3	37	94	31	14	9	12	39	15	61	23	26	31	49
Mercury	0.02	mg/kg	0.5	<0.05	0.12	<0.05	0.11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.08	0.03	0.02	<0.02	0.02	0.04	0.03	0.05	0.15	0.13	0.18	0.11
Molybdnenum	2	mg/kg	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<2	2	<2	<2	<2	<2	<2	<2	<2	---	---	---	--
Nickel	1	mg/kg	10	---	---	---	---	---	---	---	---	---	---	---					2	3	3	2	2	2	2	1	1	3	3	4	3
Silver	1	mg/kg	20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<1	1	<1	<1	<1	<1	<1	1	<1	---	---	---	--
Zinc	1	mg/kg	120	220	5	36	3	390	83	79	100	29	32	18	13	6	140	4	90	210	62	25	21	28	91	110	110	17	26	31	**130**
BTEXN (2013 NEPM)																															
Benzene	0.2	mg/kg	0.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Toluene	0.5	mg/kg	85	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Ethylbenzene	0.5	mg/kg	55	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Total Xylenes	0.5	mg/kg	40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Total Petroleum Hydrocarbon (TPH)																															
TPH C6-C9	0.2	mg/kg	45	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
TPH C10-C14	0.2	mg/kg	110	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.3	0.9	2.7	2.8	2.1	1.6	3.7	6.8	5.4	---	---	---	4.3
TPH C15-C28	0.4	mg/kg	300	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	24	39	30	22	7.1	36	16	51	46	---	---	---	39
TPH C29-C36	0.4	mg/kg		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	25	53	36	20	5.6	34	17	41	51	---	---	---	42
TPH >C36	0.4	mg/kg	2800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	10	23	16	8.8	3.1	14	8.2	15	23	---	---	---	17.8
Monocylic Aromatic Hydrocarbons																															
Styrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,3,5-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,2,4-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Carbon tetrachloride	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Chlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
DCM	10	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<10	<10	<10	<10	<10	<10	<10	<10	<10	---	---	---	--
Hexachlorobutadiene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Methyl *tert* Butyl Ether	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Perchloroethene (PCE)	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Trichloroethylene(TCE)	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Vinyl Chloride	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
1,1-Dichloroethane	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
1,2-Dichloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,1-Dichloroethene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
cis-1,2-Dichloroethene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
trans-1,2-Dichloroethene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
1,1,1-Trichloroethane	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
1,1,1,2-Tetrachloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,1,2,2-Tetrachloroethane	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,2-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,3-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,4-Dichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
1,2,3-Trichlorobenzene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
2-Methylnaphthalene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
PAH																															
Naphthalene	0.1	mg/kg	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Acenaphthylene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Acenaphthene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Fluorene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Phenanthrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Anthracene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Fluoranthene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Pyrene	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Benz(a)anthracene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Chrysene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Benzo(b)fluoranthene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Benzo(k)fluoranthene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Benzo(a)pyrene	0.2	mg/kg	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Indeno(1,2,3-c,d)pyrene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Dibenz(a,h)anthracene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Benzo(ghi)perylene	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Carcinogenic PAHs (as BaP TEQ) (LOR) [c]	0.2	mg/kg	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Sum of polycyclic aromatic hydrocarbons	0.1	mg/kg	300	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
OCP																															
Aldrin	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
alpha-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
beta-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
delta-BHC	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Hexachlorobenzene (HCB)	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Heptachlor	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Heptachlor epoxide	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Bifenthin	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Total Chlordane	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Chlorpyrifos	0.02	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	---	---	---	--
alpha-Endosulfan	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
beta-Endosulfan	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Endosulfan sulfate	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Endosulfan (sum)	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
BromophosEthyl	0.05	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	--
Dieldrin	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
4.4`-DDE	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Endrin	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
4.4`-DDD	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
4.4`-DDT	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Sum of DDD + DDE + DDT	0.01	mg/kg	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Lindane	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Methoxychlor	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Sum of Aldrin + Dieldrin	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
Oxychlordnae	0.01	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	---	---	---	--
OPP																															
Diazinon	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Ethion	0.05	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	--
Fenitrothion	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Malathion	0.1	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---	---	--
Trifluralin	0.2	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Polychlorinated Biphenyls (PCB)																															
PCB (Total)	0.2	mg/kg	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---	---	---	--
Phenolic Compounds																															
Phenol	0.05	mg/kg	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	---	---	--

Acronyms:

mbgl = metres below ground level
LOR = Limit of Reporting
mg/kg = milligrams per kilogram
ug/kg = micrograms per kilogram
NA= Samples were not analysed for this specific analyte.
NL = Vapour concentration reach saturation point and cannot increase to a point which would result in an unacceptable health risk.
F1 to F4 = Four carbon chain fractions based on fractions adopted in the Canada-wide standard for petroleum hydrocarbons (PHC) in soil. For comparison to assessment criteria, only F1, F2, F3 and F4 are applied.
'---" = Criteria have not been derived for these chemical constituents/compounds.
[a] In the absence of HIL values, the soil standards for the protection of human health from Canada (Nova Scotia) have been adopted.
[b] In the absence of site specific soil parameters, the most conservative EILs have been adopted.
[c] Carcinogenic PAHs TEQ have been calculated using the 8 carcinogenic PAH TEFs.

