Guideline for the Assessment and Management of Acid Sulfate Soils

EHTM Attachment 9B

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Contents

Abbreviations

Term / Acronym	Meaning
ASS	Acid sulfate soils
AAASS	Atlas of Austrlaian Acid Sulfate Soils
ANC	Acid neutralising capacity
ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure (1999, as amended 2013)
CSIRO	The Commonwealth Scientific and Industrial Research Organisation; an Australian Government agency responsible for scientific research
DIT or the Department	Department for Infrastructure and Transport
DSI	Detailed Site Investigation
EHIA	Environment and Heritage Impact Assessment
EHTM	Environment and Heritage Technical Manual
EPA	South Australian Environment Protection Authority
EPP	Environment Protection Policy
EP Act	*Environment Protection Act 1993*
MBO	Monosulfidic black ooze
mAHD	metres Australian Height Datum
PASS	Potential Acid Sulfate Soils
PCA	Potentially Contaminating Activity
The Standard	EPA (2013) Standard for the production and use of waste derived fill
WQ EPP 2015	Environment Protection (Water Quality) Policy 2015

1 Introduction

The Guidelines for the Assessment and Management of Acid Sulfate Soils (the Guideline) forms Attachment 9B of the Department's Environment and Heritage Technical Manual (EHTM). This guideline provides instruction for the assessment and management of acid sulfate soils (ASS) which may be disturbed during construction of infrastructure projects or maintenance activities. This document applies to a range of Department programs and projects including road, rail, marine and other infrastructure, as required. The document applies to employees of the Department (direct or contracted) and others operating under the direction of the Department.

It is expected that, unless otherwise approved by the Department, Contractors undertaking the works described in this Guideline are suitably qualified professionals, listed on, or that can demonstrate their eligibility to be listed on, the Department's Professional and Technical Services Prequalification for Contamination Services.

1.1 Performance Outcomes

To meet the performance requirements under this Guideline, unless specified otherwise in the Contract documentation, the following shall be achieved:

- Assessment of impacts and implementation of management/mitigation measures to minimise the risk for significant impacts to occur as a result of disturbing acid sulphate soils.

1.2 Legislative Context

The relevant legislation and guidelines with regard to the assessment and management of acid sulfate soil are as follows:

- *Environment Protection Act 1993* Section 25;
- Environment Protection (Water Quality) Policy 2015 (WQ EPP 2015); and
- EPA Guideline, Site Contamination – acid sulfate soil materials EPA 638/07 (November 2007).

In addition, all works undertaken during the assessment of potential beneficial reuse of solid waste must be undertaken in accordance with the relevant EPA) Standards and Guidelines as well as the National Environment Protection (Assessment of Site Contamination) Measure (1999, as amended 2013).

Waste soil that contains any sulfidic ores or soils or any other waste does not classify as virgin material. Furthermore any activity that causes oxidation of iron sulfides in ASS material (sulfidic material) resulting in formation of sulfuric material is considered a potentially contaminating activities as prescribed in the Environment Protection Regulations (2009).

2 Acid Sulfate Soils

'Acid sulfate soils' (ASS) is the name given to those soils or sediments in which sulfuric acid may be produced, is being produced, or has been produced in amounts that have a lasting effect on main soil characteristics.[1] These soils contain sulfide minerals (principally iron sulfides) or are affected by geochemical or biochemical transformations of sulfide minerals. In coastal regions iron sulfides are formed during contemporary or historical sea-level inundation when seawater or brackish waters containing dissolved sulfate cover organic-rich environments such as swamps, mangroves, salt marshes or tea-tree.

Under oxygen-depleted conditions, iron present within soils or sediments combines with sulfur from sulfate to form iron sulfides, in particular pyrite (FeS_2). When these sulfides are disturbed and exposed to air, oxidation occurs and sulfuric acid is produced. These soils may either contain acidity or have the potential to form acid in amounts that either drain into waterways or react with carbonates and clay minerals in soils or sediments to liberate dissolved aluminium, iron, manganese, and other metal(loid)s such as copper and arsenic. If a buildup of acid or dissolved ions then occur, this can be extremely toxic to plants and animals in adjacent water bodies.

Prolonged exposure of coastal ASS to air also causes 'soil ripening' – an irreversible loss of water resulting in physical, chemical and biological changes to the soil. Soils can shrink fifty per cent or more by volume, particularly if peat topsoil is oxidised or areas are drained. This in effect causes lower elevations in drained areas compared to those that remain undrained. ASS are widespread throughout the world in coastal and inland areas.

ASS may be acidic (i.e. contain sulfuric material, pH<4; (e.g. Figure 2-1) or may have the potential to generate sulfuric acid when exposed to oxygen because of the presence of sulfide minerals, principally pyrite (i.e. they contain hypersulfidic or hyposulfidic materials (Figure 2-1 and Figure 2-2).

The following nationally accepted definitions of ASS materials are used to define the 'potential' or 'actual' acidification hazard[2]:

- **Hypersulfidic material:** sulfidic material that had a field pH of 4 or more and the pH dropped by at least 0.5 units to less than 4 when incubated at field capacity for at least 8 weeks
- **Hyposulfidic material:** sulfidic soil material that had a field pH of 4 or more and the pH dropped by at least 0.5 units to not less than 4 when incubated at field capacity for at least 8 weeks
- **Sulfuric material:** soil material that has a pH <4 (1:1 by weight in water, or in a minimum of water to permit measurement) when measured as a result of the oxidation of sulfidic materials and evidence of sulfidic material, such as underlying sulfidic material and/or the presence of yellow masses of jarosite along old root channels and faces of peds
- Monosulfidic material: soil material containing ≥0.01% acid volatile sulfide.

Classification of ASS materials and conceptual terminology used to describe ASS materials are summarised in Table 2-1.

Table 2-1 Classification of ASS Materials and Hazards

ASS Classification	Conceptual terminology	Definition (summarised)	Hazards[1]		
			Acidity hazard	**Metal mobilisation**	**Deoxygenation**
Sulfuric material	Actual ASS (AASS)	ASS materials that have been oxidised and are severely acidic (pH ≤ 4) when measured as a result of the oxidation of sulfidic materials and evidence of sulfidic material, such as underlying sulfidic material and/or the presence of yellow masses of jarosite along old root channels and faces of peds	Existing - almost certain extreme impact	Existing - almost certain major impact	Latent - possible moderate impact
Sulfidic materials: (3 types):	ASS material containing greater than or equal to 0.01% Reduced Inorganic Sulfur (RIS) by mass. The three types of sulfidic material include:				
Hypersulfidic material	Potential ASS (PASS)	ASS materials that will form *sulfuric material* and become severely acidic (pH ≤ 4) if allowed to oxidise completely	Latent - almost certain extreme impact	Latent - almost certain major impact	Latent - possible moderate impact
Hyposulfidic material	Non-ASS	ASS materials that would not become severely acidic if allowed to oxidise completely. Commonly form moderately acidic soils upon oxidation (pH 4 ≥ 5.5)	Latent - possible moderate impact	Latent – likely moderate impact	Latent - possible moderate impact
Monosulfidic material	PASS or Non-ASS	ASS material containing greater than or equal to 0.01% Acid Volatile Sulfide. Commonly form moderately acidic soils upon oxidation (pH 4 ≥ 5.5)	Latent – possible major impact	Latent – likely major impact	Latent – almost certain major impact

[1] Health and ecological risk assessment methodologies are detailed in Schedule B4 of the of the National Environment Protection (Assessment of Site Contamination) Measure as varied 2011). Disturbance of ASS materials is a potentially contaminating activity. The level of health and ecological risk associated with each identified ASS hazard is specific to the nature of the site and disturbance proposed.

When ASS with hypersulfidic material dry, oxidation of pyrite may cause strong acidification (pH <4) and form sulfuric material. Resaturation of ASS with sulfuric material can lead to reformation of pyrite and pH increase (but this may take months to years) due to activity of sulfate-reducing bacteria, which also require available organic carbon.

ASS can be investigated to determine the net acidity wihtin the soil. A positive net acidity indicates an acid-generating potential greater than the acid-neutralising capacity of the soil. A negative net acidity indicates an excess acid-neutralising capacity, which in theory could prevent the soil becoming an acidification hazard.

