Lower Vasse River, Busselton

Acid Sulfate Soil and Dewatering Management Plan

Prepared for

City of Busselton

February 2023

● people ● planet ● professional

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Disclaimer

Executive Summary

360 Environmental Pty Ltd (360 Environmental), part of SLR Consulting (SLR), was commissioned by the City of Busselton (the City) to conduct an acid sulfate soil (ASS) investigation and prepare and Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) for planned dredging activities along the Lower Vasse River (LVR), located in Busselton, WA (herein referred to as 'the site') (**Figure 1**). This reported is to be submitted to DWER for approval prior to the commencement of the dredging works. The City manages the LVR and due to high nutrient concentrations and subsequent extensive algal blooms, which are adversely impacting biodiversity and public amenity. The City intends to dredge a section of the LVR to remove nutrient-rich sediment. The aim is to improve water quality in the system and the wider receiving sites, including the internationally listed Ramsar wetland, Vasse Wonnerup (City of Busselton, 2019).

The site is located within an area as having a 'high to moderate risk of Actual Acid Sulfate Soil (AASS) and Potential Acid Sulfate Soil (PASS) occurring within 3 m from the native soil surface'.

Through the investigation, it was determined that potential acid sulfate soil (PASS) is present in the sediments encountered within the dredging area. Surface water results however suggest no current impacts from the oxidation of ASS. The surface water quality results also indicated elevated nutrient concentrations in the LVR with nutrients also found to desorb from sediments during elutriate testing, which is to be expected and is the primary reason for the sediment removal program to remove the nutrient-rich sediment.

The ASSDMP provides a framework for the management of return water and dewatered sediments during the proposed dredging works. Issues addressed in the ASSMP include the following:

- Timeframe of works (Section 4.2)
- Roles and responsibilities and training of contractors (Section 4.3 and 4.4)
- Water (return water and surface water) management including monitoring program (Section 5.1.2)
- Sediment (dredge spoil) management including:
  - Management of sediments and treatment (Section 5.2.1 and 5.2.2)
  - Monitoring and validation program (Section 5.2.3).
- Contingency measures
- Ongoing reporting and closure requirements (Section 7).

The management and monitoring commitments in this ASSDMP are summarised below.

Summary of ASSDMP Requirements

Component	Environmental Risks	Contractor Management Requirements	Monitoring Requirements	
			Contractor	Environmental Consultant
Return Water and Surface Water				
Return Water	Nutrient and heavy metal enriched, and acidic return water may adversely impact the water quality of the Lower Vasse River Localised increased turbidity at the return water entry point	• Set up of the mini-dredge, Geotubes laydown areas and return water channel • Selection of the polymer and dosing based on the type of sediment encountered at the site • Sediments contained within the Geo-Tubes must not be exposed to the atmosphere for the duration of dewatering to avoid oxidation of the sediments, acidification of the water and mobilisation of metals • Set-up a long enough return water channel to facilitate denitrification prior to re-entry to the LVR • Ongoing monitoring of the return-water quality to facilitate timely implementation of contingency measures, if required • At the end of the proposed activities, Geo-tube bund and return water channel should be appropriately decommissioned.	• Field monitoring of return water in accordance with **Table 7** (Section 5.1.2).	• Field monitoring and laboratory analysis of return water in accordance with **Table 7** (Section 5.1.2).
Surface Water	Dewatering may affect ASS, resulting in acidification of return water and surface water. Baseline surface water results indicate the surface water has not been impacted by the oxidation of sulfides.	• Surface water should be monitored for the duration of dredging activities.	• Field monitoring of surface water undertaken in accordance with **Table 7** (Section 5.1.2).	• Field monitoring and laboratory analysis of surface water undertaken in accordance with **Table 7** (Section 5.1.2).

Component	Environmental Risks	Contractor Management Requirements	Monitoring Requirements	
			Contractor	Environmental Consultant
Sediments				
Dredged Sediments	Oxidation of PASS through the Geo-tube dewatering process	• Active ASS management will be required once the Geotubes are dewatered and opened • Sediments will be treated in-situ within the Geo-tube lined basin, or taken offsite for treatment at a licensed facility • Treatment of sediments with Aglime (minimum 60% ENV) within 70 hours of excavation at a rate of 130 kg Aglime/m^3 • Offsite disposal at a licenced facility or reuse, assuming treatment at the above rates and waste characterisation.	• Tracking of lime volume, ASS volume, liming rates, reuse location and disposal docket to be obtained by the Earthworks Contractor and provided to the Environmental Consultant.	• Field pH testing and CRS analysis to be undertaken on treated stockpile samples and to comply with validation criteria as per **Table 8** (Section 5.2.3) • Possible waste classification prior to reuse/disposal.

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Acronym List

AHD	Australian Height Datum
AASS	Actual Acid Sulfate Soil
ASS	Acid Sulfate Soil
ASSDMP	Acid Sulfate Soil Management Plan
CRS	Chromium Reducible Sulfur
DER	Department Environment Regulation
DBCA	Department of Biodiversity, Conservation and Attractions
DWER	Department of Water and Environment Regulations
GDA	Geographic Datum Australia
LOR	Limit of Reporting
mAHD	meters Australian Height Datum
mbgl	Meters Below Ground Level
NATA	National Association of Testing Authorities
PASS	Potential Acid Sulfate Soil
WA	Western Australia
WAPC	Western Australian Planning Commission

Analytes List

As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
EC	Electrical conductivity
FRP	Filterable Reactive Phosphorus
Ni	Nickel
NH_3	Ammonia
Pb	Lead
pH_F	Field pH
pH_{FOX}	Field Peroxide pH
TKN	Total Kjeldahl Nitrogen
TN	Total nitrogen
TP	Total phosphorous
Zn	Zinc

1 Introduction

360 Environmental Pty Ltd (360 Environmental), part of SLR Consulting (SLR), was commissioned by the City of Busselton (the City) to conduct an acid sulfate soil (ASS) investigation and prepare and Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) for planned dredging activities along the Lower Vasse River (LVR), located in Busselton, WA (herein referred to as 'the site') (**Figure 1**). The City manages the LVR and due to high nutrient concentrations and subsequent extensive algal blooms, which are adversely impacting biodiversity and public amenity, the City intends to dredge a section of the LVR to remove nutrient-rich sediment. The aim is to improve water quality in the system and the wider receiving sites, including the internationally listed Ramsar wetland, Vasse Wonnerup (City of Busselton, 2019).

The site is located within an area classified by the Acid Sulfate Soil Risk Map as having a 'high to moderate risk of Actual Acid Sulfate Soils (AASS) and Potential Acid Sulfate Soil (PASS) occurring within 3 m from the ground surface' (**Figure 2**). An ASS investigation was undertaken in 2017 (Strategen, 2017) 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 field results indicated the potential presence of sulfides within the sediments with a third of the pH_{FOX} testing indicating a pH less than 3. Subsequent sampling and analysis however indicated absence of mono-sulfidic black ooze (MBO) in the Vasse River. The City of Busselton is therefore required to prepare an ASSDMP as the proposed works will involve disturbance/removal of more than 100 m^3 of sediment at the site.

To protect the ecological value of the Vasse-Wonnerup Wetlands and appropriately manage the potential acidification of sediments onsite and the potential associated impacts to the environment, ASS investigations have been undertaken within the specific project area and this ASSDMP to support the proposed dredging activities has been prepared for approval by DAWE prior to the commencement of sediment removal and associated dewatering activities.

1.1 Objectives

The objectives of the baseline investigation and ASSDMP are as follows:

- Determine the presence and nature of contaminants and ASS in the sediments within the first stage of the project area
- Describe potential risks that may occur as a result of ASS disturbance during the project dredging works
- Recommend appropriate strategies for the management of ASS and dewatering effluent during the proposed works to minimise potential environmental impacts to identified receptors
- Prepare documentation required to manage any issues associated with ASS dewatering at the site.

1.2 Scope of Work

To determine the nature and extent of ASS material and define any necessary ASS management strategies during the dredging program, 360 Environmental undertook the following scope of work:

- Advancement of sediment cores at the following locations (refer **Figure 3**):
    - four (4) sampling locations (LVR-S1, LVR-S2, LVR-S3 and LVR-S4) with two (2) samples collected downstream of Cammilleri Street, and two (2) samples between Cammilleri Street and Bussell Hwy as part of the Stage 1 investigation
    - two (2) additional sampling locations (LVR-S5 and LVR-S6) to supplement the data available for the Stage 2 dredge area.
- Collection of three (3) samples per core across different depth intervals (0-0.25, 0.25-0.5, 0.5-0.75 cm) and submission of 30 ASS samples for laboratory analysis of pH_F and pH_{FOX} as part of Stage 1 and a further ten (10) ASS samples as part of Stage 2
- Submission of ten (10) ASS samples for the Chromium Reducible Sulfur (CRS) suite as part of Stage 1 and a further three (3) as part of Stage 2
- Collection of four (4) sediment elutriate samples part of Stage 1 and a further two (2) as part of Stage 2
- Collection of six (6) surface water samples (LVR-S1 to LVR-S6) adjacent to the sediment cores to better understand the existing site conditions and for comparison against sediment elutriate data (refer **Figure 3**)
- Measurement of in situ field water quality parameters, including temperature, dissolved oxygen (DO), specific conductivity (SPC), pH and oxidation-reduction potential (ORP)
- Submission of surface water, elutriate samples for laboratory analysis of a surface water suite including:
    - Dissolved and total metals (As, Cr, Cd, Cu, Pb, Hg, Ni, and Zn)
    - Nutrients [total nitrogen (TN), total Kjeldahl nitrogen (TKN), ammonia (NH3), total phosphorus (TP), filtrable reactive phosphorus (FRP), nitrate and nitrite (NOx as N)].
- Tabulation and interpretation of the results of the baseline investigation
- Preparation of an ASSDMP including:
    - Detailed description of the current site conditions and surrounding environment
    - Summary of the nature and extent of ASS material at the site
    - Outline of the proposed dredging program
    - Evaluation of ASS and dewatering management options
    - Details of requirements and work instructions for the treatment and management of water from the sediment dewatering process
    - Details of surface water monitoring requirements

- Schedule for the validation of treated soils
- Review of risks and any requirements for on-going monitoring/treatment and close out reporting.

1.3 Regulatory Guidelines

The investigation was undertaken in accordance with the following documents:

- Department of Water and Environmental Regulation (DWER) [formerly known as Department of Environment Regulation (DER)], 2015a. *Acid Sulfate Soils Guideline Series – Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes*, Perth
- DWER (formerly known as DER), 2015b. *Acid Sulfate Soils Guideline Series – Treatment and Management of Soil and Water in Acid Sulfate Soil Landscapes*, Perth
- Commonwealth of Australia 2009, National Assessment Guidelines for Dredging.

2 Site Description and Proposed Works

2.1 Site Identification

The site comprises a portion of the LVR in Busselton, located approximately 240 km southwest of Perth, Western Australia. Most of the proposed action area (Lower Vasse River) is on Unallocated Crown Land. Adjacent areas are located on Crown Reserves and Road Reserves vested by the City of Busselton and freehold owned by the City of Busselton and the Anglican Diocese of Bunbury. The site is currently zoned as Recreation under the City of Busselton Local Planning Scheme No. 21.