Font and Cell :

- Bolded analytical data indicates detection above LOR.
- Coloured cells indicate exceedence of relevant assessment criteria.
- Coloured and underlined cells indicate exceedence of multiple assessment criteria.

Assessment of potential sediment disposal and reuse options
Lower Vasse River, Busselton
City of Busselton

Table D - Waste Classification Results

Analytes	Units	LOR	CT1 Class I	CT3 Class III	CT4 Class IV	CL1 Class I	CL3 Class III	CL4 Class IV	Mean+ 1SD	Units	LOR	ASLP1 Class I	ASLP3 Class III	ASLP4 Class IV	Mean+ 1SD (DI)
			Contaminant Threshold Concentrations			Contaminant Level Concentrations				Leachable Concentrations					
Metals															
Arsenic	mg/kg	5	14	140	1,400	500	5,000	20,000	4.2	mg/L	0.001	0.5	5	50	---
Beryllium	mg/kg	0.1	2	20	200	100	1,000	4,000	0.2	mg/L	0.001	0.1	1	10	---
Cadmium	mg/kg	0.1	0.4	4	40	100	1,000	4,000	0.5	mg/L	0.001	0.1	1	10	---
Total Chromium	mg/kg	1	10	100	1,000	500	5,000	2,000	22	mg/L	0.001	0.5	5	50	---
Copper	mg/kg	1	50,000	100,000	200,000	50,000	100,000	200,000	22	mg/L	0.001	----	----	----	---
Lead	mg/kg	1	2	20	200	1,500	15,000	60,000	62	mg/L	0.001	0.1	1	10	0.008
Mercury	mg/kg	0.02	0.2	2	20	75	750	3,000	0.06	mg/L	0.001	0.01	0.1	1	---
Molybdenum	mg/kg	2	10	100	1,000	1,000	10,000	40,000	1.4	mg/L	0.001	0.5	5	50	---
Nickel	mg/kg	1	4	40	400	3,000	30,000	120,000	2.7	mg/L	0.001	0.2	2	20	---
Silver	mg/kg	1	20	200	2,000	180	1,800	7,200	0.8	mg/L	0.001	1	10	100	---
Zinc	mg/kg	1	50,000	100,000	200,000	50,000	100,000	200,000	167	mg/L	0.001	----	----	----	---
Inorganics															
Fluoride	mg/kg	40	300	3,000	30,000	10,000	100,000	400,000	146	mg/L	0.001	15	150	1500	---
Cyanide - Total	mg/kg	1	16	160	1,600	2,500	25,000	100,000	1	mg/L	0.001	0.8	8	80	---
Cyanide - Free*	mg/kg	1	7	70	700	1,250	12,500	50,000	1	mg/L	0.001	0.35	3.5	35	---
Organics															
Benzene	mg/kg	0.2	0.2	2	20	18	180	720	0.05	mg/L	0.001	0.01	0.1	1	---
Toluene	mg/kg	0.5	160	1,600	16,000	518	5,180	----	0.05	mg/L	0.001	8	80	800	---
Ethylbenzene	mg/kg	0.5	60	600	6,000	1,080	10,800	----	0.05	mg/L	0.001	3	30	300	---
Xylene	mg/kg	0.5	120	1,200	12,000	1,800	18,000	----	0.1	mg/L	0.001	6	60	600	---
TPH C6-C9	mg/kg	0.5	----	----	----	2,800	28,000	112,000	0.1	mg/L	0.001	----	----	----	---
Total Phenol	mg/kg	0.05	28.8	288	2,880	42,500	425,000	---	0.025	mg/L	0.001	1.44	14.4	144	---
PCB	mg/kg	0.2	----	----	----	50	50	50	0.1	mg/L	0.001	----	----	----	---
Styrene	mg/kg	0.1	6	60	600	108	1,080	4,320	0.05	mg/L	0.001	0.3	3	30	---
Total PAH	mg/kg	0.1	----	----	----	100	1,000	4,000	0.1	mg/L	0.001	----	----	----	---

Investigation	SKM (1999) – Vasse River Sediment Remediation Study							
Sample ID	A-Top		A-Botttom		B-Top		B-Bottom	
Sample Date	16/12/1998		16/12/1998		16/12/1998		16/12/1998	
Type Analysis	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI
Metals								
Arsenic	<0.5	<0.01	1.7	<0.01	<0.5	<0.01	0.8	<0.01
Beryllium	---	---	---	---	---	---	---	---
Cadmium	<0.5	<0.005	<0.5	<0.005	0.6	<0.005	<0.5	<0.005
Total Chromium	21	<0.05	10	<0.05	26	<0.05	7	<0.05
Copper	15	<0.05	1	<0.05	9	<0.05	1	<0.05
Lead	30	<0.05	2	<0.05	16	<0.05	1	<0.05
Mercury	<0.05	<0.001	0.12	<0.001	<0.05	<0.001	0.11	<0.001
Molybdenum	---	---	---	---	---	---	---	---
Nickel	5	<0.05	2	<0.05	4	<0.05	<1	<0.05
Silver	---	---	---	---	---	---	---	---
Zinc	220	0.4	5	<0.05	36	**0.05**	3	<0.05
Inorganics								
Fluoride	---		---		---			---
Cyanide - Total	---		---		---			---
Cyanide - Free*	---		---		---			---
Organics								
Benzene	---		---		---			---
Toluene	---		---		---			---
Ethylbenzene	---		---		---			---
Xylene	---		---		---			---
TPH C6-C9	---		---		---			---
Total Phenol	---		---		---			---
PCB	---		---		---			---
Styrene	---		---		---			---
Total PAH	---		---		---			---