Black monosulfidic material (Figure 2-3) with gel-like consistency is common in many areas such as adjacent to the barrages in Lake Alexandrina (e.g. the Tauwitchere Barrage as shown in Figure 2-3) and in the Coorong[3,4]. Monosulfidic material comprises a low-density material, which contains monosulfide minerals (FeS) that are still waterlogged. These materials also incorporate the previously used term 'monosulfidic black ooze' (MBO). Monosulfidic material generally has a field pH of 4 or more, commonly pH >7–8, and while it may not become extremely acidic (pH <4) when drained, it can rapidly deoxygenate surface water if disturbed.

In most cases, when all three types of acid sulfate soil materials are permanently saturated or form part of a subaqueous soil they are benign unless disturbed.

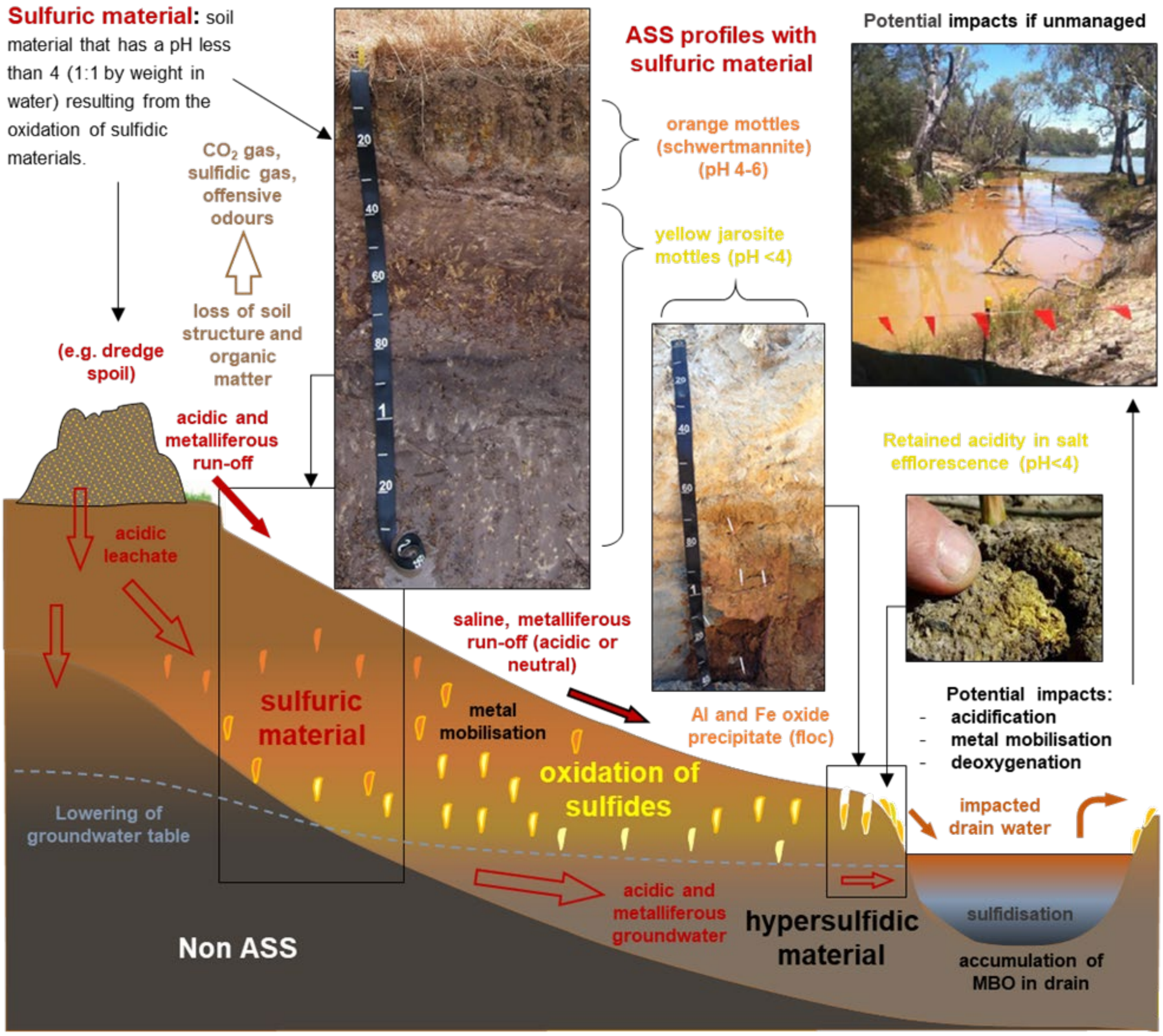

Figure 2-1 Conceptual model for the oxidation of sulfidic material and formation of sulfuric material.

Figure 2-1 illustrates characteristic features that develop when an ASS profile is drained. The typical ASS profile shows: (top soil) calcareous clay (non ASS) with neutral pH overlaying sulfuric material (pH <4) with prominent orange and pale yellow mottles containing jarosite in brown peaty clay and grey subsoil layers. Dark greyish brown hypersulfidic material (pH>4) occurs below the depth of groundwater lowering.

A B

Figure 2-2 Hypersulfidic material in permanently saturated contemporary tidal zones featuring layers with dominant: A (left) sulfidic material with highly decomposed roots from mangrove trees and samphire vegetation, and; B (right) sulfidic material with moderate

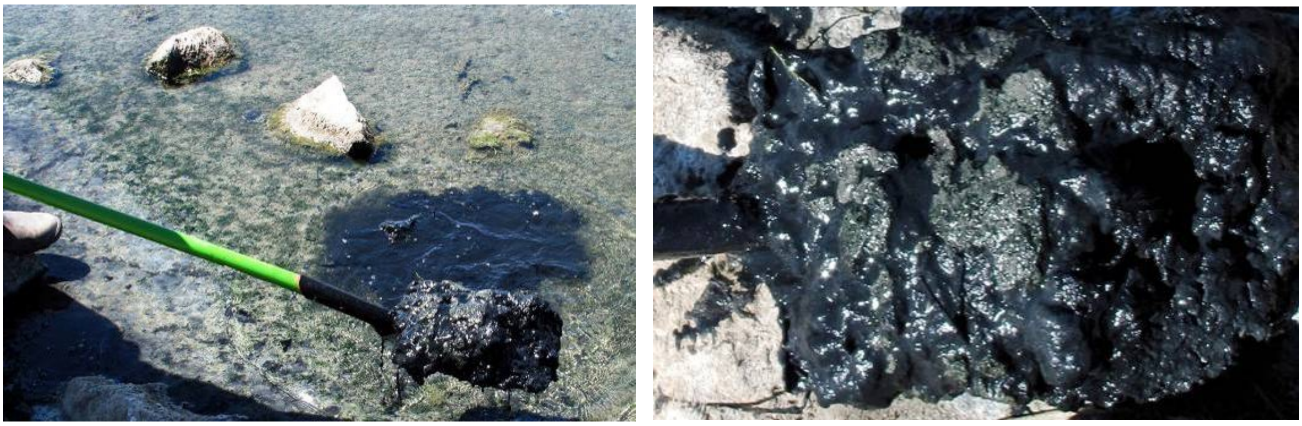

Figure 2-3 Black monosulfidic material from under water at the Tauwitchere Barrage in Lake Alexandrina adjacent to the Coorong[3].

3 Occurrence of Acid Sulfate Soils

Much pyrite in sulfidic material was formed by natural processes during the Holocene epoch (last 11,650 years) and were originally deposited in marine, estuarine or river settings and occur predominantly in low-lying areas near the coast, such as coastal floodplains, rivers and creeks, deltas, coastal flats, back swamps and mangrove areas (e.g. Figure 3-1 a, c). Contemporary acid sulfate soil materials have also formed, particularly where landscape salinisation has occurred and stable water levels have been maintained for a long period of time (e.g. River Murray pre-Millennium Drought, including inland in areas such as wetlands, rivers and lakes (e.g. Figure 3-1 b). Acidic and saline conditions inherent to acid sulfate soils landscapes are highly corrosive to concrete and steel structures (e.g. Figure 3-1 d). Of the 215,000 km^2 of ASS in Australia, 58,000 km^2 is coastal ASS and 157,000 km^2 is inland ASS[4-8].