2.2 Environmental Setting

Based on previous investigations undertaken at the site, the site environmental setting has been summarised in **Table 1**.

Table 1: Environmental Settings

Environmental Setting/ Aspect	Description
Topography	The site is relatively flat and very low-lying with elevation across the site at approximately 2 m Australian Height Datum (mAHD).
Surface Water	The site is dissected by the Vasse River which flows from west to east. The Vasse River discharges into the Ramsar Listed conservation category Vasse-Wonnerup Wetland System. Water levels in the Vasse River are controlled by a surge barrier downstream of the site and consequently the river is not tidal.
Geology	The ground in the area is composed of calcareous sand, pale and olive-yellow with the formation of sub-angular quartz. There is also silt and calcareous silt, both brownish grey and calcareous with some fine sand and shell debris with minor clay.
Acid Sulfate Soil	The project area is classified entirely as moderate to high ASS risk occurring within 3 m of natural soil surface.
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.
Heritage and Land Use	The site is on the entrance to the town centre of Busselton which is zoned as urban/residential. There is an historic church (St Mary's) and Busselton Museum which are listed in the State Heritage Register. The land use west and south of Peel Terrace is residential. The land use north and east is primarily the greater estuarine system/reserves for recreation and conservation purposes. The Vasse River itself feeds into the greater (Nationally significant) Vasse-Wonnerup Wetlands system.
Environmental Sensitive Areas	The LVR 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.

2.3 Dredging Program

As part of the implementation of the Lower Vasse River Waterway Management Plan, the City of Busselton proposes to remove sediment in stages along a 2.5 km stretch of the river channel from the Butter Factory Museum to the Busselton Bypass. The first stage consisted of targeted dredging of 4,240 m^3 of sediment (in-situ volume) along a 200 m stretch of river between the pedestrian bridge adjacent Rotary Park and the Causeway Bridge (refer **Figure 3**) over a 5-week period from 28 April to 8 June 2022. The second stage will consist of targeted dredging of approximately 7,000 m^3 of sediment along a 300 m stretch of river upstream of the Causeway Bridge and is expected to take approximately eight (8) weeks.

A dredging contractor will remove the accumulated sediment from the LVR using a GeoProTM Microdredge with a horizontal auger. The dredged sediments will be pumped into GeoProTM desludging tubes (**Image 1**), located within an onshore lined and bunded laydown area. The sediments will be retained within the tubes while the dewatering effluent (return water) will be directed back to the river via a gravity fed channel (Image 2) or contained within a sump and pumped back to the river. The sediment tubes will continue to dewater for a further few weeks upon completion of dredging. Disposal of the dewatered dredged material will occur post analysis for contamination potential, with the preferred option being to treat the sediment and use as soil nourishment for public open space, or secondarily for use as day cover at the City of Busselton Waste Facility.

A separate *Dredging Environmental Management Plan (DEMP)* (360 Environmental, 2021) has been prepared which details specific management for dredging activities.

Image 1: Stage 1 GeoProTM laydown area

Image 2: Stage 1 return water channel

2.4 Potential Receptors from ASS Dredging and Dewatering Activities

The exposure of subsurface ASS to atmospheric oxygen can cause oxidation of sulfidic materials to produce sulfuric acid, subsequently decreasing the soil pH. The leaching of oxidised ASS may result in impacts to the superficial aquifer, including acidification and the release of heavy metals and other contaminants. The geo-tubes which will contain the sediment will allow water to flow back through a designated/formed channel to the LVR. There is potential for the return water to contain elevated levels of nutrients and dissolved metals.

Due to the anoxic environment created by the geo-tubes, there will be limited oxidation of sediments therefore reducing the risks of water acidification.

Based on the environmental setting of the site, several human health and ecological receptors were identified as being sensitive to the oxidation of ASS and surface water acidification, and/or contamination from the return water:

- Lower Vasse River onsite and the wetland around the site. The Lower Vasse River is upstream from an internationally significant wetland (Vasse Wonnerup Wetland System), which is afforded its high conservation status due to the presence of conservation significant migratory birds.
- Aquatic flora and fauna inhabiting surface water bodies. Of most conservation significance is the Carter's Freshwater Mussel (CFM), which is known to inhabit the waterway within the proposed dredging area, and numerous internationally significant species of migratory birds, which are prolific in the downstream Vasse Wonnerup Wetland System.
- Local native vegetation around the site and reserves however due to the disturbed nature of the foreshore area with human presence and recreational use there is limited terrestrial fauna and flora.

3 Baseline Investigations

3.1 Methodology

Two baseline investigations have been undertaken at the site by competent field scientists to determine the presence, nature and extent of ASS and other contaminants across the LVR; Stage 1 in December 2021 and Stage 2 in December 2022.

The Stage 1 investigation included advancement of three (3) cores at four (4) sediment sampling locations (LVR-CS1/CS3-S1 to LVR-CS1/CS3-S4) (**Figure 3**) with a total of 29 ASS samples submitted for laboratory analysis of pH_F and pH_{FOX}. It is noted here that only the 0-0.25 and 0.25 to 0.5m core intervals were collected at sampling location LVR-S1 and only two (2) cores were advanced at sampling location LVR-S4. Ten (10) samples were also submitted for the CRS suite based on the pH_F and pH_{FOX} results.

The Stage 2 ASS investigation involved core samples from a wider spatial variety of sites (ASS_100 to ASS_107; **Figure 3**) to ascertain any variance within the Stage 2 dredge area. Samples were analysed from the full depth of the core due to limited variability across depth in the Stage 1 results and the dredge method resulting in a mixed material. All nine (9) samples were scheduled for pH_F and pH_{FOX} with a select three (3) also submitted for the CRS suite based on the pH_F and pH_{FOX} results.

Sediment samples (LVR-S1 to LVR-S6) were collected from the cores directly into laboratory supplied glass jars for laboratory analysis.

Surface water samples (LVR-S1 to LVR-S6) were collected directly into laboratory supplied bottles via a high flow pump from the lower half of the water column and purged for approximately five minutes before sampling was undertaken.

The six (6) elutriate samples and elutriate blank samples were also collected using a submersible pump within the LVR adjacent to the sediment sampling locations and sampled directly into laboratory supplied bottles. The water sample 'elutriate' was then analysed by the laboratory to obtain water quality of the site water used for sediment elutriate preparation. The results were used as a baseline reference for comparison with elutriate results.

The ASS, surface water and elutriate results are presented in **Table A** to **Table C**. A summary of the results is provided below.

3.2 Sampling Locations

3.2.1 ASS Sampling

Table 2 summarises the distribution of the sediment sampling locations collected for ASS purposes and the depth of collected samples. The location of the sampling location is presented on **Figure 3**.

Table 2: ASS Sampling Locations and Depths

<table>
<tr><th rowspan="2">Sample ID</th><th colspan="2">Coordinates (GDA2020, Zone 50)</th><th rowspan="2">Sampling Depth (m)</th></tr>
<tr><th>Easting</th><th>Northing</th></tr>
<tr><td>LVR-C1-S1</td><td rowspan="3">346595</td><td rowspan="3">6274902</td><td rowspan="3">0 – 0.25
0.25 – 0.5</td></tr>
<tr><td>LVR-C2-S1</td></tr>
<tr><td>LVR-C3-S1</td></tr>
<tr><td>LVR-C1-S2</td><td rowspan="3">346636</td><td rowspan="3">6275028</td><td rowspan="3">0 – 0.25
0.25 – 0.5
0.5 – 0.6</td></tr>
<tr><td>LVR-C2-S2</td></tr>
<tr><td>LVR-C3-S2</td></tr>
<tr><td>LVR-C1-S3</td><td rowspan="3">346695</td><td rowspan="3">6275068</td><td>0 – 0.25
0.25 – 0.5
0.5 – 0.6</td></tr>
<tr><td>LVR-C2-S3</td><td>0 – 0.25
0.25 – 0.5</td></tr>
<tr><td>LVR-C3-S3</td><td>0 – 0.25
0.25 – 0.5
0.5 – 0.6</td></tr>
<tr><td>LVR-C1-S4</td><td rowspan="2">346960</td><td rowspan="2">6275110</td><td rowspan="2">0 – 0.25
0.25 – 0.5
0.5 – 0.6</td></tr>
<tr><td>LVR-C2-S4</td></tr>
<tr><td>LVR ASS_100</td><td>346640</td><td>6274710</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_101</td><td>346614</td><td>6274995</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_102</td><td>346608</td><td>6274952</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_103</td><td>346592</td><td>6274907</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_104</td><td>346598</td><td>6274861</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_105</td><td>346588</td><td>6274807</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_106</td><td>346592</td><td>6274776</td><td>0-0.5</td></tr>
<tr><td>LVR ASS_107</td><td>346618</td><td>6274743</td><td>0-0.5</td></tr>
</table>

3.2.2 Sediment Sampling

Sediment samples (LVR-S1 to LVR-S4) were collected from the same four (4) sampling locations as the ASS sampling locations for Stage 1; sediment samples for Stage 2 were collected from LVR-S5 and LVR-S6 (**Figure 3**).

3.2.3 Surface Water and Elutriate Sampling

Six (6) surface water samples and six (6) elutriate samples (LVR-S1 to LVR-S6) were collected from the same four (4) sampling locations as the ASS and sediment sampling locations (**Figure 3**).

Elutriate tests investigate the desorption of contaminants from sediment particulates to waters and are used to simulate the maximum contaminant release of the return water. For the assessment of potential impact to water quality, a cumulative assessment is undertaken to account for the concentrations in the surface water and potential added concentrations released through sediment disturbance.

3.3 Assessment Criteria

DWER provides action criteria based on pH and levels of oxidisable sulfur as summarised in **Table 3.**

Table 3: ASS Assessment Criteria

Criteria	Source	Description and Application	Limitation
pH_F		• pH testing with deionised water, where pHF < 5.5 pH unit indicates an acidic soil and may be indicative of actual ASS (AASS) • Low pHF is indicative of an acidic soil that has already undergone oxidation.	• These field parameters are generally indicative and cannot provide definitive information on the nature of the ASS • Exceedance of multiple criteria provides stronger evidence for the presence of ASS, but is not definitive • Soil acidity is not perfectly represented by pH alone • Laboratory testing for SPOCAS or CRS is required to confirm the presence of ASS.
pH_{FOX}		• pH testing with hydrogen peroxide, which triggers the oxidation of sulfidic material, where pHFOX <3.0 pH unit indicates a potential ASS (PASS) • Low pH_{FOX} is indicative of a soil that contains sufficient potential acidity to become ASS if oxidised.	
pH_{FOX} - pH_F	DWER (2015a)	• The difference between pHF and pHFOX, where a difference of 3.0 or higher pH unit is indicative of PASS.	• Careful consideration needs to be given to the pH values before and after oxidation, as the decrease in pH may be due to other factors (e.g., seawater influence, buffering capacity).
CRS		• A measure of potential acidity in soil in the form of reducible sulfur • CRS concentration above the LOR indicate the presence of PASS	• Careful consideration needs to be given to the difference in pHF and pHFOX values to select the most suitable sample interval for CRS analysis • CRS analysis doesn't allow for the detection/characterization of MBO • In WA, net acidity requires exclusion of ANC as it may influence results.
Total Titratable Acidity (TAA)		• A measure of actual/existing acidity in soil • TAA concentration above the LOR indicate the presence of AASS.	
Net Acidity (Action Criteria)		• Acidity based on both potential and existing acidity • This action criteria are based on soil texture and the amount of disturbed soil material • For this site, net acidity exceeding 0.03 %S is indicative of ASS (based on fine texture silt/clay and >1000	

Criteria	Source	Description and Application	Limitation
		tonnes of disturbed materials) and will require management.	