Investigation	Strategen (2017) Acid Sulfate Soil Investigation Report				City of Busselton, 2012 Sediment Survey						
Sample ID	CR-S	CR-N	EL-N	EL-S	Section-1	Section-2	Section-3	Section-4	Section-5	Section-6	Section-7
Sample Date	05/07/2017	05/07/2017	05/07/2017	05/07/2017	18/10/2012	18/10/2012	18/10/2012	18/10/2012	18/10/2012	18/10/2012	18/10/2012
Type Analysis	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Metals											
Arsenic	<5	<5	10	<5	4	1.9	2.5	2.5	0.6	0.8	0.4
Beryllium	---	---	---	---	---	---	---	---	---	---	---
Cadmium	0.6	0.8	<0.1	0.4	0.43	<0.05	<0.05	0.31	<0.05	0.14	0.1
Total Chromium	4	5	51	9	25	12	17	17	6.1	9.2	4
Copper	---	---	---	---	---	---	---	---	---	---	---
Lead	5	6	15	3	160	35	32	20	7.9	9	3.4
Mercury	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Molybdenum	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---
Zinc	13	6	140	4	390	83	79	100	29	32	18
Inorganics											
Fluoride	---	---	---	---	---	---	---	---	---	---	---
Cyanide - Total	---	---	---	---	---	---	---	---	---	---	---
Cyanide - Free*	---	---	---	---	---	---	---	---	---	---	---
Organics											
Benzene	---	---	---	---	---	---	---	---	---	---	---
Toluene	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	---	---	---
Xylene	---	---	---	---	---	---	---	---	---	---	---
TPH C6-C9	---	---	---	---	---	---	---	---	---	---	---
Total Phenol	---	---	---	---	---	---	---	---	---	---	---
PCB	---	---	---	---	---	---	---	---	---	---	---
Styrene	---	---	---	---	---	---	---	---	---	---	---
Total PAH	---	---	---	---	---	---	---	---	---	---	---

Investigation	City of Busselton, 2018 Sediment Survey																	
Sample ID	LVRS1P		LVRS2P		LVRS3P		LVRS4P		LVRS5P		LVRS6P		LVRD1P		LVRD2P		LVRD3P	
Sample Date	29/03/2018		29/03/2018		29/03/2018		29/03/2018		29/03/2018		29/03/2018		29/03/2018		29/03/2018		29/03/2018	
Type Analysis	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI	Soil	Leachate-DI
Metals																		
Arsenic	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---
Beryllium	<0.1	---	<0.1	---	0.2	---	0.1	---	0.2	---	0.2	---	<0.1	---	<0.1	---	<0.1	---
Cadmium	0.3	---	0.7	---	0.3	---	0.2	---	0.2	---	0.3	---	0.4	---	0.3	---	0.4	---
Total Chromium	6	---	13	---	7	---	4	---	5	---	5	---	6	---	6	---	7	---
Copper	16	---	33	---	19	---	8	---	7	---	9	---	14	---	10	---	13	---
Lead	37	0.01	94	0.01	31	<0.01	14	<0.01	9	<0.01	12	<0.01	39	<0.01	15	<0.01	61	<0.01
Mercury	0.04	---	0.08	---	0.03	---	0.02	---	<0.02	---	0.02	---	0.04	---	0.03	---	0.05	---
Molybdenum	<2	---	2	---	<2	---	<2	---	<2	---	<2	---	<2	---	<2	---	<2	---
Nickel	2	---	3	---	3	---	2	---	2	---	2	---	2	---	1	---	1	---
Silver	<1	---	1	---	<1	---	<1	---	<1	---	<1	---	<1	---	1	---	<1	---
Zinc	90	---	210	---	62	---	25	---	21	---	28	---	91	---	110	---	110	---
Inorganics																		
Fluoride	140	---	130	---	120	---	120	---	150	---	130	---	150	---	140	---	140	---
Cyanide - Total	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---
Cyanide - Free*	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---	<1	---
Organics																		
Benzene	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---
Toluene	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---
Ethylbenzene	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---
Xylene	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---
TPH C6-C9	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---
Total Phenol	<0.05	---	<0.05	---	<0.05	---	<0.05	---	<0.05	---	<0.05	---	<0.05	---	<0.05	---	<0.05	---
PCB	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---
Styrene	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---	<0.1	---
Total PAH	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---	<0.2	---

Note:

[b] CL values derived as % by weight.

CL1 Class I, CL2 Class II, CL3 Class III and CL4 Class IV are the concentration limits for waste classification. CL values determined as: Class I = HIL Commercial Industrial, Class II = Class I, Class III = 10 x Class I, Class IV = 100 x Class I

ASLP values determined as: Class I = 10 x Australian Drinking Water Health Guideline (ADWG) value, Clas II = Class I, Class III = 10 x Class I, Class IV = 100 x Class I

Acronyms:

CL = Concentration Limit
ASLP = Leachable Concentration
mbgl = meters below ground level
LOR = Limit of Reporting
mg/kg = milligrams per kilograms
mg/L = milligrams per litre
---- = No guideline value has been developed for this analyte.