A. ASS with sulfuric material underlying dead mangroves and monosulfidic black ooze (MBO) or monosulfidic material in water ways behind the bund wall at Gillman

B. ASS with sulfuric material showing bright reddish orange Fe precipitates in irrigation areas Lower Murray

C. Acid sulfate soils were created as the Lower Lakes dried out during the drought in 2008 (DEWNR)

D. Impact of sulfuric material on engineered structures

Figure 3-1 Examples of disturbed coastal and inland acid sulfate soil landscapes

In South Australia, acid sulfate soils occupy approximately 2,410 km^2 (refer Figure 3-2). The risk distribution of ASS material across Australia is available from the [Australian Soil Resource Information System](). An example of the ASS map for Adelaide Metropolitan area is provided in Figure 3-3.

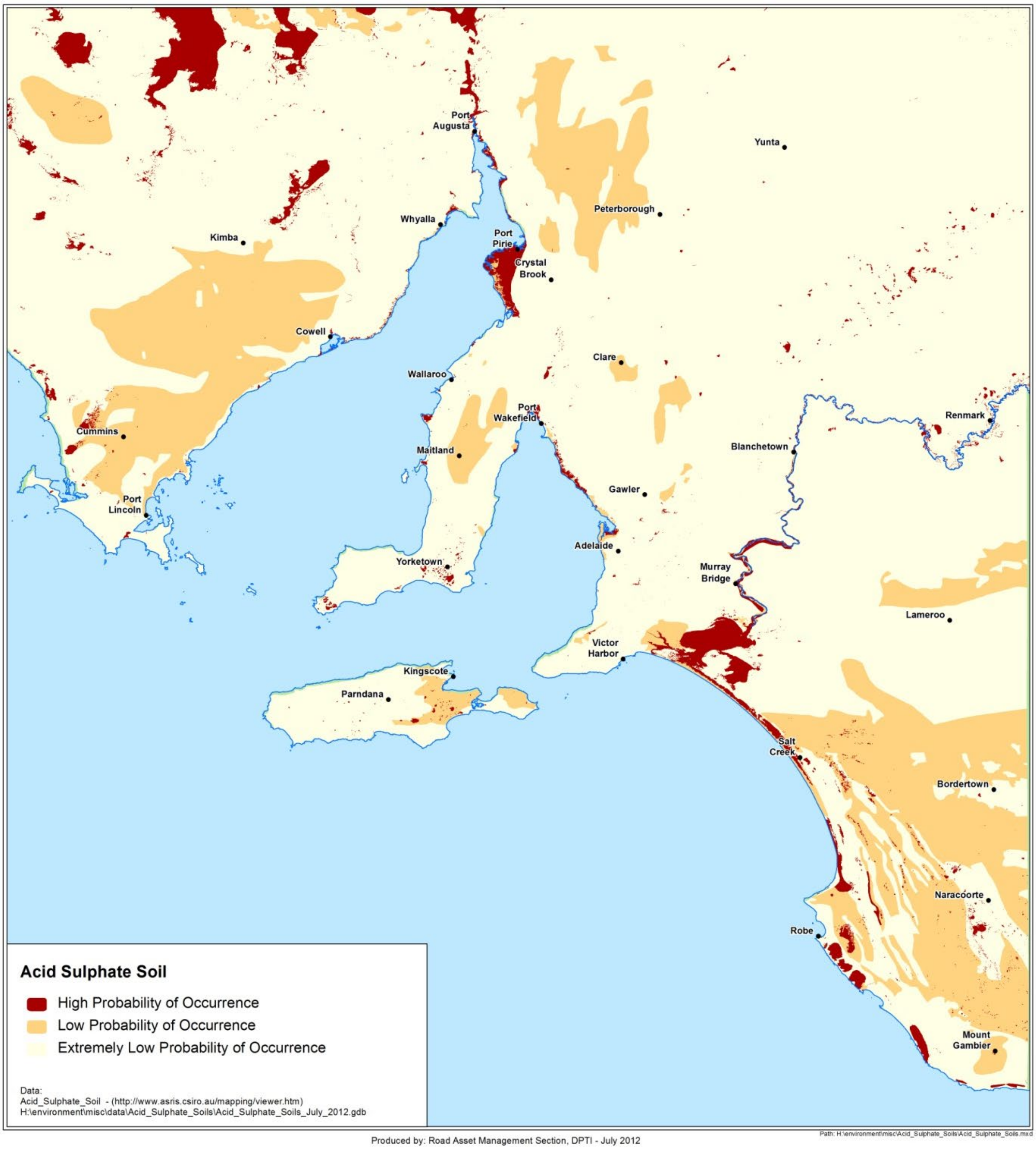

Figure 3-2 Map of probability of occurrence of ASS in South Australia (developed from www.asris.csiro.au).

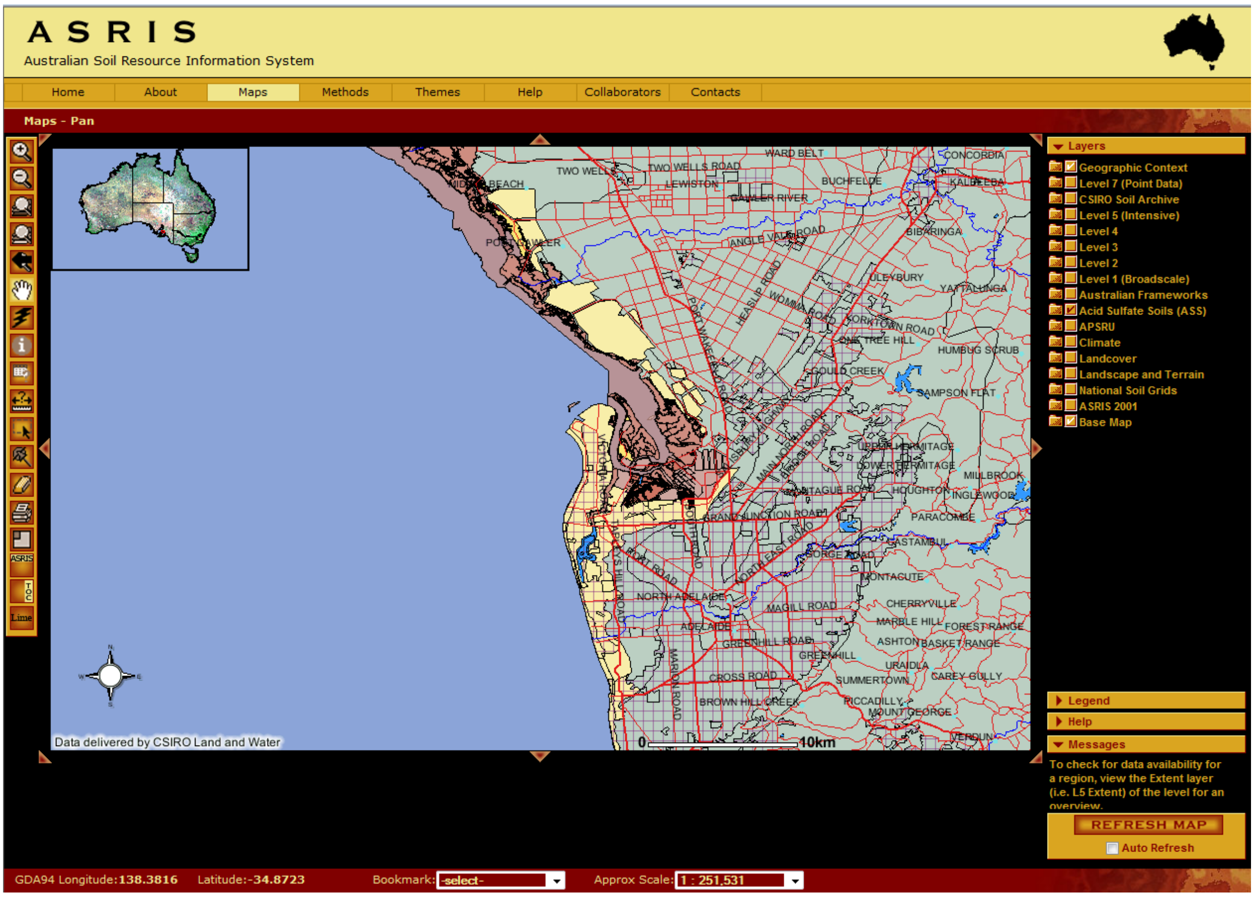

Figure 3-3 ASRIS ASS material Metropolitan Map (www.asris.csiro.au)