Surface water analytical results were compared to Tier 1 (screening level) criteria to evaluate risk to human health and ecological values (**Table 4**). The assessment criteria adopted are appropriate within the context of the site and surrounding receptors.

Table 4: Surface Water Assessment Criteria

Criteria	Source	Description and Application
Recreational Water (RW)	ANZ (2018). Australian and New Zealand Guidelines for Marine Water Quality	• Australian Standard water quality guideline appropriate for recreational water use (boating)
Lowland River (LR)		• Australian Standard water quality guideline most appropriate for the water conditions of the site and surrounding area
Freshwater (FW) 95% species protection		

Sediment water analytical results were compared to Tier 1 (screening level) criteria to evaluate risk to human health and ecological values (**Table 5**). The assessment criteria adopted are appropriate within the context of the site and surrounding receptors.

Table 5: Sediment Assessment Criteria

Criteria	Source	Description and Application
Default Guideline Values (DVG)	ANZ (2018). Australian and New Zealand Guidelines for Marine Water Quality	• The sediment DGVs indicate the concentrations below which there is a low risk of unacceptable effects occurring to protect aquatic ecosystems
Upper Guideline Value (GV-High)		• Th GV-high provides an indication of concentrations at which toxicity-related adverse effects are observed. As such, the GV-high value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems.

3.4 Sediment Description

The following lithology was encountered during the sediment investigations:

- 0 – 0.25 m: Clayey SILT - Dark brown, high plasticity, very soft
- 0.25-0.6 m: Silty CLAY – Dark brown, moderate plasticity, soft
- From 0.6 m: clayey SAND – Red, medium to coarse grained, poorly graded, subangular to subrounded.

A strong acidic odour was reported to be present between 0 m and 0.6 m, whilst no evidence of shells or MBO was observed in the samples.

3.5 ASS Results

The results of the ASS field testing are presented in **Table A**. These results are screened against the assessment criteria detailed in Section 3.3. The results are summarised as follows:

- pH_F ranges from 7.3 to 8.8 indicating absence of AASS.
- pH_{FOX} ranges from 1.7 to 6.1. Fifteen (15) of the 40 samples were below the pH threshold of 3 pH units that is indicative of PASS.
- pH changes ranged from 1.5 to 6.7, with 21 samples decreasing by more than 3. This indicates that these samples have the potential to be PASS.
- All samples with extreme reaction rating had pH_F, pH_{FOX} or difference in pH measurements that indicated PASS.
- pH_{KCl} ranged between 6.1 and 8.4 indicating that there is no actual acidity and/or retained acidity in any of the samples.
- CRS ranged from 1.84%S to 3.32%S in the 13 analysed samples indicating potential sulfidic acidity (PASS).
- Total actual acidity (TAA) was not detected above the laboratory limits of reporting (LOR) of <0.02%S in the 13 analysed samples indicating an absence of actual acidity (AASS).
- Acid Neutralising Capacity (ANC) is only effective when $pH_{KCl} \geq 6.5$ which is the case in most of the samples. Sediments contain ANC between 0.41%S and 1. 93%S with an average of 0.95% S which indicates that the sediment has some ability to buffer acidity and resist the lowering of the pH.
- Net Acidity excluding ANC ranged between 1.84%S and 3.32%S, with all 13 analysed samples exceeding the ASS management criterion of 0.03%S.

Based on the results as summarised above, sediments from the LVR are considered to be PASS between surface and 0.6 metres depth. Whilst there is some inherent ANC within the sediments, it is insufficient to fully buffer the acid generation potential. The ANC may however offer some buffering capacity in the return water given the sediments will be dewatered under anoxic conditions.

3.6 Surface Water Results

Field parameters from the baseline sampling of LVR (LVR-S1 to LVR-S6) are provided in **Table B** and are summarised as follow:

- Surface water temperature ranged between 21°C (LVR-S1) and 23.6°C (LVR-S4).
- Surface water field pH ranged between 7.32 (LVR-S1) and 8.68 (LVR-S4), indicating neutral to alkaline conditions. Most pH values were inside of the ANZECC (2000) lowland river (LR) range (6.5-8).

- Surface water SPC ranged between 21 µS/cm (LVR-S2) and 1,961 µS/cm (LVR-S1), indicating surface water is fresh to marginal.
- Surface water DO ranged between 2.95 mg/L (LVR-S6) and 13.22 mg/L (LVR-S4), indicating aerobic conditions.
- Surface water ORP ranged between -30.2 mV (LVR-S4) to -288.9 mV (LVR-S2), indicating reducing to strongly reducing conditions during the Stage 1 baseline. During the Stage 2 baseline event, ORP was recorded in the range 83.9 mV (LVR-S1) to 86.1 mV (LVR-S6) indicating oxidizing conditions.
- Surface water NTU ranged between 5.64 NTU (LVR-S4) to 77.2 NTU (LVR-S1) and was typically outside the LR range (10-20 NTU).

Analytical results from the baseline surface water monitoring event are provided in Table B and are summarised as follow:

- Laboratory pH ranged from 7.67 (LVR-S5) to 8.49 (LVR-S3) indicating near neutral to alkaline conditions.
- Total nitrogen (TN) and TKN concentrations ranged from 1.0 mg/L (LVR-S5/S6; Stage 2) to 1.8 mg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) and exceeded the LR assessment criterion for TN in all samples except LVR-S4 in Stage 1 with no exceedances reported in Stage 2. TN is present primarily as organic nitrogen (org-N) on the basis that:
  - Nitrate and nitrite (NOx as N) was either not detected above the LOR of 0.01 mg/L, or detections of 0.01 mg/L to 0.02 mg/L were reported across all of the samples
  - Ammonia (as N) was detected in LVR-S1; Stage 1 (0.01 mg/L) and all sites in the Stage 2 area (LVR-S1, S5, S6; 0.3 mg/L); however it was below the FW assessment criteria in all samples.
- Total phosphorus (TP) concentrations ranged from 0.3 mg/L (LVR-S4) to 0.48 mg/L (LRV-S1) and exceeded the LR assessment criteria for TP in all samples.
- Reactive phosphorus (FRP) concentrations ranged from 0.1 mg/L (LVR-S4; Stage 1) to 0.25 mg/L (LVR-S5/S6; Stage 2) and exceeded the LR assessment criteria for FRP in all samples.
- Total and dissolved Cd, Cr, Cu, Hg, and Ni and dissolved Pb were not detected above the LOR in any of the samples and total Pb results were all below assessment criteria.
- Total and dissolved As concentrations were below the assessment criteria.
- Total Fe was reported in the range 0.514 mg/L (LVR-S4; Stage 1) to 0.860 mg/L (LVR-S6; Stage 2), with all samples exceeding the RW criteria. Dissolved Fe was reported in the range 0.193 mg/L (LVR-S4; Stage 1) to 0.406 mg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area), with three sites exceeding the RW criteria (LVR-S1, S2, S5).
- Total Zn ranged between 0.001 mg/L (LVR-S1) and 0.004 mg/L (LVR-S3) whilst dissolved Zn was only detected above the LOR in LVR-S3 and LVR-S4 between 0.001 mg/L and

0.002 mg/L. Concentrations at all sites for both stages were below the assessment criteria.

3.7 Elutriate Results

Elutriate results are provided in Table C and as summarised as follow:

- pH ranged between 7.4 (LVR-S6; Stage 2) and 8.38 (LVR-S3; Stage 1) across all sites indicating absence of water acidification.
- Total nitrogen (TN) and TKN ranged between 5.6 mg/L (LVR-S5; Stage 2) and 15.1 mg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) with all sites exceeding the LR criterion for TN.
- Total phosphorus (TP) concentrations ranged from 0.3 mg/L (LVR-S6; Stage 2) to 3.25 mg/L (LRV-S1; Stage 1) and exceeded the LR assessment criteria for TP at all sites.
- Reactive phosphorus (FRP) concentrations ranged from 0.2 mg/L (LVR-S4; Stage 1 and LVR-S6; Stage 2) to 2.6 mg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) with all sites exceeding the LR assessment criteria for FRP.
- Total As concentrations ranged between 4.9 µg/L (LVR-S4; Stage 1) and 21.5 µg/L (LVR-S6; Stage 2) with all sites except LVR-S4 above the assessment criteria.
- Total Cd and Hg were not detected above the LOR at any of the Stage 1 sites nor LVR-S6 in Stage 2, but LVR-S5 (Stage 2) Cd exceeded the FW criterion with 0.3 µg/L and Hg was detected at 0.08 µg/L, compliant with the FW criterion.
- Total Cr ranged from 0.6 µg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) to 35.4 µg/L (LVR-S5; Stage 2), with two of the four sites in Stage 1 and both sites in Stage 2 exceeding the assessment criteria.
- Total Cu ranged between 2.5 µg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) and 53 µg/L (LVR-S5; Stage 2) with all sites exceeding the FW assessment criteria.
- Total Pb ranged between 1.9 µg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area and LVR-S2; Stage 1) and 46.4 µg/L (LVR-S5; Stage 2) with LVR-S3 (Stage 1) and both Stage 2 sites exceeding the assessment criteria.
- Total Ni ranged between 1.2 µg/L (LVR-S1; Stage 1 baseline event, Stage 2 dredge area and LVR-S2; Stage 1) and 11.0 µg/L (LVR-S5; Stage 2) with all sites below the FW assessment criteria.
- Total Zn ranged between 6.0 µg/L (LVR-S2; Stage 1) and 141 µg/L (LVR-S5; Stage 2) with two of the Stage 1 sites (LVR-S3/S4) and both Stage 2 sites (LVR-S5/S6) above the FW assessment criteria.