Font and Cell :

- Coloured cells indicate exceedence of relevant assessment criteria
- Bolded analytical data indicates detection above LOR

Table E - Leachate Results

Investigation							SKM (1999) – Vasse River Sediment Remediation Study				City of Bussleton - 2018 Sediment Investigation									Bio Soil, 2020 - Bioremediation		
Sample ID							A-Top	A-Botttom	B-Top	B-Bottom	LVRS1P	LVRS2P	LVRS3P	LVRS4P	LVRS5P	LVRS6P	LVRD1P	LVRD2P	LVRD3P	Sediment 1	Sediment 2	Sediment 3
Laboratory							Australian Environmental Laboratories				ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL	ARL
Date Sampled							16/12/1998	16/12/1998	16/12/1998	16/12/1998	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	29/03/2018	26/10/2018	26/10/2018	26/10/2018
Analyte	**LOR**	**Units**	**Uncontaminated Fill**	**ANZECC & ARMCANZ Fresh Water**	**ADWG - Drinking Water**	**DoH NPUG**																
Arsenic - Dissolved	0.001	mg/L	0.01	0.013	0.01	0.1	<0.01	<0.01	<0.01	<0.01	---	---	---	---	---	---	---	---	---	<0.001	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	0.0002	0.0002	0.002	0.02	<0.005	<0.005	<0.005	<0.005	---	---	---	---	---	---	---	---	---	<0.002	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	0.003	0.001	0.05	0.5	<0.05	<0.05	<0.05	<0.05	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	0.002	0.0014	2	20	<0.05	<0.05	<0.05	<0.05	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	0.00005	0.00006	0.001	0.01	<0.001	<0.001	<0.001	<0.001	---	---	---	---	---	---	---	---	---	<0.0002	<0.0002	<0.0002
Lead	0.01	mg/L	0.003	0.0034	0.01	300	<0.05	<0.05	<0.05	<0.05	**0.01**	**0.01**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel - Dissolved	0.01	mg/L	0.01	0.011	0.02	0.2	<0.05	<0.05	<0.05	<0.05	---	---	---	---	---	---	---	---	---	<0.01	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	0.01	0.008	3	3	**0.4**	<0.05	**0.05**	<0.05	---	---	---	---	---	---	---	---	---	**0.02**	**0.04**	**0.04**

Acronyms:

LOR = limits of reporting
mg/L = milligrams per liter

Font and Cell :

- Coloured cells indicate exceedence of relevant assessment criteria
- Bolded analytical data indicates detection above LOR