In South Australia, Coastal ASS are typically associated with Coastal Plain and Lower Alluvial Plain soils[9], and with undifferentiated Quaternary coastal marine sediments of the St Kilda Formation, and to a lesser extent the underlying Quaternary (Pleistocene) clays of the Pooraka Formation (based on the Geological Survey of South Australia 1:250,000 Map Sheet Series). Coastal ASS are common where saline groundwater comes close to the land surface (within approximately 1 m or so) and where flooding and waterlogging are common. Coastal ASS with monosulfidic material may occur in tidally influenced and permanently inundated areas (subaqueous soils), mudflats, sabkahs or buried beneath fill soils (or waste) in re-claimed coastal wetlands. The St Kilda sediments consist of a variety of sedimentary materials derived from marine beach, coastal dune, estuarine and back barrier lagoon depositional environments. These sedimentary units may extend many kilometres inland or occur at depth in areas that were once covered by seawater during the Holocene interglacial, when sea levels reach up to 6 m above present day heights.

The occurrence of ASS in Lakes and River Floodplain settings gained attention during the millennial drought (2000-2010) when large areas of the Lower Lakes and River Murray wetlands acidified. Inland ASS are likely to occur in floodplain and wetland environments containing organic-rich sediments, or in areas where saline groundwater tables are in close proximity to the soil surface. In South Australia inland ASS are typically associated with wetland soils, waterlogged subsoils and deeper sediments of the Monoman Formation. The lower Loxton-Parilla Sands are also likely to be sulfidic and have potential to acidify if disturbed during construction or groundwater dewatering activities.

4 Potential Impacts of Acid Sulfate Soils

ASS with sulfuric (pH<4) material can affect land use, development and amenity of the surrounding environment and may have an impact on the following:

- Engineering and landscaping works:
  - Sulfuric acid generation can result in the corrosion of concrete, steel and some aluminium alloys used in buildings, drainage systems and roads (e.g. Figure 3-1 c).
  - The use of ASS material as site fill material or in embankments can affect plant growth.
- Agricultural practices:
  - Both acidity and increased mobilisation of soluble metals commonly arsenic (As), aluminium (Al), nickel (Ni), cobalt (Co), iron (Fe) and manganese (Mn), may result in direct plant toxicity and decreased uptake availability of some nutrients, as well as a potential reduction in farm productivity.
  - ASS material may also result in a decrease in animal productivity via a decrease in pasture quality and an increased uptake of aluminium and iron by grazing animals.
- Fish and aquatic life:
  - Acidic waters entering estuarine, coastal or riverine environments can result in mortality of fish and crustaceans and can affect plants through direct acid exposure, smothering of aquatic plants by iron precipitates and toxicity by aluminium and other metal(loid)s.
- Local Amenity:
  - The presence of ASS material can produce an offensive odour, predominantly due to hydrogen sulfide (H2S - rotten egg gas).
- The potential environmental impact of acid sulfate soil material depends on a number of factors, including:
  - Exposure to oxidising conditions - hypersulfidic material will not generate acidic discharge unless exposed to oxygen or other oxidising agents;
  - The nature and extent of the sulfidic characteristics of the material - these characteristics can vary widely and will affect both the amount and concentrations of acidic discharge and the rate of generation;
  - The capacity for self-neutralisation - acidic discharge may be neutralised, depending on the amount and type of neutralising material available in the soil;
  - The buffering capacity of the receiving environment - acidic discharge may be neutralised by the presence of organic material, limestone or dolomite and the buffering effects of some water in the receiving environment;
  - The proximity to risk receptors (e.g. drinking water supply offtakes, sensitive aquatic ecosystems).

These factors determine the environmental risk posed by ASS and should be assessed on a case-by-case basis.

5 Assessment Procedure

An assessment of the potential for acid sulphate soils to be present within the project area and encountered during project works should be identified early in the planning phase of a project. This information is to be documented within the environment and heritage impact assessment documentation as well as being identified within the project risk assessment. The extent of ASS within the project area will have potential implications on construction methodology as well as construction materials selection.

The aim of this guideline is to provide a practical method to identify and manage inland and coastal acid sulfate soil (ASS) risks in South Australia. The assessment method comprises the following 7 Steps:

Step 1- Initial Characterisation

The initial or screening stage involves verification of the presence of ASS materials at a particular site. The Atlas of Australian Acid Sulfate Soils (AAASS) and/or State agency mapping websites (e.g. NatureMaps) should be consulted to assess the potential presence of ASS (see BOX 1).

BOX 1

Check the ASRIS website www.asris.csiro.au and relevant State agency mapping websites (e.g. NatureMaps) to assess the potential presence of ASS within the project area.

The Atlas of Australian Acid Sulfate Soils (AAASS)

The AAASS was compiled to provide a consistent national collation of Australia's acid sulfate soils. The AAASS is housed within the Australian Soil Resource Information System (ASRIS), a web-based hazard assessment tool providing information about the distribution and properties of both coastal and inland acid sulfate soils across Australia.

The AAASS represents the most extensive depiction of ASS across the nation to date. AAASS web-based hazard assessment tool *note: you need to check the 'acid sulfate soils box' on the right hand side Layers Menu and refresh the map*

AAASS Data Repository

The desktop review stage may provide sufficient detail on ASS characteristics and extent to establish the risk level for small scale disturbances. Figure 5-1 and Figure 5-2 provide additional tools for assessing the likely presence of ASS materials occurring and the potential need for management based on the location and size of disturbance proposed.

Note that survey data (to determine the elevation of the project area in m AHD) may be obtained from the project survey (if available) or from the SA Property and Planning Atlas (refer to the Location Layer and turn on the Survey Marks dataset).