3.8 Sediment Results

Sediment results are provided in **Table D** and as summarised as follow:

- TOC ranged between 4.74% (LVR-S4) and 14.1% (LVR-S1).
- Total nitrogen (TN) and TKN ranged between 4,000 mg/kg (LVR-S5; Stage 2) and 11,000 mg/kg (LVR-S2; Stage 1). TN was predominantly present as org-N at all sites on the basis that NOx (as N) was either not detected above the LOR of <0.01 mg/kg or detected at low concentrations.
- Total phosphorus (TP) concentrations ranged from 368 mg/kg (LVR-S5; Stage 2) to 2,400 mg/kg (LRV-S4; Stage 1) with TP at significantly lower concentrations in the Stage 2 dredge area.
- Total As concentrations ranged between 4.17 mg/kg (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) and 5.21 mg/L (LVR-S6; Stage 2) with all samples below the assessment criteria whilst extractable As was detected at three of the six sites (LVR-S1, S5 and S6).
- Total Cd concentrations ranged between 0.3 mg/kg (LVR-S5/S6; Stage 2) and 0.8 mg/kg (LVR-S4; Stage 1) whilst extractable Cd ranged between 0.26 mg/kg (LVR-S5; Stage 2) and 0.7 mg/kg (LVR-S4; Stage 1). All samples were below the assessment criteria.
- Total Cr ranged from 18.5 mg/kg (LVR-5; Stage 22) and 25.5 mg/kg (LVR-S1; Stage 1 baseline event, Stage 2 dredge area) whilst extractable Cr ranged between 1.2 mg/kg (LVR-S5; Stage 2) and 2.9 mg/kg (LVR-S4; Stage 1). All samples were below the assessment criteria.
- Total Cu ranged between 16.3 mg/kg (LVR-S5; Stage 2) and 73.5 mg/kg (LVR-S4; Stage 1) exceeding the DGV in half the sites (LVR-S1, S2, S4). Extractable Cu ranged from <LOR (LVR-S4; Stage 1) and 10.8 mg/kg (LVR-S6; Stage 2) remaining below the assessment criteria.
- Total Pb ranged between 47.6 mg/kg (LVR-S1) and 123 mg/kg (LVR-S2) whilst extractable Pb ranged from 36.4 mg/kg (LVR-S1) and 105 mg/kg (LVR-S4). All samples exceeded the DGV except in LVR-S1 (Stage 1 baseline event, Stage 2 dredge area).
- Total Hg ranged between 0.08 mg/kg (LVR-S3; Stage 1) and 0.16 mg/kg (LVR-S5; Stage 2) whilst extractable Hg was not detected above LOR at any site. All samples were below the assessment criteria.
- Total Ni ranged between 8.1 mg/kg (LVR-S2; Stage 1) and 11.7 mg/kg (LVR-S3; Stage 1 and LVR-S6; Stage 2) whilst extractable Ni ranged between 1.1 mg/kg (LVR-S1/S4; Stage 1) and 3.1 mg/kg (LVR-S6; Stage 2). All samples were below the assessment criteria.
- Total Zn ranged between 110 mg/kg (LVR-S6; Stage 2) and 504 mg/kg (LVR-S4; Stage 1) whilst extractable Zn ranged between 97.9 mg/kg (LVR-S6; Stage 2) and 500 mg/kg (LVR-S4) with all samples below the assessment criteria except LVR-S4 (Stage 1; total and extractable) which exceeded the DGV.

3.9 Conclusions and Recommendations of Acid Sulfate Soil Investigation

Based on the results from the ASS investigation, the following conclusions are drawn:

- Net Acidity and CRS ranged between 0.83%S and 3.32%S, with all 13 samples exceeding the ASS management criterion of 0.03%S. Based on the analytical results the dark brown silty CLAY and clayey SILT are considered to be PASS. Whilst there is some inherent ANC within the sediments, it is insufficient to fully buffer the acid generation potential. The ANC may however offer some buffering capacity in the return water.
- Surface water does not currently appear to show evidence of acidification or the presence of elevated heavy metal concentrations. Nutrient concentrations were elevated at all sites.
- Sediments exhibited elevated nutrient (TN, TP) concentrations and slightly elevated (above DGV criteria) concentrations of Cu, Pb and Zn in the Stage 1 area, but not in Stage 2. Under acidic conditions, these metals are more likely to be released into the water.
- Elutriate results can indicate the desorption of contaminants from sediments into the water column and the undiluted results can indicate the pore water concentrations of targeted contaminants. Results indicate elevated (above assessment criteria) concentrations of nutrients (TN, TP, FRP, NH-N) and metals (As, Cr, Cu, Pb and Zn) however, concentrations of TN, TP and FRP in the surface water samples also exceeded the assessment criteria. Ammonia was reported to be higher in LVR-S1 in both the surface water and elutriate samples compared to the other sampling locations. All surface water samples reported concentrations below the assessment criteria whereas elutriate results exceeded the criteria in all locations. With a 15x dilution factor applied (a conservative dilution factor derived from the NAGD guidelines), the elutriate results are compliant with the acute toxic ammonia assessment criteria. Heavy metals were generally elevated in the elutriate samples with sporadic guideline exceedances across all sites. It is expected that the actual release of nutrients and metals into the system from the return water will be lower than the elutriate results given the dilution that will occur when return water mixes into the river.

4 Overview of Management Requirements

4.1 Scope and Objectives

The objective of this ASSDMP is to provide a framework for the management ASS and dewater during the dredging and dewatering works. Issues addressed by the ASSDMP include the following:

- Training of contactors
- Evaluation of ASS management options
- Management of sediment dredging
- Dewatering strategy
- Evaluation of dewatering effluent treatment and disposal options
- Sediment handling, treatment, and storage operations
- Monitoring and validation program
- Ongoing reporting and closure requirements
- Contingency measures and proposed corrective actions.

4.2 Timeframe

Stage 1 of the project was completed between April and June 2022 and Stage 2 is scheduled to commence in March/April 2023 with an expected dredging duration of approximately ten (10) weeks. All dredging works will be undertaken during hours stipulated in the *Environmental Protection (Noise) Regulations 1997* (0700-1900 Monday to Saturday). No project activities will be undertaken on Sundays or Public Holidays.

The desludging tubes will continue to dewater for several weeks beyond the completion of dredging until the sediment is sufficiently dry to open the tubes, treat (if required) and dispose offsite. The remaining section(s) of the Lower Vasse River proposed dredge areas, extending up to the Busselton Bypass, will be dredged in future.

4.3 Roles and Responsibilities

For successful implementation of the ASSDMP, the general roles and responsibilities of parties involved are described in **Table 6** below.

Table 6: Roles and Responsibilities

Roles	Responsibilities
Project Manager (City of Busselton)	• Facilitate overall compliance with this ASSDMP. • Responsible for ensuring ongoing effective communication with Dredging contractor. • Appointing and managing suitably qualified Contractors. • Community/stakeholder consultation, where required.

Roles	Responsibilities
Dredging Contractor	• Set-up, implementation, and supervision of dredging and dewatering works to ensure overall compliance with this ASSDMP. • Ensure contract documentation specifies the responsibilities of contractors consistent with the ASSDMP. • Responsible for compliance with legislative requirements.
Earthworks Contractor	• Setup of laydown areas • Treatment and removal of dredged and dewatered sediment • Compliance with this ASSDMP • Responsible for compliance with legislative requirements.
Environmental Consultant	• Provide advice on the environment and related legislation to Project Manager and assist them in managing environmental issues. • Review performance monitoring reports. • Monitor and report on environmental performance. • Undertake scheduling of analysis for dewater validation and surface water during site works. • Promote a consultative approach by interacting with personnel at all levels within the project team.

4.4 Training and Orientation

Training and orientation/toolbox sessions should be conducted for all dredging contractor staff, particularly those involved in works related to the disturbance of ASS and management of dewatering of the sediment tubes. These sessions will be conducted prior to the commencement of dredging to ensure all staff are aware of the environmental requirements for managing sediments and dewatering effluent.

5 Acid Sulfate Soil Management Plan

Based on the proposed activities at the site the following media will require management:

- Return water from the dewatering of the GeoProTM desludging tubes (Geo-tubes) for release back into the LVR
- Dewatered ASS-containing sediments from the GeoProTM desludging tubes for future reuse/disposal.

5.1 Water

5.1.1 Water Management

During the dredging works there will be a requirement to manage return water inflow from the geotextile bags to the river. Therefore, a return water and surface monitoring program and other management measures will be undertaken to protect the environmental values of the river. The key impacts and risks are as follows:

- Nutrient and heavy metal enriched, and acidic return water may adversely impact the water quality of the Lower Vasse River
- Localised increased turbidity from the return water entry point.

The following management actions have been designed to mitigate the above risks:

- Sediments will be pumped out from the mini dredge directly in enclosed pipes in which flocculant will be added to separate the solids from the liquids. 99% of the solids will be bound to the polymer including nutrients with only 10% or less of nutrient concentrations expected to be present in the return water as the remainder is expected to be captured in the Geo-tubes. Determining the right polymer and the dosing is the key element to getting the tubes to work efficiently. The dredge contractor will be responsible for the selection of the polymer and dosing based on the type of sediment encountered at the site and a review of the results of investigations undertaken to date.
- The Geo-tubes will be set up on a lined and impermeable laydown area, so that infiltration of return water to ground is avoided. The size and installation of the Geo-tube laydown area will be determined by the Dredging Contractor.
- The Geo-tubes provide an anoxic environment during sediment dewatering and consequently sediments will not be exposed to the atmosphere for the duration of dewatering to avoid oxidation of the sediments that could result in the oxidation of the sediments mobilisation of metals and acidity within the return water.

- The return water channel will be set up from the Geo-Tubes to the river ensuring that the channel is of sufficient length to facilitate denitrification prior to re-entry to the LVR. The aim of this is to reduce (denitrify) the bioavailable nutrients through oxygenation and biodegradation to minimise the potential for these additional nutrients to adversely impact the water quality of the receiving body and potentially cause undesirable side effects, such as algal blooms.
- Ongoing validation testing of the LVR surface water and return-water will be undertaken by either the Environmental Consultant or Dredging Contractor. Results should be subject to assessment criteria and contingency measures detailed in **Table 6.**
- Following the completion of dredging, return water will continue to flow back to the river until the flow diminishes and can be allowed to infiltrate to ground beneath the tube laydown area.
- At the end of the proposed activities, the Geo-tube bund and return water channel should be decommissioned, in accordance with **Section 6**.

5.1.2 Water Monitoring Program

The key objectives of the monitoring program will be to confirm that the mobilisation of contaminants from dredging or return water from dewatering of dredge spoil will not adversely impact the river environment and adjacent surface water body. The proposed water monitoring program during and post-dredging is outlined in **Table 7**. Water monitoring will occur at the following four locations, to be geospatially established once the area of disturbance (active dredging and/or return water discharge) or silt curtain location (if deployed) is defined:

- Near the return water outflow point from the GeoProTM desludging tubes (LVR-RW1)
- At the point of return water discharge in the LVR (LVR-RW2)
- Upstream of the disturbance area at a suitable location to represent background condition (LVR-US)
- Downstream (preferably within 100 m) of the disturbance area (LVR-DS1)
- Suitable location further downstream of the disturbance area, but within the same representative water body (LVR-DS2).

For the duration of the project, the return water and the LVR water samples will be compared against each other and compared to the pre dredging monitoring (surface water and elutriate results presented in **Table B** and **C**) to ascertain any potential impact to water quality.

In addition, the Department of Water and Environmental Regulation (DWER) will provide the continuous measurements from the in-situ probe recently installed within the project area to enable further comparison.