Table F - ASS Results

Sample ID	Laboratory	Date Sampled	Laboratory Results and Calculations													
			Assessment Criteria	pH_F	pH_{FOX}	pH Change	Reaction	pH_{KCl}	Potential Sulfidic Acidity – Chromium Reducible Sulfur (CRS)		Actual Acidity – Titratable Actual Acidity		Acid Neutralising Capacity		Net Acidity	
				0.1	0.1	0.1	-	0.1	0.01	-	-	2	0.05	-	-	-
				pH units	pH units	pH units	-	pH Units	%S	mol H^+/t	%S	mol H^+/t	%CaCO3	mol H^+/t	%S	mol H^+/t
			Assessment Criteria SAND	<5.5	<3.0	>3.0	>2	-	0.03	18	0.03	-	-	-	0.03	18
			Assessment Criteria CLAY	<5.5	<3.0	>3.0	>2		0.03	18	0.03	-	-	-	0.03	18
			Assessment Criteria CLAY/ Silt	<5.5	<3.0	>3.0	>2	-	0.03	18	0.03	-	-	-	0.03	18
Strategen (2017) Acid Sulfate Soil Investigation Report																
CR-S 3-3.5	ARL	05/07/2017		7.9	2.2	5.7	2	9	---	---	<0.005	<2	---	---	0.29	180
CR-S 5.5-5.75	ARL	05/07/2017		8	1.5	6.5	1	7.4	---	---	<0.005	<2	---	---	0.29	180
CR-N 2-2.25	ARL	05/07/2017		7.8	1.6	6.2	4	7.9	---	---	<0.005	<2	---	---	0.61	380
CRN- 2.5-3	ARL	05/07/2017		8.8	1.4	7.4	4	8	0.46	290	<0.005	<2	---	---	0.93	580
CR-N 5.5-5.75	ARL	05/07/2017		8.8	2	6.8	4	7.9	---	---	<0.005	<2	---	---	0.56	350
EL-N 1.5-2	ARL	05/07/2017		8.5	5.4	3.1	2	9.7	---	---	<0.005	<2	---	---	<0.005	<5
EL-N 4-4.45	ARL	05/07/2017		8.2	6	2.2	2	9	0.95	590	<0.005	<2	---	---	0.86	540
EL-S 2-2.5	ARL	05/07/2017		7.9	5.9	2	2	8.8	---	---	<0.005	<2	---	---	0.19	120
EL-S 2.5-3	ARL	05/07/2017		8.2	6.1	2.1	2	8.7	---	---	<0.005	<2	---	---	0.15	94
LVRS1C1T	ARL	29/03/2018		---	---	---	---	---	2	1247.4	---	---	2.5	50.0	2.0	1247.4
LVRS1C2T	ARL	29/03/2018		---	---	---	---	---	2.1	1309.77	---	---	1.4	28.0	2.1	1309.8
LVRS1C3T	ARL	29/03/2018		---	---	---	---	---	2.2	1372.14	---	---	1.9	38.0	2.2	1372.1
LVRS1C1B	ARL	29/03/2018		---	---	---	---	---	1.5	935.55	---	---	0.92	18.4	1.5	935.6
LVRS1C2B	ARL	29/03/2018		---	---	---	---	---	1.3	810.81	---	---	0.55	11.0	1.3	810.8
LVRS1C3B	ARL	29/03/2018		---	---	---	---	---	1.7	1060.29	---	---	0.61	12.2	1.7	1060.3
LVRS2C1T	ARL	29/03/2018		---	---	---	---	---	1.2	748.44	---	---	2	40.0	1.2	748.4
LVRS2C2T	ARL	29/03/2018		---	---	---	---	---	1.6	997.92	---	---	2.6	51.9	1.6	997.9
LVRS2C3T	ARL	29/03/2018		---	---	---	---	---	1.6	997.92	---	---	3.2	63.9	1.6	997.9
LVRS2C1B	ARL	29/03/2018		---	---	---	---	---	1.2	748.44	---	---	0.74	14.8	1.2	748.4
LVRS2C2B	ARL	29/03/2018		---	---	---	---	---	1.2	748.44	---	---	5.2	103.9	1.2	748.4
LVRS2C3B	ARL	29/03/2018		---	---	---	---	---	1.9	1185.03	---	---	2.4	48.0	1.9	1185.0
LVRS3C1T	ARL	29/03/2018		---	---	---	---	---	2.2	1372.14	---	---	1.4	28.0	2.2	1372.1
LVRS3C2T	ARL	29/03/2018		---	---	---	---	---	1.8	1122.66	---	---	2	40.0	1.8	1122.7
LVRS3C3T	ARL	29/03/2018		---	---	---	---	---	2	1247.4	---	---	2.1	42.0	2.0	1247.4
LVRS3C1B	ARL	29/03/2018		---	---	---	---	---	0.85	530.145	---	---	0.61	12.2	0.9	530.1
LVRS3C2B	ARL	29/03/2018		---	---	---	---	---	1.2	748.44	---	---	0.61	12.2	1.2	748.4
LVRS3C3B	ARL	29/03/2018		---	---	---	---	---	1.5	935.55	---	---	1.5	30.0	1.5	935.6
LVRS4C1T	ARL	29/03/2018		---	---	---	---	---	2.5	1559.25	---	---	1.8	36.0	2.5	1559.3
LVRS4C2T	ARL	29/03/2018		---	---	---	---	---	2	1247.4	---	---	1.8	36.0	2.0	1247.4
LVRS4C3T	ARL	29/03/2018		---	---	---	---	---	2.7	1683.99	---	---	2	40.0	2.7	1684.0
LVRS4C1B	ARL	29/03/2018		---	---	---	---	---	1.3	810.81	---	---	1.2	24.0	1.3	810.8
LVRS4C2B	ARL	29/03/2018		---	---	---	---	---	2.7	1683.99	---	---	1.9	38.0	2.7	1684.0
LVRS4C3B	ARL	29/03/2018		---	---	---	---	---	2.2	1372.14	---	---	0.24	4.8	2.2	1372.1
LVRS5C1T	ARL	29/03/2018		---	---	---	---	---	2.2	1372.14	---	---	1.9	38.0	2.2	1372.1
LVRS5C2T	ARL	29/03/2018		---	---	---	---	---	2.2	1372.14	---	---	1.7	34.0	2.2	1372.1
LVRS5C3T	ARL	29/03/2018		---	---	---	---	---	2.7	1683.99	---	---	2.1	42.0	2.7	1684.0
LVRS5C1B	ARL	29/03/2018		---	---	---	---	---	1.9	1185.03	---	---	2.1	42.0	1.9	1185.0
LVRS5C2B	ARL	29/03/2018		---	---	---	---	---	1.6	997.92	---	---	1.6	32.0	1.6	997.9
LVRS5C3B	ARL	29/03/2018		---	---	---	---	---	4.4	2744.28	---	---	12	239.8	4.4	2744.3
LVRS6C1T	ARL	29/03/2018		---	---	---	---	---	2.1	1309.77	---	---	3	59.9	2.1	1309.8
LVRS6C2T	ARL	29/03/2018		---	---	---	---	---	2.6	1621.62	---	---	2.6	51.9	2.6	1621.6
LVRS6C3T	ARL	29/03/2018		---	---	---	---	---	2.4	1496.88	---	---	2.1	42.0	2.4	1496.9
LVRS6C1B	ARL	29/03/2018		---	---	---	---	---	2.7	1683.99	---	---	1.3	26.0	2.7	1684.0
LVRS6C2B	ARL	29/03/2018		---	---	---	---	---	0.31	193.347	---	---	0.33	6.6	0.3	193.3
LVRS6C3B	ARL	29/03/2018		---	---	---	---	---	1.4	873.18	---	---	6.1	121.9	1.4	873.2
Bio Soil Solutions, 2020 – Soil Bioremediation																
Sample 1	ARL	26/10/2018		3.7	2.6	1.1	---	3.7	0.01	6.237	0.30	190	---	---	0.3	200.0
Sample 2	ARL	26/10/2018		3.7	2.5	1.2	---	3.8	<0.01	0	0.27	170	---	---	0.3	170.0
Sample 3	ARL	26/10/2018		3.7	2.7	1	---	3.7	0.01	6.237	0.30	190	---	---	0.3	200.0

Acronyms:

1.915555556

mbgl indicates metres below ground level

%S = percentage sulfur

"---" = criteria have not been derived for these chemical constituents/compounds.