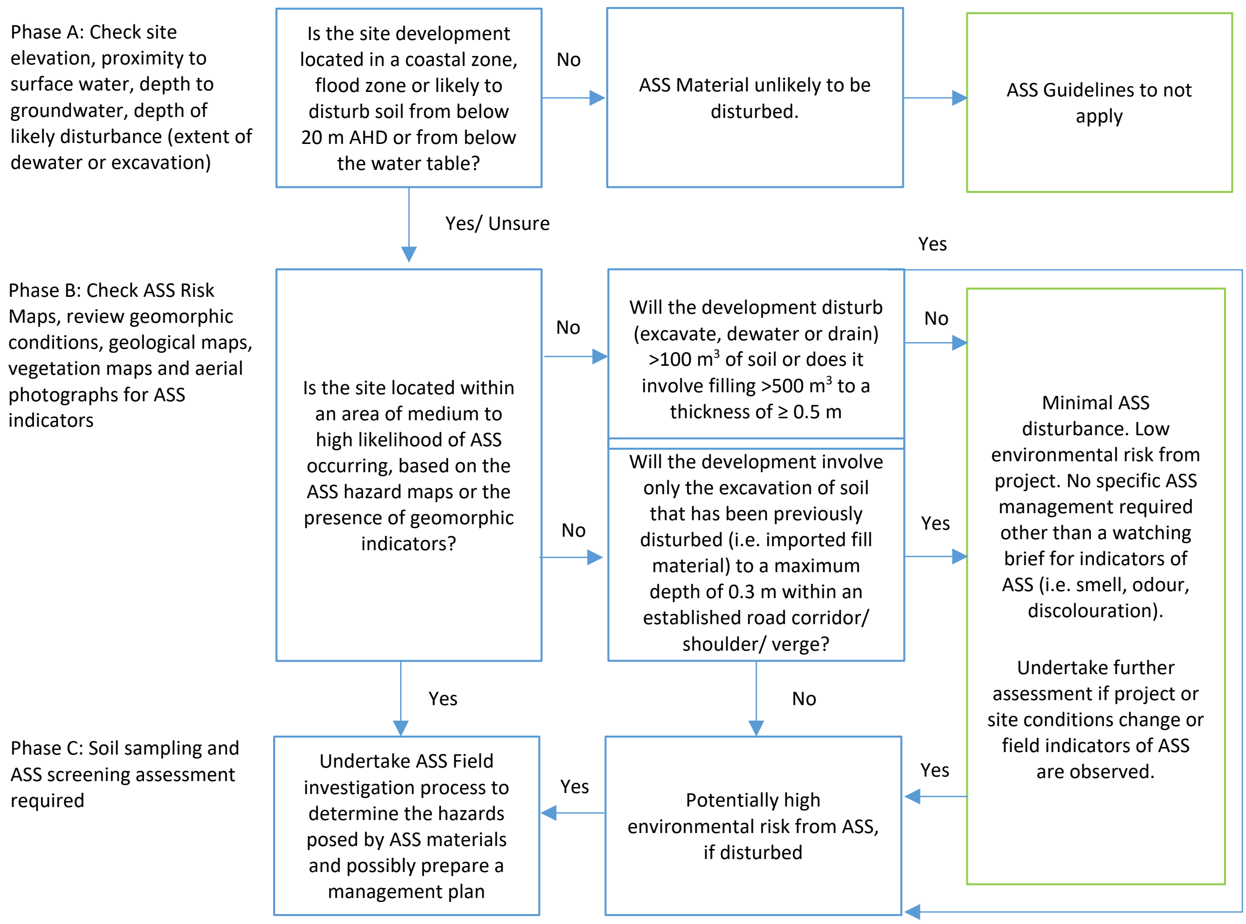

Figure 5-1 Summary of Desktop Assessment criteria for both coastal and inland environments (refer also to Figure 5-2).

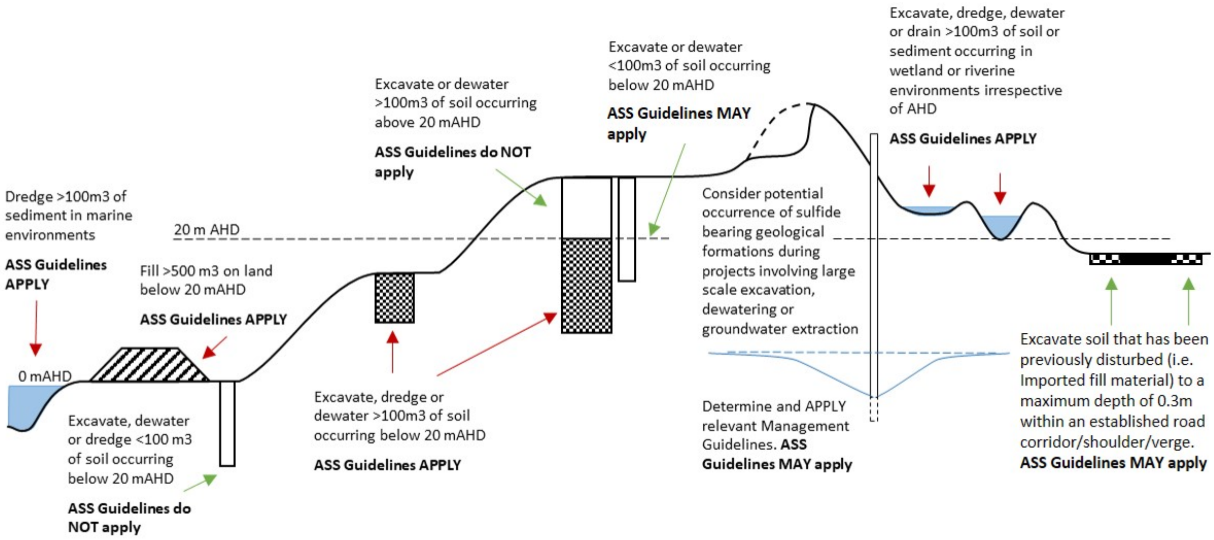

Figure 5-2 Areas and developments that may require an ASS investigation and management plan.

Coastal ASS are likely to be found in coastal embayments and estuarine back swamps, or in buried marine geological formations below about 20 m AHD (Australian Height Datum). Inland ASS are likely to occur in riverine, lacustrine and wetland sediments irrespective of elevation.

Step 2 - Problem categorisation

Undertake a literature review on ASS characteristics and extent (e.g. the AAASS and State agency or CSIRO maps and data bases should be interrogated to estimate percentage coverage of ASS), site characteristics, historical background, background monitoring data and environmental values.

This information is used to construct a conceptual site model (e.g. soil-regolith model) to identify the various types and subtypes of coastal ASS and the generalised pathways of formation and exposure within the project area as well as receptors that require protection (Figure 2-1) is an example of a conceptual site model).

Step 3 - Design an ASS Material Detailed Site Investigation

Design a more detailed field ASS investigation that addresses the sampling plans (e.g. number of sampling sites along key transects) and the suite of laboratory methods to use. The investigations should be designed to address gaps identified in the conceptual site model and be sufficient to inform management requirements during the construction and operation of the project.

All ASS Material Detailed Site Investigations (DSI) should be designed and executed by suitably qualified site contamination consultants with experience undertaking ASS Assessments. The DSI involves taking soil samples, either in-situ or from stockpiled material post-excavation for field and laboratory testing.

The design of the investigation should be specific to the project location and type of ASS material understood to be potentially present (e.g. adopting procedures specifically suitable for coastal areas such as tidal zones and mangrove swamps). This can encompass the re-sampling or sampling of soil layers from geographically well-distributed and locally representative sites (soil profiles) and analysed using a combination of standard methods: (i) soil morphology, (ii) field pH testing, (iii) peroxide testing, (iv) acid-base accounting, (v) soil incubation (ageing), and (vi) selected samples for metal mobilisation analyses. In this regard, standard field observations and laboratory tests sufficient to diagnose coastal ASS must be undertaken by consulting the following National and Regional guidelines and other resources.

BOX 2

Use the following guidance to appropriately identify and assess ASS during site investigations.

Field methods:

- National Acid Sulfate Soils Guidance (2018) National acid sulfate soils sampling and identification methods manual — technical and practical advice on the identification and sampling of ASS materials prior to field investigations. Also provides sampling requirements necessary to define the extent of ASS materials in the landscape.

Laboratory methods:

- National Acid Sulfate Soils Guidance (2018) National acid sulfate soils identification and laboratory methods manual — sets out the current good practice ASS laboratory analytical methods for soil samples.

Assessment Criteria

- EPA Guideline, Site Contamination – acid sulfate soil materials EPA 638/07 (November 2007) – provides developers with procedural advice to avoid environmental harm from ASS and to implement best practice environmental management principles.
- National Acid Sulfate Soils Guidance (2018) National acid sulfate soils identification and laboratory methods manual - Used to conclusively identify the presence or absence of ASS and to quantitatively assess associated hazards.

If dredging or dewatering is being undertaken as part of the project works the relevant National Guidance documents should be consulted and used (refer to Box 3). When determining the borehole sampling density, reference should be made to Schedule B(2) of the National Environmental Protection (Assessment of Site Contamination) Measure (1999, as amended 2013), Australian Standards AS 4482.1, and National Guidance documents (refer to Box 2).

If sampling from stockpiles, the exhumed material should be managed with the assumption that it contains problematic ASS material i.e. ASS with sulfuric material, hypersulfidic material and/or monosulfidic material). The stockpile sampling density and testing requirements will depend upon specific project details, but should be undertaken having regard to the density requirements specified in the Australian Standards 4482.1 and National Guidance documents.

Step 4 – Execute ASS Investigation

Conduct detailed field and laboratory investigations in accordance with the ASS Investigation Design using field and laboratory protocols. Pending any field observations, modifications to the designed analytical schedule may be required.