Table 7: Surface Water and Return Water Monitoring Program

Stage	Media	Frequency	Monitoring Location	Field Measurements	Laboratory Analysis	Responsibility	Performance Criteria	Contingency Measure
During dredging	Surface Water	Daily for first week, then weekly thereafter	Two (2) downstream and one (1) upstream of the disturbance area and outside of the silt curtains, if deployed.	pH, temperature, ORP, DO, EC, NTU TA (field), Talk (field) if pH<7	---	Dredging Contractor/ Environmental Consultant	pH >6 pH unit Downstream NTU commensurate with background (baseline/upstream) water quality	If parameters exceed the performance criteria, one or more of the contingency measures detailed in Section 5.1.3 will be implemented.
		Twice for first week, then weekly thereafter	Two (2) downstream and one (1) upstream of the disturbance area and outside of the silt curtains, if deployed, for first week. One (1) downstream sample thereafter.	---	pH, TTA, TAlk, Cl/SO_4[1] Nutrient suite (TN, TKN, TP, NOx, NH_3, FRP) Total Al and Fe Dissolved metals (Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Zn)		Nutrients below lowland river criteria, or commensurate with background/baseline surface water quality Metals below FW and RW criteria, or commensurate with background/baseline	
	Return Water (from geotextile tubes)	Daily for first week, then weekly thereafter	One location within return chute near geo-tube water release area, one location at the LVR discharge point (if water treatment occurs).	pH, NTU TA (field), TAlk (field) if pH<7	---	Dredging Contractor/ Environmental Consultant	N/A – to inform management strategies only	If return water results are exhibiting a continuous upward trend across three or more events, additional strategies outlined
		Daily for duration of dredging		pH	---		pH >6 pH unit	

[1] Laboratory analysis of TA, TAlk, Cl/SO_4 for the first week only, or unless pH<7 or trending downward for more than two events.

Stage	Media	Frequency	Monitoring Location	Field Measurements	Laboratory Analysis	Responsibility	Performance Criteria	Contingency Measure
		Twice for first week, then weekly thereafter		---	pH, TA, TAlk, Cl/SO_4[2] Nutrient suite (TN, TKN, TP, NOx, NH_3, FRP) Total Al and Fe Dissolved metals (Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Zn)		N/A – to inform management strategies only	in Section 5.1.3 shall be implemented.
Post dredging	Surface Water	Weekly until dewatering ceases (include one event at completion of dewatering)	One (1) downstream and one (1) upstream of the return water discharge location	pH, temperature, ORP, DO, EC, NTU TA (field), TAlk (field) if pH<7	Nutrient suite (TN, TKN, TP, NOx, NH_3, FRP) Total Al and Fe Dissolved metals (Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Zn)	Dredging Contractor / Environmental Consultant	Turbidity comparable within and outside silt curtains, if deployed. Nutrients commensurate with baseline/background surface water quality Metals below FW and RW criteria, or commensurate with background/baseline	If parameters exceed the performance criteria, then further monitoring will be required until levels are commensurate with baseline/background levels.
	Return Water (from geotextile tubes)	If acceptable during dredging – no monitoring required	---	---	---	---	---	If water quality during dredging exceeded performance criteria, monitoring shall continue as per the dredging regime until water flow cease.

[2] Laboratory analysis of TA, TAlk, Cl/SO_4 for the first week only, or unless pH<7 or trending downward for more than two events.

5.1.3 Contingency

If the monitoring undertaken as per **Section 5.1.2** indicates an unacceptable impact to the water quality of the LVR, the following contingency measures may be applied, as appropriate and in consultation with the relevant specialists:

- Extending/widening the return water path to facilitate aeration and hence volatilisation, nitrification, and potentially denitrification to reduce ammoniacal nitrogen in the return water prior to re-entry into the LVR.
- Set-up an in-line system for the treatment of return water with lime to create buffering capacity, if pH indicates acidification is occurring.
- Return water directed through a pad of yellow sand and/or dosing with Phoslock to reduce phosphorous levels prior to re-entry to the LVR.
- Other return water treatment methods, as discussed with DWER.
- Additional monitoring (locations and/or frequency) of the LVR, and review of recent weather events, or anthropogenic sources, to determine the cause of the impact.
- Cease dredging to reduce return water flow to the LVR. This is considered the least preferred option and will only be actioned if there is potential for significant impact to the downstream Vasse Wonnerup Wetland System.

5.2 Sediment (Dredge Spoil)

5.2.1 Sediment Management

The ASS investigation has identified that elevated levels of net acidity in sediments present in the LVR represents a risk of acid generation. As a result, the main risk from this material is oxidation of ASS through the dewatering process.

ASS management strategies for these sediments are as follows:

- Sediments will be pumped out from the mini dredge directly in enclosed pipes into the Geo-Tubes.
- Sediments contained within the Geo-Tubes must not be exposed to the atmosphere for the duration of dewatering to avoid oxidation of the sediments and mobilisation of metals.
- After the sediment is sufficiently dewatered, the sediment in the Geo-Tubes will be sampled via inspection points and scheduled for pH_F and pH_{FOX} at a rate commensurate with the volume of the bags (1 sample per 125 m^3), with CRS suite scheduled on at least 25% of samples.
- Following receipt of ASS results from post-dewatered sediment to confirm liming rates, the Geo-Tubes will be opened and the sediment lime dosed in-situ, or at a licensed

treatment facility, with an appropriate acid neutralising material (typically Aglime), as detailed in **Section 5.2.3** within 70 hours (if in-situ) by an excavator or backhoe.

- Validation sampling (i.e. field pH and net acidity as detailed in **Section 5.2.4**) of the treated and neutralised sediment material will be conducted post-treatment to confirm appropriate neutralisation has been undertaken.
- Sediment will only be reused/disposed offsite following waste characterisation. The sampling effort and analytical suite (inclusive of metals and hydrocarbons at minimum) will be reflective of the intended reuse/disposal location of the sediment.

5.2.2 Lime Application

The following measures should be adopted to ensure appropriate liming treatment of ASS material:

- Liming of ASS should be undertaken within 70 hours of opening the Geo-tubes (if treated in-situ) by mechanical mixing with finely crushed limestone (e.g. Aglime) into stockpiled soils:
  - A backhoe, excavator or similar should be used to grade the Aglime uniformly through the sediments
  - Aglime should be blended a minimum of two times (in perpendicular directions) and may need to be mixed several more times (pending validation results) to ensure adequate blending of liming material.
- Aglime is the preferred neutralising agent and should be applied at a rate of 130 $kgCaCO_3/m^3$, or higher if indicated by the post-dewatered sediment ASS results, of sediment based on the following (**Table A**):
  - Aglime should have an effective neutralising value (ENV) of 60% or greater. Allowances in dosing rates must be made if the nominated neutralising agent has an ENV less than 60%
  - Application rates can be calculated using the formula below, provided in with Section 2.5.1 of DWER (2015b) Treatment and management of soil and water in acid sulfate soil landscapes:

Lime needed (kg CaCO3/m3 soil) = Bulk density (t/m3) x Net acidity (% x 30.59) x Stochiometric conversion x safety factor x (100/ENV)

where:

  - Stochiometric conversion of sulfuric acid to calcium carbonate ($CaCO_3$) = 1.02
  - Safety factor = 1.5
  - Bulk density = 1.6
  - ENV = 60 (or the value provided by the supplier).
- All ASS material should be limed and treated within 70 hours of exposure, if material is treated in-situ, or as per the requirements of the treatment facility if taken offsite.

5.2.3 ASS Treatment Criteria and Validation

A validation and monitoring programme should be implemented to assess the efficacy of the treatment of ASS onsite. No treated material should be reused or removed from site, until the necessary validation testing has been undertaken and the material has been confirmed as suitable for backfilling by the Environmental Consultant.

The sampling frequency and validation criteria for treated ASS material and its associated leachate/runoff is provided in **Table 8**. Validation sampling should be conducted by the Environmental Consultant and confirmatory results be presented in the closure report.

Table 8: ASS Validation Sampling Density and Validation Criteria

Sample Media	Sample Density	Validation Criteria
Sediment	1 sample per 125 m^3	• 6.0 < pHF < 8.5 pH unit • pH_{FOX} > 5.0 pH unit • Liming material thoroughly mixed with soil (visual).
	25 % of validation soil samples tested for CRS suite.	• Potential acidity (i.e. CRS) < 0.03 %S • Actual acidity (i.e. TTA) < 0.03 %S • Net acidity < 0.02 %S.

If treated ASS material fails to meet the validation criteria in **Table 8**, additional treatment and subsequent revalidation is required.

5.2.4 Offsite Disposal/Reuse

If offsite disposal/reuse is required, ASS material should be treated and neutralised prior to offsite disposal/reuse, in accordance with application rates detailed in **Section 5.2.3**.

Dependent upon the disposal/reuse strategy, waste classification may also be required to determine suitability of the sediments for offsite disposal/reuse. At a minimum, heavy metals and hydrocarbons should be analysed.

Dockets from trucks and the receiving waste facility should be retained by the contractor for inclusion in the closure reporting, along with laboratory certificates detailing that soil have been neutralised.

5.2.5 Management Practices

The contractor shall always adopt best current management practice. Complete records of all testing and treatment will be required to be maintained by the contractor. Any modifications to the proposed works may require amendments to the ASSDMP. Nominated changes will be approved by the Environmental Consultant prior to their implementation.

5.2.6 Contingency

If sediments are unable to be uniformly blended with Aglime in-situ within the opened Geo-tubes in the lined basin, additional lime treatment and blending may be required to be undertaken on a separate lime dosing pad as follows:

- ASS will be transferred from the Geo-tubes lined basin and placed on compacted limestone treatment pads comprising a minimum thickness of limestone of 150 mm. The thickness of the ASS will not exceed 0.5 m. The location of the pads will be near the working area as determined appropriate by the Dredging Contractor. The limestone treatment pad(s) will be designed to intercept and convey excess free water towards an infiltrating guard layer of loosely compacted limestone at the low point of the storage apron and will include a 150 mm high perimeter bund of compacted crushed limestone around each pad (with the exception of plant and vehicle access points).
- Mechanical mixing of additional Aglime will occur in accordance with Section 5.2.2 until the performance criteria are met.
- Following mixing, surface area of the stockpile will be minimised to reduce the extent of material exposed to atmospheric oxygen. This may involve:
    - Shaping the stockpile and/or capping or lining it with a material that will minimise its drying by wind and sun and prevent the ingress of rainfall. This management practice will apply to soils collected from above the water table.
    - Spraying the surface of the stockpile to keep it moist using iron-free or neutralising solution. The spray will need to be carefully managed to prevent over-wetting of the stockpile material and should comprise of a fine mist to prevent desegregation of the soil from the stockpile surface.
- All stockpiles will be labelled, clearly stating the date and time when the first material was excavated and stockpiled.
- All treated sediment on the limestone pad should be subject to inspection and validation testing and conform to performance criteria in accordance with Section 5.2.3 by the Environmental Consultant, prior to reuse or offsite disposal.

6 Decommissioning of Infrastructure

Once dewatering is complete and the sediments removed from the Geo-tubes, the laydown area, the return water channel, and Geo-tubes will be removed and disposed of by the Dredging Contractor.

At the ASS treatment pad (if used), it is considered possible that metals may precipitate out from stockpiled ASS, thus resulting in elevated metal concentrations on treatment pads. Once the ASS treatment pads are no longer in operation, validation testing should be undertaken the determine whether the material is suitable for retention and reuse onsite or if offsite disposal is necessary.

The following sampling methodology should be applied for decommissioning testing:

- Soil samples should be collected to a depth of 0.3 mbgl in a fixed grid pattern
- The number of samples collected should conform to the *DWER (2019) Landfill Waste Classification Waste Definitions 1996 (as amended in 2019)*
- Soil samples should be analysed for pH_F, pH_{FOX}, CRS and metals (Al, As, Be, Cd, Cr, Fe, Pb, Hg, Mo, Ni, Se, Ag)
- Standard QA/QC should be undertaken, including the collection and analysis of QC samples at acceptable frequencies.