PASS = Potential Acid Sulfate Soil

NASS = Non Acid Sulfate Soil

AASS = Actual Acid Sulfate Soil

ANC = Acid Neutralising Capacity

Font and Cell :

- Coloured cells indicate exceedence of relevant assessment criteria
- Bolded analytical data indicates detection above LOR

**Department of Water and Environmental Regulation (formerly Department of Environment Regulation), 2015. Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes. Western Australia.*

Appendices

Appendix A
Factsheet -
Assessing whether material is waste

Factsheet - Assessing whether material is waste

Purpose

The purpose of this Fact Sheet is to:

(a) set out the matters relevant to determining whether material is "waste" within the meaning of the *Environmental Protection Act 1986* (EP Act) and the *Waste Avoidance Resource Recovery Act 2007* (WARR Act) and their associated regulations; and

(b) thereby provide information to industry on how the Department proposes to assess whether material is waste when exercising its powers and performing its functions under this legislation.

DWER considers that it is the responsibility of the person in possession of material to determine whether it is waste or not.

If you are unsure of whether the material you hold is waste or whether certain provisions in the legislation apply to you, DWER recommends that you seek your own legal advice.

Background

DWER administers Part V Division 3 of the EP Act, including the licensing of prescribed premises. A number of prescribed premises categories in the *Environmental Protection Regulations 1987* (EP Regulations) are defined by reference to activities involving waste occurring on the premises. There are also a number of offence provisions in the EP Act which make it an offence to do certain things with waste.

DWER also administers the WARR Act and the *Waste Avoidance and Resource Recovery Levy Regulations 2008* (WARR Levy Regulations). These regulations provide for a levy to be payable in respect of "waste disposed of to landfill" at certain categories of prescribed premises as defined in the EP Regulations (categories 63, 64 and 65).

The assessment of whether certain material is waste is therefore important to the application of these Acts and regulations.

The decisions of Justice Beech and the Court of Appeal in *Eclipse Resources Pty Ltd v the State of Western Australia* [No. 4] [2016] WASC 62 and *Eclipse Resources Pty Ltd v The Minister for Environment [No 2]* [2017] WASCA 90; (Eclipse case) provide guidance on the matters relevant to determining whether material is waste.

Ultimately, whether or not material is waste in a particular case will depend on all the facts and circumstances of that case.

Definition of waste

Waste is defined section 3(1) of the EP Act and section 3(1) of the WARR Act to include matter:

(a) whether liquid, solid, gaseous or radioactive and whether useful or useless, which is discharged to the environment; or

(b) prescribed to be waste.

This inclusive definition is not exhaustive, meaning that the term ‘waste’ in the EP Act and WARR Act also has its ordinary dictionary meaning.

In the Eclipse case, the Courts confirmed that, "waste", at least, includes:

(a) “anything left over or superfluous, as excess material, by-products etc., not of use for work in hand” (i.e. unwanted or excess material, viewed from the perspective of its source); and/or

(b) any matter whether useful or useless which is gotten rid of into the environment.

Relevant factors in assessing whether material is waste

There are a number of relevant factors that should be considered in an assessment of whether material is waste, as set out below.

Whether certain material is waste must be assessed at a particular point in time. Material may cease to be waste, because, for example, it has been reprocessed into a new product or recycled. However, the new product or recycled material may become waste again if it becomes excess to the requirements of its owner.

Point of view of the source/producer

For the purposes of the licensing and waste levy regimes, whether material that is received at premises is waste or not must be assessed from the perspective of the person who is the source/producer of the material and not the receiver of the material.

Accordingly, the fact that the receiver of the material considers it useful (e.g. to fill their land) and economically valuable (e.g. as a substitute for purchased fill material) does not mean that the material is not waste.

If material is unwanted or excess to requirements, viewed from the perspective of its source/producer, the material is waste.

The source/producer of material that is excavated at one site and taken to another will be the owner of the material at its source. This will often be (but will not necessarily always be) the owner of the land from which the material is excavated.

Nature of the material

There is no requirement that material must be environmentally harmful in order to be waste. The nature/composition of material is not *determinative* of whether it is waste. However, the nature of material may be relevant in the broad sense that it may explain why the material is not wanted by its source/producer.

If material is contaminated with a substance that would prevent it (practically or legally) from being used for its ordinary purpose, this may be relevant to the assessment of whether or not it is wanted by its source/producer.

Concept of being 'unwanted'

Even if material is left over from, or a by-product of, a particular project and not wanted by its source/producer for that project, it may still be wanted by them for use for some other project (on the same site or a different site) or for sale to a third party.

Material wanted by its producer/source for use in some other project or for sale to another person is not considered to be waste.

For example, if the owner of a building demolished the building and did not want the bricks resulting from the demolition, the bricks would be considered waste. However, if the owner wanted the bricks to build a wall on another site that he/she owned or wanted them to sell to a third party for use by the third party, the bricks would not be considered waste.