Presence of Field Indicators On-Site

Potential ASS material indicators as described by the EPA ASS material guideline (EPA 638/07) and national sampling guidance documents listed above (Box 2) include:

Indicators for potential acid sulfate soil conditions include:

- waterlogged, unripe muds (soft, buttery texture, blue grey or dark greenish grey) or estuarine silty sands or sands (mid to dark grey) or bottom sediments of estuaries and tidal lakes (dark grey to black);
- a pH of less than 7 (The pH scale changes by 10 with each unit. So a pH of 4 is 10 times more acid than pH 5 and 100 times more acid than pH 6.0);
- positive peroxide test; or
- hydrogen sulfide (H_2S) odour (e.g. the smell of rotten eggs);

indicators for actual acid sulfate soil materials and conditions include:

- unusually clear or milky blue-green drainage water within or flowing from the area (aluminium released by the sulfuric material or ASS material acts as a flocculating agent);
- extensive iron stains (reddish orange colour) on any drain or pond surfaces, or iron-stained water and mineral deposits;
- water of pH<6.5 in adjacent streams, drains, groundwater or ponding on the surface;

- soil pH <4;
- jarosite present in surface encrustations or in any material dredged or excavated and left exposed;
- corrosion of concrete and/ or steel structures; or
- sulfurous smell when the soils are oxidised or disturbed.

Based on the desktop and field investigations, a decision can be made as to whether ASS materials are likely to be disturbed, and whether further assessment is required to quantify and manage the hazards. Where there is sufficient certainty that ASS materials will not be disturbed, no further assessment will be required. This decision (to undertake no further assessment) must be supported by an appropriate level of the detailed sampling and laboratory analysis if the development site is in an area where ASS materials are mapped or are expected to occur.

Interpretation of Soil and/or Water Testing Results

The DSI is required to classify ASS material types, which ultimately define the hazards associated with ASS disturbance. This information is required to identify appropriate management requirements, which may include treatment, onsite reuse or disposal.

Analysis of ASS materials is undertaken to determine if the soils are likely to generate any net acidity, and the quantity of this acidity and any acid neutralising capacity (ANC) present which collectively is known as the acid base account (see National Guidance on identification and laboratory methods, Box 2).

As detailed in the National Acid Sulfate Soils Guidance documents (refer to Box 3), action criteria based on net acidity (Table 5-1) trigger the need to prepare an ASS management plan that addresses the acidity and other ASS hazards (e.g. metal mobilisation and deoxygenation) that may be applicable to a project site.

Action Criteria

As clay content tends to influence a soil's natural buffering capacity, the action criteria are grouped by three broad texture categories – coarse, medium and fine, and by the magnitude of ASS disturbance. If the Net Acidity of any individual soil material tested is equal to or greater than the action criterion further ASS investigations are required and a detailed ASS management will need to be prepared.

Table 5-1 Action criteria Based on The Texture and Volume of Material Disturbed

Type of material		**Net Acidity#**			
		1–1000 t materials disturbed		**> 1000 t materials disturbed**	
Texture range* **(NCST 2009)**	**Approximate clay content (%)**	**% S-equiv. (oven-dried basis)**	**mol H^+/t (oven-dried basis)**	**% S-equiv. (oven-dried basis)**	**mol H^+/t (oven-dried basis)**
Fine: light medium to heavy clays	> 40	≥ 0.10	≥ 62	≥ 0.03	≥ 18
Medium: clayey sand to light clays	5–40	≥ 0.06	≥ 36	≥ 0.03	≥ 18
Coarse and Peats: sands to loamy sands	< 5	≥ 0.03	≥ 18	≥ 0.03	≥ 18

* If bulk density values are not available for the conversion of cubic meters to tonnes of soil, then the default bulk densities, based on the soil texture may be used – as outlined in Sullivan et al (2018).

Net Acidity can only include a soil material's measured Acid Neutralising Capacity where this measure has been corroborated by other data (for example slab incubation data) that demonstrates the soil material does not experience acidification during complete oxidation under field conditions. Source: Adapted from Dear et al. (2014). Concentrations provided on an 'oven-dried basis.'

The National ASS Guidelines (Box 2) provide additional information and Case Studies relating to the identification of ASS materials, laboratory methods and applying the assessment criteria. When applying the assessment criteria it is important to note that disturbances of poorly-buffered sands with very low pyrite levels (<0.3% S) have led to groundwater acidification and subsequent arsenic contamination of domestic water supplies in Western Australia. The adoption of a lower action criteria may be applicable to some circumstances in South Australia.

All analytical methods have limitations, and the acid base accounting methods are not intended to assess indirect effects of disturbing ASS which may include:

- Release of soluble and flocculated iron, aluminium and other metals and metalloids (for example As, Cd, Co, Cr, Cu, Ni, Mn, Zn) or nutrients;
- Deoxygenation of surface waters by monosulfides or organic matter; and
- Release of noxious gases.

Further guidance on the assessment and management of these hazards can be obtained from the following documents listed in Box 3:

BOX 3

Use the following national guidance to assess and appropriately manage ASS you encounter during different soil management activities.

Dewatering:

- Guidance for the dewatering of acid sulfate soils in shallow groundwater environment**s** — technical and practical advice on managing ASS to help prevent or minimise harm to the environment.

Dredging:

- Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management — technical and procedural advice to avoid environmental harm from ASS encountered during dredging projects.

Disturbance of monosulfidic black ooze (MBO):

- Overview and management of monosulfidic black ooze (MBO) accumulations in waterways and wetlands — *technical and procedural advice to assess and manage MBOs encountered in waterways and wetlands.*

Step 5 - Assess Hazard/ Risk

The DSI results should be used to determine the spatial distribution of three relative hazards - (i) Acidification, (ii) Metal Mobilisation and or (iii) Deoxygenation, associated with the presence of ASS materials and various ASS subtypes.

The hydrogeochemical processes that are responsible for these hazards are inherently linked, in that both acidification and redox status are likely to influence the mobilisation of metals and metalloids. These hazards may present:

- an 'existing' risk to environmental receptors i.e. where the hazard has been measured or observed; or
- a 'potential' hazard to environmental receptors i.e. where laboratory analyses of soil properties indicates that a hazard is likely to eventuate if environmental conditions are changed (refer to Table 2-1 and Table 5-2)

The net acidity values of all samples tested should be compared to the appropriate ASS action criteria (see Table 5-1) to determine the magnitude of the acidity hazard, which will assist in determining the available management options. To guide management planning, a risk category can be assigned to different areas of a project area (referred to as map units). The map units may represent soil types or for small homogeneous sites they may represent areas (or volumes) of proposed ASS disturbance. Maps and cross-sections populated with ASS characteristics provide an effective means to evaluate the environmental risk posed by a planned disturbance. Note that environmental risk increases in line with net acidity and the level of treatment needed.

The development and presentation of ASS hazard maps are described further in Case Studies in Appendix B). The presence of key risk receptors (e.g. water supplies, aquatic species, vegetation such as mangrove swamps) and pathways should be assessed. A conceptual site model should be utilised to identify hazards and risks under the management scenarios being considered (e.g. excavation, stockpiling and treatment for disposal, or to manage the implementation of wetting and drying cycles at a wetland site).

Table 5-2 General Relationships between ASS Material and Hazard Types

Acid sulfate soil type	Acidification Hazard	Metal Mobilisation Hazard	Deoxygenation Hazard
Sulfuric material *(Actual ASS)*	Existing	Existing	Potential
Hypersulfidic material *(Potential ASS)*	Potential	Potential	Potential
Monosulfidic material	Potential	Potential	Potential
Hyposulfidic material	Potential	Potential	Potential
Moderately acidic material	Potential or existing	Potential	Potential
Non-acid sulfate soils	Negligible	Negligible	Negligible

Likelihood:	High / Mod / Low	High / Mod / Low	High / Mod / Low
Consequence (environmental degradation):	Soil and groundwater acidification to pH 4 or less	Mobilisation of metals and contaminants due to dispersal of sulfides, oxidation products and/or acidic leachate	Deoxygenation of surface waters due to the formation and disturbance of MBO

Step 6 - Decide on Management Options

A summary of general management principles and options for the main ASS hazards encountered is provided below. The hazard ratings and management principles need to be applicable to the ASS hazards identified at the site and project details.

Assess Project Alternatives to Avoid Impacts

Where ASS with sulfuric and hypersulfidic materials are present or suspected to occur on a site, where practical, the materials should not be disturbed. It may be appropriate to select an alternative non-acid sulfate soil site rather than undertake remediation of impacts caused by disturbance of ASS materials. If an alternative site is not feasible, works should be designed to minimise the need for excavation or disturbance of ASS materials.

Prepare an ASS Management Plan

Where disturbance of the ASS material is unavoidable, the main objective of management is to prevent or minimise the potential for on- and off-site impacts, using the most cost-effective and environmentally sustainable methods. The suitability of management measures will depend on the nature and location of the ASS material. An ASS Management Plan should be prepared by a suitably qualified consultant prior to start of works.