The validation assessment criteria are provided in **Table 8**, with the additional criteria that metals concentration should conform to the *NEPM ASC (2013)* Health Investigation Levels (HIL) and Ecological Investigation Levels (EIL) for Public Open Space/recreational land use.

If validation samples fail to conform to the validation assessment criteria, the material should be disposed to an appropriate landfill facility upon waste classification. All transport and waste acceptance dockets should be obtained and provided to the Environmental Consultant for record keeping.

7 Reporting

For reporting purposes, the following documents should be retained by the Dredging Contractor, and provided to the Environmental Consultant for record keeping purposes:

- Volume and dates of dredged sediment
- Volumes and dates of Aglime imported to site
- ENV of Aglime
- Volume and dates of ASS treated
- Spatial tracking of treated sediment stockpiles
- Chain of Custodies, Sample Receipts and Laboratory Certificates for any laboratory analysis
- Calibration certificates for equipment used
- Daily management of ASS undertaken
- Reuse locations of ASS material
- Offsite disposal dockets, if aplicable.

Reporting requirements are summarised in Table 9 below.

Table 9: Surface Water Management Reporting Requirements

Responsibility	Report	To Whom	Timing
Sediment Dredge Spoil			
Dredging Contractor	Proposed ASS treatment methodology statement	City of Busselton, Environmental Consultant	Prior to award of contract
Dredging Contractor	Daily return water pH testing Log of treatment operation tracking	Environmental Consultant	Daily
Environmental Consultant	Soil validation results and advice	Environmental Consultant	Within 48-72 hours of receipt of samples
Environmental Consultant	Closure report	City of Busselton, DWER	Following completion of proposed works
Surface Water			
Dredging Contractor	Proposed water quality methodology statement	City of Busselton, Environmental Consultant	Prior to award of contract
Dredging Contractor	Daily water quality testing	Environmental Consultant	Daily
Dredging Contractor/ Environmental Consultant	Water quality results and advice	Environmental Consultant	Within 48-72 hours of receipt of samples
Environmental Consultant	Closure reports	City of Busselton, DWER	Following completion of earthworks

A closure report will be prepared following the completion of dredging, dewatering works, ASS treatment and validation and before reuse/disposal of sediment.

The closure report will be written in accordance with Appendix D of *DWER (2015b) Treatment and management of soil and water in acid sulfate soil landscapes* and should contain the following information:

- Summary of site works undertaken
- Field and analytical results of sediment, surface water and return water monitoring
- Assessment of monitoring results against the appropriate assessment criteria and requirements of the operating strategy
- Recommendations for additional monitoring and/or remedial works, if required.

8 Adaptive Management

This ASSDMP has been prepared for the Lower Vasse River Sediment Removal Project as a whole, however the management strategies have been based on detailed information collected as part of the baseline investigation for the first and second stages of the project. Following the completion of each stage of sediment removal and prior to the commencement of future stages, the ASSDMP should be reviewed and revised, where appropriate.

Management of future stages will rely on information obtained from baseline data collected immediately prior to the commencement of that stage and adaptive management strategies shall be formed based on these future results.

9 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.

Subject to the terms of the contract between the Client and 360 Environmental Pty Ltd, copying, reproducing, disclosing, or disseminating parts of this report is prohibited (except to the extent required by law) unless the report is produced in its entirety including this page, without the prior written consent of 360 Environmental Pty Ltd.

10 References

360 Environmental (2021) Dredge Environmental Management Plan, prepared for City of Busselton.

360 Environmental (2022) Stage 1 Baseline Water and Sediment Quality Report, prepared for City of Busselton.

Australia New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2018) *National Water Quality Management Strategy, Australian Water Quality Guidelines for Fresh and Marine Waters*

Department of Environment Regulation (2014a) *Assessment and Management of Contaminated Sites, Contaminated Sites Guidelines*, Government of Western Australia, December 2014

Department of Environment Regulation, 2015a. *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes. Western Australia.*

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

Figures

Legend

- Development Footprint
- Proposed Dredge Area
- Proposed Laydown Areas for the temporary storage of Geomembrane bags

- CADASTRAL BOUNDARY SOURCED FROM LANDGATE 2021
- AERIAL PHOTOGRAPHY SOURCED FROM LANDGATE 2021
- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

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0 100 200 300 m
Meters

LOCALITY MAP

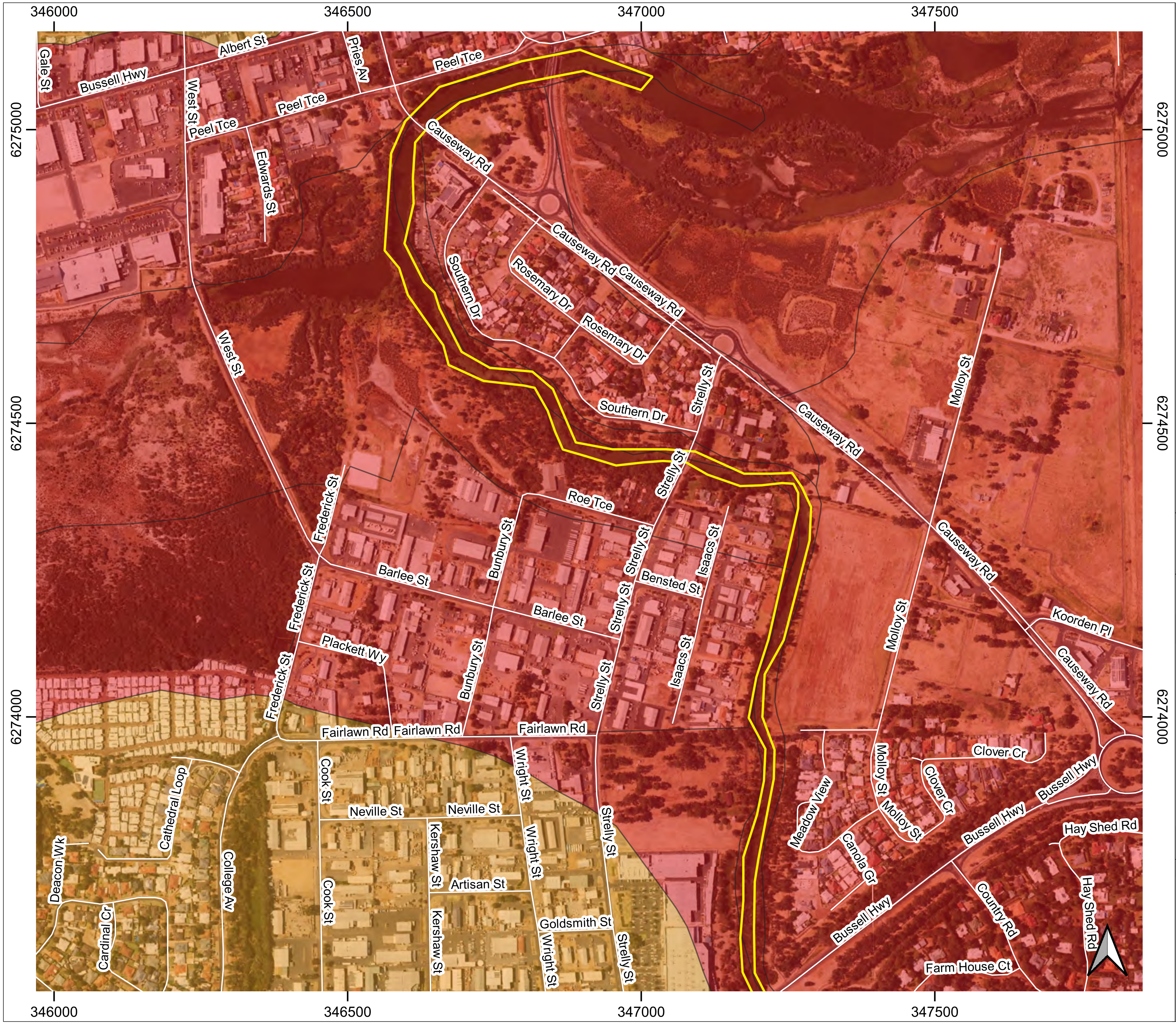
PROJECT NO	DATE	REVISION
4602	11/01/2022	1
CREATED	CHECKED	APPROVED
VM	AW	JP

City of Busselton, Lower Vasse River

Acid Sulfate Soil Dewatering Management Plan

Figure 1

Site Location



Legend

- Development Footprint
- Proposed Dredge Area

Acid Sulfate Soil

- High to moderate risk
- Moderate to low risk

- CADASTRAL BOUNDARY SOURCED FROM LANDGATE 2021
- AERIAL PHOTOGRAPHY SOURCED FROM LANDGATE 2021
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VM	AW	JP

City of Busselton, Lower Vasse River

Acid Sulfate Soil Dewatering Management Plan

Figure 2

ASS Risk Map

346500 346750 347000

346500 346750 347000

6275000 6274750

Legend

- Proposed Dredge Area
- Stage 1 Dredging Area
- Stage 2 Dredging Area

Sampling Locations

- Sediment Sampling Location
- Surface Water Sampling Location
- Sediment and Surface Water Sampling Locations
- Acid Sulfate Soil Sampling Location

- CADASTRAL BOUNDARY SOURCED FROM LANDGATE 2023
- AERIAL PHOTOGRAPHY SOURCED FROM LANDGATE 2023
- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

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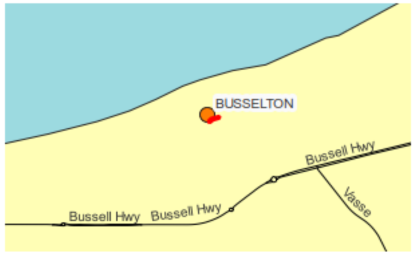
LOCALITY MAP



PROJECT NO	DATE	REVISION
4602	11/01/2022	1
CREATED	CHECKED	APPROVED
VM	AW	JP

City of Busselton, Lower Vasse River

Acid Sulfate Soil Dewatering Management Plan

Figure 3

Sampling Locations

Tables

4602

City of Busselton
Lower Vasse River
Baseline Investigation
Table A: Acid Sulfate Soil Analytical Results