Payments relating to the materials

Whether or not a third party pays for material or is paid to receive material from its producer/source, is a relevant consideration in assessing whether the material is waste.

If the producer of material pays a third party to receive it and dispose of it for them, this indicates that the producer does not want the material and it is waste. However, if material is sold by a producer to a third party, this will generally indicate that the material is a valuable commodity wanted by the producer for sale.

Substantially transformed

Material that is waste at a certain point in time may stop being waste if it is re-used in certain ways, sufficiently processed or is recycled.

It is recognised in categories 13, 39, 44, 61, 61A, 62 and 67A in Schedule 1 of the EP Regulations, in section 5(1) of the WARR Act and in regulation 5(1)(b) of the WARR Levy Regulations that waste may be transformed into something else through re-use, processing (including treatment), recycling or use in energy recovery.

However, the decisions of the courts in the Eclipse case confirmed that the use of waste *as fill* to be buried does not qualify as the "re-use" of waste within the meaning of the WARR Levy Regulations or WARR Act. Waste that is buried and used as fill is considered "waste disposed of to landfill" within the meaning of the Levy Regulations.

When assessing whether material is waste, or still waste, at any particular point in time it may be relevant to consider whether and how it has been transformed into a product or good and the extent of the transformation or conversion. A mere intent to convert waste into a product or good is not sufficient.

The fact that material has been subject to some degree of processing does not necessarily mean that it has become a product or ceased to be waste. For example, the courts have found that merely sorting waste to exclude some contaminants does not mean that the material is no longer waste.

Consideration of whether material that is waste at a particular point in time has been substantially or materially transformed and converted into a product or good so that it is no longer waste at a different point in time will depend on a number of factors, such as:

- the type of processes the waste has been subjected to;

- the degree or extent of the transformation of the material; whether the essential nature, form and/or utility of the material has been substantially or materially changed;
- whether any relevant specifications or standards (including environmental specifications and standards) have been met; and
- whether there is an economic demand for the material in its altered state.

Examples

Two examples are provided below to illustrate how these factors are used by DWER to assess whether material is waste.

Scenario 1

At Premises A mixed construction and demolition materials are accepted onto the premises from third parties and directed to a sorting area. The third parties bringing the materials to Premises A do not want them and either pay the owner/occupier of Premises A to take them or give them to the owner/occupier for free.

Large pieces of plastic, timber, metal and plant material are removed from the materials by an excavator. The residual 'sorted' materials are buried on Premises A to raise the level of the land and fill a void.

In this scenario, the incoming materials are unwanted by their sources. They are not processed to substantially or materially transform them into something new. Essentially the same materials that were accepted at the premises are deposited and buried to level the land. The materials buried are considered to be waste by DWER.

Scenario 2

At Premises B, mixed construction and demolition materials are accepted from third parties onto the premises. The third parties bringing the materials to Premises B do not want them and either pay the owner/occupier of Premises B to take them or give them to the owner/occupier for free.

- The materials are processed in a number of different ways including (but not necessarily limited to) the following:
- An excavator breaks up large materials and removes reinforced steel. The materials are also passed through a jaw crusher;
- The materials then pass through vibratory screens, air blowers and under belt magnets that remove plastics, metals and other undesirable materials;
- After initial screening the materials pass through a hand picking station where any residual contaminants are removed;
- Finally, the materials are passed through an impact crusher and two screens which separate the materials into different size fractions;
- The processed materials are tested for asbestos content and against relevant Main Roads material specifications;

- Subject to meeting asbestos and Main Roads specifications, the materials are sold as recycled fill sand, road base and drainage aggregate to third parties.

In this scenario, the incoming materials are regarded as waste by DWER at the time of their receipt at Premises B. However, the materials are substantially and materially transformed through processing into new products that are different to the materials accepted at the gate. There is also a market for these products. When purchased and used by consumers these products would not be classified as waste by DWER.

Any contaminant materials screened out during the processing of the construction and demolition materials received at Premises B that are not wanted by the owner/occupier of Premises B to make recycled fill sand, road base and drainage aggregate would remain waste in DWER's view.

Feedback and More Information

The Department is keen to receive feedback on this factsheet to ensure the content is clear and helpful.

If you wish to provide feedback or for further information, please email DWER at info@dwer.wa.gov.au or phone 6364 7000.

Legislation

This document is provided for information only. It should not be relied upon to address every aspect of the relevant legislation. Please refer to the State Law Publisher (SLP) for copies of the relevant legislation, available electronically from the SLP website at www.slp.wa.gov.au.

Appendix B
Cost Estimate Derivation

Sediment Disposal and Reuse Options
Lower Vasse River, Busselton
City of Busselton
Appendix B - Cost Analysis