Common management approaches include:

- Designing the works to avoid or minimise the need for excavation or disturbance of acid sulfate soil materials by:
  - Undertaking shallow excavations and drainage measures – viable where the ASS is at deeper levels
  - Avoiding lowering of groundwater and/ or surface water levels that may result in exposure of ASS material
  - Covering the surface with clean soil if acid sulfate soils materials are close to the surface.
- Prevent Oxidation – this may include staging the project to prevent oxidation and placing potential acid sulfate soil materials into an anaerobic environment (typically below the watertable).
- Minimise oxidation rate and isolate higher risk materials from exposure – this may include covering with soil or water to reduce oxygen availability and control of water movement, or other means (e.g. use of organic mulch) to reduce the oxidation rate.

- Contain and treat acid drainage to minimise risk of significant off-site impacts – typically installation of a leachate collection and treatment system. Contain acidic leachate within the soil profile using barriers.
- Neutralise acidity and manage the movement/ discharge of toxic oxidation products. Provide an agent to neutralise acid as it is produced –alkaline materials are physically incorporated into the soil to increase the overall pH of the product. Various neutralising agents are available but will depend on site specific conditions however may include dolomite, magnesite, hydrated lime and less often red mud, cement kiln dust or crushed concrete. The appropriate method should be discussed with a suitably qualified consultant.
- Treat acidic leachate before discharging into the receiving waters in accordance with the WQ EPP 2015.
- Collection and disposal to an appropriately licensed waste facility (a landfill facility that has a license condition to accept acid sulfate soil materials).
- Manage stockpiled materials – stockpiled acid sulfate soil material needs to be managed to ensure no adverse environmental impacts occur. Management measures should include:
  - Minimising the quantity and duration of storage;
  - Minimising the surface area that can be oxidised;
  - Covering the soil to minimise infiltration;
  - Stormwater control measures;
  - Controlling erosion and collection/ treatment of runoff.

The recommended maximum time period for short term stockpiling of ASS material (excluding monosulfidic materials which ideally should not be stockpiled), is detailed in Table 5-3.

Table 5-3 Indicative Maximum Periods for Short Term Stockpiling of ASS Material

Type of Material		Duration of Stockpile	
Texture Range	**Approx. Clay Content (%)**	**Days**	**Hours**
Coarse Texture Sands to Loamy Sands	≤ 5	Overnight	18
Medium Texture Sandy Loams to Light Clays	5-40	2.5	70
Fine Texture Medium to Heavy Clays and Silty Clays	≥ 40	5	140

Source: DEWPC (2007)

Reuse of ASS material requires an assessment by a suitably qualified consultant in accordance with the EPA Waste Derived Fill Guidelines and/ or the ASC NEPM (1999, as amended 2013) guidelines to determine suitable reuse options and/ or disposal options (as outlined in Box 4).

BOX 4

Notes on the use or reuse of waste soils:

- Waste soil that contains any sulfidic ores or soils or any other waste does not classify as virgin material.
- If a soil is excavated for removal from a site, then this becomes a waste and therefore the waste soil requires management in accordance with the EPA Standard for the production and use of waste derived fill (2013). Furthermore, the waste would be considered to be generated by a potentially contaminating activity (as defined by Environment Protection Regulations 2009), being any activity that causes oxidation of iron sulfides in ASS material (sulfidic material) resulting in formation of sulfuric material.
- Therefore, further investigations are required to consider re-use of ASS material on- and off-site.

An ASS material Management Plan should be prepared by a suitably qualified consultant prior to the excavation or disturbance of ASS material. The management plan should be prepared in accordance with the National ASS Management Guidelines.

Environmental management of on-site remediation should include:

- Environmental condition of the site and adjacent areas and potential impacts of the works proposed;
- Description of the proposed development and works;
- Description of the proposed ASS material management measures for all stages of construction and operation;
- Outline of a monitoring program for soils, surface water, groundwater and air during construction and operations, including parameters, monitoring locations, monitoring frequency, laboratory analysis and reporting protocols.
- Description of contingency measures to deal with unexpected events and failure of management measures and Remedial Management Plan (RMP).

Further information to include for particular activities (e.g. dredging, dewatering) is outlined in the National Guidance documents (see http://www.waterquality.gov.au/issues/acid-sulfate-soils).

Case studies of management of acid sulfate soils on Departmental infrastructure projects are included in Appendix A.

Step 7 - Monitoring

Both soil and water quality monitoring should be undertaken to detect changes in ASS conditions and nature of effluent discharges, and to assess the potential impact of the discharge on the downstream environment during project works.

Note on Work Health and Safety

Care should be taken in handling oxidised ASS materials and leachate as it may have a low pH. As well as the normal personal protective equipment, chemical gloves and protective eye wear should be worn. A risk assessment should be undertaken prior to handling the material.

6 Reporting

Unless specified otherwise in Contract Documentation the following reporting applies to each phase of the project. Reporting shall be provided to the Department's Technical Services Environment Unit for review and acceptance. Any report(s) that may require submission to the EPA are required to have been written/signed/endorsed by a Certified Environmental (Site Contamination) Practitioner. Where analytical data has been collected or utilised in the preparation of a report, a data quality assessment must be undertaken as part of the reporting. Further details regarding the project phases as detailed below can be found in the Introduction to the EHTM.

6.1 Proving

During the Proving Phase of a project, the following information may be required for input into an options assessment, the EHIA Report and to inform the cost estimation of the project.

Initial characterisation

This initial characterisation (Step 1 of the assessment procedure) and supporting documentation are to be incorporated into the EHIA report and summarised in the planning and/or design reports. Where multiple project options are being assessed and compared, the initial characterisation information is to be reported in a suitable location to inform such option comparisons.

6.2 Pre-Delivery/ Delivery

During the Pre-Delivery/ Delivery Phase of the project, an acid sulfate soil assessment and preparation of a management plan may be required (to be informed by the initial characterisation). Where not undertaken during the previous project phase, the initial characterisations should be undertaken at this phase of the project for the preferred design option.

Acid Sulfate Soil Assessment

Where required (as identified during the initial characterisation of the project works), a report detailing the outcomes of the next steps of assessment (including intrusive investigation) is required. This report should include the following as a minimum:

- Background and scope of works adopted for the assessment;
- Detailed summary of the approach and methodology for the assessment;
- Comparison of results to relevant guideline criteria in summary tables;
- A detailed data quality assessment;
- Clear and concise interpretation of results and risk assessment;
- Recommendations for management of risks during construction and operation of the project (as necessary) as well as discussion of any limitations/ data gaps/ further assessment that may be required; and
- Supporting information including, but not limited to, figures (showing all relevant project details and sample locations), tabulated data, field data sheets, photographs, data quality assessment, equipment calibration certificates, certified analytical laboratory analytical reports and statistical assessments.

The outcomes of the assessment are to be incorporated into the EHIA report. The assessment should also be summarised in the planning and/ or design reports.

Where management of acid sulfate soils is identified to be required during project works, the following is required:

Acid Sulfate Soil Monitoring and Management Program

A management plan that forms part of a Contractor's Environmental Management Plan (or a standalone document) that identifies methods for addressing the requirements and/ or recommendations of the acid sulfate soils assessment.

AND

Handover Documentation

Ongoing management of the final location of the acid sulfate soil material may be required. Ongoing environmental management requirements (type of maintenance works, recommended frequency to ensure that the design function is maintained and responsibility) are to be detailed in project handover documentation.

The Department must be provided with the surveyed final location (depth and extent) details of the material. Details of the final location of the reused material are to also be included in final as-built drawings and within the *Post Occupation Report* for the project.

6.3 Realisation

During the Realisation Phase, ongoing maintenance of any acid sulfate soil management areas may be required in accordance with handover documentation.