Sample ID	Laboratory	Date Sampled	Laboratory Sample Number	Simplified Lithology	Acid Sulfate Soils Field				Laboratory Results and Calculations													ASS Interpretation
					Field pH				pH_{KCl}	Potential Sulfidic Acidity		Actual Acidity		Acid Neutralising Capacity		Net Acidity		Net Acidity Minus Acid Neutralising Capacity		Lime Calculation		
					pH_F	pH_{FOX}	pH Change	Reaction	pH_{KCl}	Chromium Reducible Sulfur (CRS)		Titratable Actual Acidity								Liming Rate	Lime rate excl ANC	
					0.1	0.1	0.1	-	0.1	0.005	10	0.02	2	0.01	10	0.02	10	0.02	10	-	95	
					pH units	pH units	pH units	-	pH Units	%S	mol H^+/t	%S	mol H^+/t	%S	mol H^+/t	%S	mol H^+/t	%S	mol H^+/t	kg/CaCO3/t	kg Aglime/t	
				Assessment Criteria SILT/ CLAY (>1000 tonnes)	<5.5	<3.0	>3.0	>2	-	-	-	-	-	-	-	0.03	18	0.03	18	-	-	
LVR-C1-S1-025	ALS	15/12/2021	EP2115603001	Clayey SILT: Dark brown, high plasticity, very soft	7.9	2.3	5.6	Moderate	7.9	3.32	2070	<0.02	<2	0.79	490	2.8	1750	3.32	2070	131	156	PASS
LVR-C1-S1-2550	ALS	15/12/2021	EP2115603002	Silty CLAY: dark brown, moderate plasticity, soft	7.8	2.3	5.5	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	PASS
LVR-C2-S1-025	ALS	15/12/2021	EP2115603003	Clayey SILT: Dark brown, high plasticity, very soft	7.6	3.7	3.9	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C2-S1-2550	ALS	15/12/2021	EP2115603004	Silty CLAY: dark brown, moderate plasticity, soft	7.7	2.3	5.4	Moderate	7.8	2.82	1760	<0.02	<2	0.73	456	2.33	1450	2.82	1760	109	132	PASS
LVR-C3-S1-025	ALS	15/12/2021	EP2115603005	Clayey SILT: Dark brown, high plasticity, very soft	7.9	5.5	2.4	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C3-S1-2550	ALS	15/12/2021	EP2115603006	Silty CLAY: dark brown, moderate plasticity, soft	8	5.4	2.6	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C1-S2-025	ALS	15/12/2021	EP2115603007	Clayey SILT: Dark brown, high plasticity, very soft	7.6	6.1	1.5	Moderate	8.3	3	1870	<0.02	<2	1.59	990	1.94	1210	3	1870	91	140	PASS
LVR-C1-S2-2550	ALS	15/12/2021	EP2115603008	Silty CLAY: dark brown, moderate plasticity, soft	7.5	5	2.5	Strong	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C1-S2-5060	ALS	15/12/2021	EP2115603009	Silty CLAY: dark brown, moderate plasticity, soft	7.8	4.2	3.6	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C2-S2-025	ALS	15/12/2021	EP2115603010	Clayey SILT: Dark brown, high plasticity, very soft	7.3	5.8	1.5	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C2-S2-2550	ALS	15/12/2021	EP2115603011	Silty CLAY: dark brown, moderate plasticity, soft	7.6	1.8	5.8	Extreme	7.8	2.59	1610	<0.02	<2	0.53	330	2.23	1390	2.59	1610	105	121	PASS
LVR-C2-S2-5060	ALS	15/12/2021	EP2115603012	Silty CLAY: dark brown, moderate plasticity, soft	7.9	4.8	3.1	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C3-S2-025	ALS	15/12/2021	EP2115603013	Clayey SILT: Dark brown, high plasticity, very soft	7.7	5.8	1.9	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C3-S2-2550	ALS	15/12/2021	EP2115603014	Silty CLAY: dark brown, moderate plasticity, soft	7.3	4.6	2.7	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C3-S2-5060	ALS	15/12/2021	EP2115603015	Silty CLAY: dark brown, moderate plasticity, soft	7.9	3.7	4.2	Moderate	7.9	2.92	1820	<0.02	<2	0.75	465	2.43	1510	2.92	1820	114	137	PASS
LVR-C1-S3-025	ALS	15/12/2021	EP2115603016	Clayey SILT: Dark brown, high plasticity, very soft	7.7	5.3	2.4	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C1-S3-2550	ALS	15/12/2021	EP2115603017	Silty CLAY: dark brown, moderate plasticity, soft	7.6	1.9	5.7	Extreme	7.2	2.91	1810	<0.02	<2	1.09	254	2.64	1640	2.91	1810	123	136	PASS
LVR-C1-S3-5060	ALS	15/12/2021	EP2115603018	Silty CLAY: dark brown, moderate plasticity, soft	7.7	1.9	5.8	Extreme	---	---	---	---	---	---	---	---	---	---	---	---	---	PASS
LVR-C2-S3-025	ALS	15/12/2021	EP2115603019	Clayey SILT: Dark brown, high plasticity, very soft	7.9	5.5	2.4	Moderate	8	2.8	1740	<0.02	<2	0.41	678	2.07	1290	2.8	1740	97	131	PASS
LVR-C2-S3-2550	ALS	15/12/2021	EP2115603020	Silty CLAY: dark brown, moderate plasticity, soft	7.5	2	5.5	Extreme	---	---	---	---	---	---	---	---	---	---	---	---	---	PASS
LVR-C3-S3-025	ALS	15/12/2021	EP2115603021	Clayey SILT: Dark brown, high plasticity, very soft	7.7	4.6	3.1	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C3-S3-2550	ALS	15/12/2021	EP2115603022	Silty CLAY: dark brown, moderate plasticity, soft	7.7	1.9	5.8	Strong	---	---	---	---	---	---	---	---	---	---	---	---	---	PASS
LVR-C3-S3-5060	ALS	15/12/2021	EP2115603023	Silty CLAY: dark brown, moderate plasticity, soft	7.7	1.8	5.9	Extreme	6.1	2.06	1290	<0.02	4	----	----	2.07	1290	2.07	1290	97	97	PASS
LVR-C1-S4-025	ALS	15/12/2021	EP2115603024	Clayey SILT: Dark brown, high plasticity, very soft	7.6	5	2.6	Moderate	---		---	---	---	---	---	---	---	---	---	---	---	---
LVR-C1-S4-2550	ALS	15/12/2021	EP2115603025	Silty CLAY: dark brown, moderate plasticity, soft	7.4	1.8	5.6	Extreme	7.4	2.8	1750	<0.02	<2	0.49	307	2.48	1540	2.8	1750	116	131	PASS
LVR-C1-S4-5060	ALS	15/12/2021	EP2115603026	Silty CLAY: dark brown, moderate plasticity, soft	7.3	1.7	5.6	Extreme	6.4	2.8	1750	<0.02	<2	---	---	2.8	1750	2.8	1750	131	131	PASS
LVR-C2-S4-025	ALS	15/12/2021	EP2115603027	Clayey SILT: Dark brown, high plasticity, very soft	7.6	5.4	2.2	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C2-S4-2550	ALS	15/12/2021	EP2115603028	Silty CLAY: dark brown, moderate plasticity, soft	7.5	2.6	4.9	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-C2-S4-5060	ALS	15/12/2021	EP2115603029	Silty CLAY: dark brown, moderate plasticity, soft	7.5	1.8	5.7	Extreme	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-100	ALS	30-11-2022	EP2216322-007	Silty CLAY: dark brown, moderate plasticity, soft	7.1	5.4	1.7	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-100B	ALS	30-11-2022	EP2216322-008	Silty CLAY: dark brown, moderate plasticity, soft	7.6	5.8	1.8	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-101	ALS	30-11-2022	EP2216322-009	Silty CLAY: dark brown, moderate plasticity, soft	8.6	1.9	6.7	Extreme	7.6	2.79	1740	<0.02	<2	0.62	387	2.38	1480	2.79	1740	111	131	PASS
LVR-ASS-102	ALS	30-11-2022	EP2216322-010	Silty CLAY: dark brown, moderate plasticity, soft	8.2	5.5	2.7	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-103	ALS	30-11-2022	EP2216322-011	Silty CLAY: dark brown, moderate plasticity, soft	7.8	6	1.8	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-104	ALS	30-11-2022	EP2216322-012	Silty CLAY: dark brown, moderate plasticity, soft	7.4	5.9	1.5	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-105	ALS	30-11-2022	EP2216322-013	Silty CLAY: dark brown, moderate plasticity, soft	7.8	4.6	3.2	Extreme	8.4	1.84	1150	<0.02	<2	1.52	947	0.83	515	1.84	1150	39	86	PASS
LVR-ASS-106	ALS	30-11-2022	EP2216322-014	Silty CLAY: dark brown, moderate plasticity, soft	7.6	5.5	2.1	Moderate	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LVR-ASS-107	ALS	30-11-2022	EP2216322-015	Silty CLAY: dark brown, moderate plasticity, soft	8.8	2.2	6.6	Extreme	8.2	2.44	1520	<0.02	<2	1.93	1210	1.15	715	2.44	1520	54	114	PASS

Acronyms:

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.

City of Busselton
Lower Vasse River
Baseline Investigation
Table B: Surface Water Analytical Results

Sample ID						LVR-S1	LVR-S2	LVR-S3	LVR-S4-1	LVR-S1	LVR-S5	LVR-S6
Laboratory Sample No.						EP2115595001	EP2115595002	EP2115595003	EP2115595004	EP2216322-001	EP2216322-002	EP2216322-003
Sample Matrix						Water	Water	Water	Water	Water	Water	Water
Laboratory						ALS	ALS	ALS	ALS	ALS	ALS	ALS
Date Sampled						15/12/2021	15/12/2021	15/12/2021	15/12/2021	30-11-2022	30-11-2022	30-11-2022
Analyte	**LOR**	**Units**	**ANZECC & ARMCANZ (2018) Freshwater**	**ANZECC & ARMCANZ (2000) Lowland River**	**ANZECC & ARMCANZ (2000) Recreational Water**							
Field Parameters												
Temperature	----	°C	----	----	----	**21.0**	**21.4**	**21.6**	**23.6**	**21.7**	**21.9**	**21.6**
Dissolved Oxygen	----	mg/L	----	----	----	**4.22**	**6.21**	**6.48**	**13.22**	**3.46**	**3.72**	**2.95**
Specific Conductivity	----	mS/cm	----	----	----	**1.961**	**0.044**	**0.021**	**1.252**	**0.982**	**0.985**	**0.986**
pH	----	pH unit	----	0.65-8.0	----	**7.32**	**7.54**	**7.61**	**8.68**	**7.37**	**7.42**	**7.29**
Oxydation-reduction Potential	----	mV	----	----	----	**-210.9**	**-288.9**	**-224.8**	**-30.2**	**83.9**	**84.3**	**86.1**
Turbidity	----	NTU	----	10-20	----	**77.2**	**62.12**	**28.57**	**5.64**	-	-	-
Water Quality Parameters			----									
pH	0.01	pH unit	----	0.65-8.0	----	**7.78**	**8.12**	**8.49**	**8.48**	**7.73**	**7.67**	**7.7**
Nutrients			----									
Total Nitrogen (as N)	0.1	mg/L	----	1.2	----	**1.8**	**1.7**	**1.7**	**1.2**	**1**	**1**	**1**
Total Kjeldahl Nitrogen (as N)	0.1	mg/L	----	----	----	**1.8**	**1.7**	**1.7**	**1.2**	**1**	**1**	**1**
NOx (as N)	0.01	mg/L	----	0.15	0.045	<0.01	<0.01	<0.01	<0.01	**0.01**	**0.02**	**0.01**
Ammonia as N	0.01	mg/L	----	0.9	0.91	**0.01**	<0.01	<0.01	<0.01	**0.33**	**0.3**	**0.33**
Ammonium as N	0.01	mg/L	----	0.08	----	<0.01	<0.01	<0.01	<0.01	**0.33**	**0.3**	**0.33**
Phosphate total (as P)	0.01	mg/L	----	0.065	----	**0.48**	**0.43**	**0.42**	**0.3**	**0.4**	**0.38**	**0.39**
Reactive Phosphorus as P	0.01	mg/L	----	0.04	----	**0.24**	**0.18**	**0.18**	**0.1**	**0.24**	**0.25**	**0.25**
Heavy Metals (Total)												
Aluminium	5	ug/L	55	----	200	**38**	**38**	**43**	**53**	**30**	**30**	**60**
Arsenic	0.2	ug/L	13	----	50	**0.8**	**0.8**	**0.8**	**0.8**	<1	<1	**1**
Cadmium	0.05	ug/L	0.2	----	5	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1
Chromium	0.2	ug/L	1	----	50	<0.2	<0.2	<0.2	<0.2	<1	<1	<1
Copper	0.5	ug/L	1.4	----	1000	<0.0005	<0.0005	<0.0005	<0.0005	<1	<1	<1
Iron	2	ug/L	----	----	300	**699**	**688**	**615**	**514**	**800**	**840**	**860**
Lead	0.1	ug/L	3.4	----	50	**0.2**	**0.2**	**0.2**	**0.3**	<1	<1	<1
Mercury	0.4	ug/L	0.6	----	1	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Nickel	0.5	ug/L	11	----	100	<0.5	<0.5	<0.5	<0.5	<1	<1	<1
Zinc	1	ug/L	8	----	5000	**1**	**2**	**4**	**2**	<5	<5	<5
Heavy Metals (Dissolved)												
Aluminium	5	ug/L	55	----	200	**13**	**9**	**16**	**11**	<10	<10	<10
Arsenic	0.2	ug/L	13	----	50	**0.7**	**0.7**	**0.7**	**0.7**	<1	<1	<1
Cadmium	0.05	ug/L	0.2	----	5	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1
Chromium	0.2	ug/L	1	----	50	<0.2	<0.2	<0.2	<0.2	<1	<1	<1
Copper	0.5	ug/L	1.4	----	1000	<0.0005	<0.0005	<0.0005	<0.0005	<1	<1	<1
Iton	2	ug/L	----	----	300	**406**	**333**	**289**	**193**	**260**	**340**	**300**
Lead	0.1	ug/L	3.4	----	50	<0.1	<0.1	<0.1	<0.1	<1	<1	<1
Mercury	0.4	ug/L	0.6	----	1	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Nickel	0.5	ug/L	11	----	100	<0.5	<0.5	<0.5	<0.5	<1	<1	<1
Zinc	1	ug/L	8	----	5000	<1	<1	**1**	**2**	<5	<5	<5