Options	Item	Units	Rate	Aglime/ Lime (Tonnes)	Volume of sediments (m3)	Sediment tonnes (density 1.8 T/m3)	Weight of Sediment after lime dosing (T)	Distance to be travelled	Loading/unloading (hours)	Number of trips (truck)	Estimated Total cost	Cost +30%
Option 1: Landfill Disposal												
1. Transport of untreated ASS	Transport (18 m3 truck)	per hour	$ 180	---	7,065	---	---	60km to Vidler Rd Landfill and return (1 hour)	1	150	$ 27,000	$ 35,100
2. ASS treatment at Landfill	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	$25/tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,854	$ 18,010
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 35,325	$ 45,920
3. Disposal of treated ASS	Landfill Fees	per tonne	$ 60	---	7,065	12,720	13,495	---	---	---	$ 809,700	$ 1,052,610
									TOTAL		**$ 911,629**	**$ 1,185,120**
Option 2: Onsite reuse for Wetland Rehabilitation												
1. ASS Treatment onsite	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	$25/tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,965	$ 18,150
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 63,600	$ 82,680
	Validation Sampling	per 500 m3	$ 75		7,065	12,720	13,495	---	---	26	$ 1,950	$ 2,540
2. Transport of treated ASS	Transport (18 m3 truck)	per hour	$ 180	---	7,065	12,720	13,495	1.5km to Wetland and return (10 min)	1	290	$ 78,300	$ 101,790
3. Wetland Rehab		Once-off	$ 100,000	---	---	---	---	---	---	---	$ 100,000	$ 130,000
4. Monitoring and reporting		Per year	$ 70,000	---	---	---	---	---	---	---	$ 70,000	$ 91,000
									TOTAL		**$ 353,565**	**$ 459,640**
Option 3: Reuse as infill by the City												
1. ASS Treatment onsite	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	$25/tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,965	$ 18,150
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 63,600	$ 82,680
	Validation Sampling	per 500 m3	$ 75	---	7,065	12,720	13,495	---	---	26	$ 1,950	$ 2,540
2. Transport of treated ASS	Transport (18 m3 truck)	18m3 truck	$ 180	---	7,065	12,720	13,495	20km from site to Rendez-vous Rd return (0.75 hour)	1	290	$ 91,350	$ 118,760
3. Pond infill	Earthworks	Covered by the city	---	---	---	---	---	---	---	---	$ -	$ -
4. Monitoring and Reporting	GW wells	Initial Set up	$ 20,000	---	---	---	---	---	---	---	$ 20,000	$ 26,000
		Per year	$ 70,000	---	---	---	---	---	---	---	$ 70,000	$ 91,000
									Onsite Treatment TOTAL		**$ 286,615**	**$ 372,610**

Sediment Disposal and Reuse Options
Lower Vasse River, Busselton
City of Busselton

Option 4: Reuse as daily landfill cover												
1. Transport of untreated ASS	Transport (18 m3 truck)	per hour	$ 180	---	7,065	---	---	60km to Vidler Rd Landfill and return (1 hour)	1	150	$ 54,000	$ 70,200
2. ASS treatment at Landfill	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	$25/tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,965	$ 18,150
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 35,325	$ 45,920
	Validation Sampling	per 500 m3	$ 75		7,065	12,720	13,495	---	---	26	$ 1,950	$ 2,540
3. Earthwork	Covered by the City	no additional fee	$ -	---	---	---	---	---	---	---	$ -	$ -
									TOTAL		**$ 130,990**	**$ 170,290**
Option 5: Reuse as growing Media												
1. ASS Treatment onsite	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	per tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,965	$ 18,150
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 63,600	$ 82,680
	Validation Sampling	per 500 m3	$ 75	---	7,065	12,720	13,495	---	---	26	$ 1,950	$ 2,540
2. Transport of treated ASS	Transport (18 m3 truck)	per hour	$ 127.5	---	7,065	12,720	13,495	30km from site to Pigot Road Gravel Pit (1.25 hour)	1	75	$ 21,520	$ 27,980
3. Bioremediation	Growing media (1:1 mulch/treated sed)	per tonne	$ 70	---	7,065	12,720	13,495	---	---	---	$ 944,650	$ 1,228,050
	Transport (18 m3 truck)	per hour	127.5	---	---	---	13,495	Source Unknown (allow 2 hours)	1	75	$ 28,688	$ 37,290
4 Monitoring (1st year)	Soil testing	Quarterly	$5,000	---	---	---	---	---	---	---	$ 20,000	$ 26,000
									TOTAL		**$ 1,120,123**	**$ 1,456,170**
Option 6: Reuse by a 3rd Party												
1. ASS Treatment onsite	Aglime	per tonne	$ 30	775	---	---	---	---	---	---	$ 23,250	$ 30,230
	Crushed Limestone for treatment pad	per tonne	$ 25	100	---	---	---	---	---	---	$ 2,500	$ 3,250
	Lime/Aglime Delivery	per hour	$ 95	875	---	---	---	Redgate Lime, Witchcliff (2 hrs return)	1	49	$ 13,965	$ 18,150
	Mixing	per m3	$ 5	---	7,065	12,720	13,495	---	---	---	$ 63,600	$ 82,680
	Validation Sampling	per 500 m3	$ 75	---	7,065	12,720	13,495	---	---	26	$ 1,950	$ 2,540
2. Transport of treated ASS	Transport (18 m3 truck) - cost covered by third party	per hour	$ 95	---	7,065	12,720	13,495	Site to be defined (allow 1 hour)	1	706	$ 134,140	$ 174,380
3 Sale of Treated Material to 3rd Party	Estimated rate (to be negotiated)	per tonne	-$ 15	---	7,065	12,720	13,495	---	---	---	-$ 202,425	-$ 263,150
4. Monitoring and reporting	Responsibility of 3rd Party	per year	$ -	---	---	---	---	---	---	---	$ -	$ -
									TOTAL		**$ 36,980**	**$ 48,080**