Notes
ANZECC & ARMCANZ 2018 - Values tabulated are based on slightly to moderately degraded ecosystems - 95% Protection Level
ANZECC & ARMCANZ 2000 - Values tabulated are based on slightly to moderately degraded ecosystems - 95% Protection Level
LOR = limits of reporting
mg/L = milligrams per litre
ug/L = micrograms per litre
NA= not applicable as these fractions are non volatile and hence not of concern for vapour inhalation
"---" = criteria have not been derived for these chemical constituents/compounds.

[a] = Protection level unknown
[b] = 99% protection level used

Font and Cell :
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City of Busselton
Lower Vasse River
Baseline Investigation
Table C: Elutriate Analytical Results

Sample ID						LVR-S1	LVR-S2	LVR-S3	LVR-S4	LVR-S5	LVR-S6
Laboratory Sample No.						EP2115595-006	EP2115595-007	EP2115595-008	EP2115595-009	EP2216322-005	EP2216322-006
Sample Matrix						Elutriate	Elutriate	Elutriate	Elutriate	Elutriate	Elutriate
Laboratory						ALS	ALS	ALS	ALS	ALS	ALS
Date Sampled						15/12/2021	15/12/2021	15/12/2021	15/12/2021	30-11-2022	30-11-2022
Analyte	**LOR**	**Units**	**ANZECC & ARMCANZ (2018) Freshwater**	**ANZECC & ARMCANZ (2000) Lowland River/ Freshwater**	**ANZECC & ARMCANZ (2000) Recreational Water**						
Water Quality Parameters											
pH	0.01	pH unit	----	6.5-8.0	----	8.35	8.44	8.36	8.38	7.46	7.4
Nutrients											
Total Nitrogen (as N)	0.1	mg/L	----	1.2	----	15.1	15	11.1	5.8	5.6	8.8
Total Kjeldahl Nitrogen (as N)	0.1	mg/L	----	----	----	15.1	15	11.1	5.8	5.6	8.8
NOx (as N)	0.01	mg/L	----	0.15	0.045	<0.01	<0.01	<0.01	<0.01	0.02	0.01
Ammonia as N	0.02	mg/L	----	0.9	0.91	12.1	12	7.12	3.73	4.51	8.26
Ammonium as N	0.01	mg/L	----	0.08	----	10.7	10.4	6.3	2.98	4.44	8.14
Phosphate total (as P)	0.01	mg/L	----	0.065	----	3.25	1.63	1.27	0.4	0.78	0.3
Reactive Phosphorus as P	0.01	mg/L	----	0.04	----	2.61	1.32	0.9	0.16	0.71	0.2
Heavy Metals (Total)											
Arsenic	0.2	ug/L	13	----	50	21.1	13.4	15.4	4.9	19.1	21.5
Cadmium	0.05	ug/L	0.2	----	5	<0.05	<0.05	<0.05	<0.05	0.3	<0.2
Chromium	0.2	ug/L	1	----	50	2	1	0.6	1.2	35.4	5.5
Copper	0.5	ug/L	1.4	----	1000	2.5	2.6	3.5	3	53	4
Lead	0.1	ug/L	3.4	----	50	1.9	1.9	4.4	3	46.4	3.8
Mercury	0.1	ug/L	0.6	----	1	<0.1	<0.1	<0.1	<0.1	0.08	<0.04
Nickel	0.5	ug/L	11	----	100	1.7	1.3	1.2	1.4	11	1.1
Zinc	1	ug/L	8	----	5000	8	6	12	12	141	7

Notes
ANZECC & ARMCANZ 2018 - Values tabulated are based on slightly to moderately degraded ecosystems - 95% Protection Level
ANZECC & ARMCANZ 2000 - Values tabulated are based on slightly to moderately degraded ecosystems - 95% Protection Level
LOR = limits of reporting
mg/L = miligrams per litre
"---" = criteria have not been derived for these chemical constituents/compounds.
Elutriate results are raw (undiluted) and do not account for existing surface water concentrations
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City of Busselton
Lower Vasse River
Baseline Investigation
Table D: Sediment Analytical Results

Sample ID					LVR-S1	LVR-S2	LVR-S3	LVR-S4	LVR-S5	LVR-S6
Laboratory Sample No.					EP2115595-006	EP2115595-007	EP2115595-008	EP2115595-009	EP2216322-005	EP2216322-006
Sample Matrix					Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Laboratory					ALS	ALS	ALS	ALS	ALS	ALS
Date Sampled					15/12/2021	15/12/2021	15/12/2021	15/12/2021	30-11-2022	30-11-2022
Analyte	**LOR**	**Units**	**DGV**	**GV-High**						
Physicochemical Parameters										
Total Organic Carbon	0.02	%	---	---	**14.1**	**9.2**	**11.7**	**4.74**	**7.24**	**5.29**
Total Soluble Salts	5	mg/kg	---	---	**15500**	**12400**	**15800**	**14000**	-	-
Moisture content	1	%	---	---	**83.2**	**87.7**	**83.3**	**82.3**	**75.3**	**84.1**
Nutrients										
Total Nitrogen (as N)	20	mg/kg	---	---	**7660**	**11000**	**7460**	**7930**	**4000**	**9310**
Total Kjeldahl Nitrogen (TKN)	20	mg/kg	---	---	**7660**	**11000**	**7460**	**7930**	**4000**	**9310**
NOx (as N)	0.1	mg/kg	---	---	<0.2	<0.2	**0.6**	<0.2	**0.7**	**0.5**
Total Phosphorus (as P)	2	mg/kg	---	---	**2000**	**1330**	**2060**	**2400**	**368**	**871**
Heavy Metals (Total)										
Arsenic	1	mg/kg	20	70	**4.17**	**4.63**	**4.36**	**5.2**	**4.62**	**5.21**
Cadmium	0.1	mg/kg	1.5	10	**0.6**	**0.5**	**0.5**	**0.8**	**0.3**	**0.3**
Total Chromium	1	mg/kg	80	370	**25.5**	**20.8**	**24.7**	**23.9**	**18.5**	**24**
Copper	1	mg/kg	65	270	**67**	**65.9**	**51.8**	**73.5**	**16.3**	**48.6**
Lead	1	mg/kg	50	220	**47.6**	**123**	**75.8**	**122**	-	-
Mercury	0.01	mg/kg	0.15	1	**0.1**	**0.11**	**0.08**	**0.13**	**0.16**	**0.12**
Nickel	1	mg/kg	21	52	**11.6**	**8.1**	**11.7**	**10.4**	**8.2**	**11.7**
Zinc	1	mg/kg	200	410	**164**	**192**	**180**	**504**	**115**	**110**
Heavy Metals (Extractable by ICPMS)										
Arsenic	1	mg/kg	20	70	**1.4**	<1.0	<1.0	<1.0	**1.1**	**2.6**
Cadmium	0.1	mg/kg	1.5	10	**0.56**	**0.46**	**0.39**	**0.7**	**0.26**	**0.3**
Total Chromium	1	mg/kg	80	370	**2.3**	**1.8**	**1.4**	**2.9**	**1.2**	**1.5**
Copper	1	mg/kg	65	270	**2.4**	**1.8**	**1.8**	<1.0	**1**	**10.8**
Lead	1	mg/kg	50	220	**36.4**	**84.4**	**55**	**105**	-	-
Mercury	0.1	mg/kg	0.15	1	<1.00	<1.00	<1.00	<1.00	<0.1	<0.1
Nickel	1	mg/kg	21	52	**1.1**	**1.3**	**1.2**	**1.1**	**1.2**	**3.1**
Zinc	1	mg/kg	200	410	**141**	**165**	**147**	**500**	**99.7**	**97.9**
Total Recoverable Hydrocarbons in Soil - Solica Gel Cleanup										
TRH C10-C14	50	mg/kg	---	---	<150	<150	<150	<150	-	-
TRH C15-C28	100	mg/kg	---	---	<300	<300	<300	<300	-	-
TRH C29-C36	100	mg/kg	---	---	<300	<300	<300	<300	-	-
TRH C10-C36 (Total)	50	mg/kg	280	550	<150	<150	<150	<150	-	-
Total Recoverable Hydrocarbons (2013 NEPM)										
TRH>C10-C16	50	mg/kg	---	---	<150	<150	<150	<150	**2.2**	**9.0**
TRH>C10-C16 less Naphthalene (F2)	50	mg/kg	---	---	<150	<150	<150	<150	**2.2**	**9.0**
TRH >C16-C34 (F3)	100	mg/kg	---	---	<300	<300	<300	<300	**48.1**	**169.9**
TRH >C34-C40 (F4)	100	mg/kg	---	---	<300	<300	<300	<300	**19.1**	**57.6**
TRH>C10 - C40 (Total)	50	mg/kg	280	550	<150	<150	<150	<150	**69.3**	**236.2**

Notes

mg/kg = milligram per kilogram

LOR = limits of reporting

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.

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