7 Regional Guidelines and References

Regional Guidelines:

- Fitzpatrick, et al. (2011b) Technical guidelines for assessment and management of inland freshwater areas impacted by acid sulfate soils. CSIRO Land and Water Science Report, 05/11.
- Mosley et al. (2019). A Guide to Managing Acid Sulfate Soil Risks in River Murray Wetlands – Acid Sulfate Soil Assessment for Riverine Recovery Program Wetlands. Acid Sulfate Soils Centre Report: ASSC_155, The University of Adelaide.
- Fitzpatrick et al. (2017a). Understanding and managing irrigated acid sulfate and salt-affected soils: A handbook for the Lower Murray Reclaimed Irrigation Area. Acid Sulfate Soils Centre. Report ASSC_086. 127 pp. University of Adelaide Press. DOI: https://doi.org/10.20851/murray-soils
- Fitzpatrick et al. (2018a). Methods for detailed desktop, field and laboratory characterisation of Acid Sulfate Soils in Managed Wetlands. Acid Sulfate Soils Centre Report: ASSC_154. 110 pp.

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2. Isbell, I and National Committee on Soil and Terrain (2016) *The Australian Soil Classification*, Second edition.
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4. Fitzpatrick Rob, Steve Marvanek, Bernie Powell and Gerard Grealish (2010) Atlas of Australian Acid Sulfate Soils: Recent developments and future priorities. In: RJ Gilkes and N Prakongkep (Editors). Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a Changing World; ISBN 987-0-646-53783-2; Published on DVD; http//www.iuss.org; Symposium WG 3.1 Processes in acid sulfate soil materials; 2010 Aug 1–6, Brisbane, Australia; IUSS; 2010, pp 24-27.
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7. Fitzpatrick, R.W., Shand, P. & Merry, R.H. (2009) Chapter 3. Acid Sulfate Soils. In: Jennings J.T. (Ed.). ‘Natural History of the Riverland and Murraylands’. Royal Society of South Australia (Inc.) Adelaide, South Australia pp. 65-111
8. Fitzpatrick R.W, Thomas BP, Merry RH, and Marvanek S (2012) *A Field Guide to estuarine soil-landscapes in Barker Inlet, South Australia.* Acid Sulfate Soils Centre (ASSC), The University of Adelaide. Report ASSC_005. 50 pp
9. Hall JAS, Maschmedt DJ and Billing NB, 2009, The soils of Southern South Australia. The South Australian Land and Soil Book Series, Volume 1; Geological Survey of South Australia, Bulletin 56, Volume 1 and 2. Government of South Australia

Other Resources:

- Ahern C R, McElnea AE, Sullivan LA (2004) Acid Sulfate Soils Laboratory Methods Guidelines, Queensland Department of Natural Resources, Mines and Energy.
- Ahern C R, Ahern M R and Powell B (1998a) *Guidelines for sampling and analysis of Acid sulfate soils in Queensland*

http://screwpile.com.au/eng_files/715Acid%20Sulfate%20Soil%20Sampling%20Recommendations.pdf

- Ahern C R, Stone Y and Blunden (1998b) *Acid Sulfate Soils Assessment Guidelines* Published by the Acid Sulfate Soil Management Advisory Committee, Wollongbar, NSW http://www.planning.nsw.gov.au/rdaguidelines/documents/NSW%20Acid%20Sulfate%20Soils%20Assessment%20Guidelines.pdf
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- Department of Environment, Water and Catchment Protection, WA (2007) *Acid sulfate soils guideline series – Draft Treatment and management of disturbed acid sulfate soils and acidic ground and surface waters http://www.wicc.southcoastwa.org.au/reports/ass2/ass2.html*
- Environment Protection and heritage Council and the Natural Resource management Ministerial Council (2011) *National Guidance for the Management of Acid Sulfate Soils in inland aquatic ecosystems.*
- National Environment Protection Council (NEPC) (1999, as amended 2013) *The National Environment Protection (Assessment of Site Contamination) Measure (NEPM),* http://www.ephc.gov.au/sites/default/files/ASC_NEPM__ASC_NEPM_199912.pdf
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- Standards Australia (2005) AS4482.1-2005 *Guide to the investigation and sampling of sites with potentially contaminated soil Part1:Non-volatile and semi-volatile compounds.*
- SA Environment Protection Authority (2007) EPA 638/07 *Guideline - Site Contamination – acid sulfate soil materials*. http://www.epa.sa.gov.au/xstd_files/Site%20contamination/Guideline/guide_sc_acid.pdf
- South Australian Coast Protection Board (2003) *A Strategy for Implementing CPB Policies on Coastal Acid Sulfate Soils in South Australia No 33.*
- *Southern Cross GeoScience (2011) Acid Sulfate Soils Short Course Manual South Australia*

Appendix A – Acid Sulfate Soil Case Studies

ASS Case Study 1 - South Road Superway

Acid Sulfate Soils Management Plan prepared by Urban Superway Joint Venture

The South Road Superway project (Superway) involved the construction of an elevated roadway above the existing South Road. The SRS is approximately 2.8 km in length and runs between the intersection of Days Road in the south and the Port River Expressway. The elevated roadway rests upon a series of piers which are supported by clusters of piles up to 30m deep. Many of the piers in the northern section of the site are situated within an existing drain that is identified in the CSIRO Database (ASRIS) as having a high probability of ASS occurrence. The presence of ASS material was confirmed by soil investigations undertaken by Coffey during the project planning phase. Further detailed soil investigations were undertaken pre-construction to delineate the exact location of sulfuric material and sulfidic material within the project site and to estimate volumes of each material type likely to be excavated during construction.

Key ASS risks associated with this project include the discharge of acidic runoff from soil stockpiles and impact upon adjacent aquatic environments as the drain flowed into the Barker Wetland, an area of high biodiversity, and therefore had a potential risk of fish kill if acid runoff occurred. In addition there was the potential for inhibition of plant growth in areas where material is reused (e.g. Northern Connector).

The management plan provides details and guidance on the following issues:

- Treatment pad design
- Management of stockpiled materials:
  - Minimising surface area to reduce potential for oxidisation
  - Timeframes for stockpiling untreated ASS material
- Neutralisation of ASS material and estimated liming rates
- Neutralisation of leachate and runoff
- Verification testing and sampling rates
- Field indicators, field testing and contingency measures to be followed where ASS material is encountered outside of areas identified by detailed investigations.

During construction material excavated from areas where ASS material ASS material was known to occur, or where site indicators for ASS material were observed, the spoil was segregated and transferred to a designated ASS treatment area for assessment and treatment (neutralisation), if required. Due to the piling method used and the vertical distribution of ASS material within the soil profile (occurring within two narrow bands), it was not possible to prevent the inclusion of non- ASS material.

The need for soil neutralisation was determined through field tests (pHF, pHFOX and effervescence) of stockpiled material, at a rate of one sample per 500m3 of soil. The accuracy of field testing was verified by sending approximately 25% of field samples for laboratory analysis. When required, Aglime, was applied as a neutralising agent at the rate of approximately 1kg per tonne of soil, as determined in the detailed soil investigations undertaken by Coffey. However, in most instances, field and lab testing indicated that neutralisation was not required. This may be due to a number of factors including the relative amounts of ASS and non-ASS material within the stockpile, the Acid Neutralising Capacity (ANC) of the soil (both ASS and non-ASS) and the relatively low stockpile sampling rate.

Following neutralisation and verification, material was relocated within the stockpiling area and sampled for classification in accordance with EPA and NEPM soil criteria.

Piling rig operating within the North Arm West drain, an area identified as having a high probability of acid sulfate soil occurrence (ASRIS).

ASS Case Study 2 - South Road Superway - Fulton Hogan - Service Relocation Works

Potential Acid Sulfate Soils Management Plan prepared by SKM (now Jacobs)

This project involved the relocation of various underground services to accommodate construction of the South Road Superway (Superway) and included works in a variety of locations within the Superway project site and surrounding area. The works involved extensive earthworks and dewatering to construct the new service alignments.

A desktop assessment was conducted to determine the likelihood of ASS material within the project site. This assessment considered information contained on the CSIRO Database (ASRIS), previous ASS studies undertaken within the project area (soil investigations undertaken by Coffey, 2010, during the Superway planning phase) and aspects of the local environment including ground and surface water conditions and local topography within the project site. This assessment identified two service alignments with a low risk of encountering acid sulfate soils within the project site. No high risk locations were identified within the project site. No further soil sampling or testing was undertaken to confirm the findings of this assessment or to confirm the precise locations of ASS material within the project site. As such, the plan did not provide specific guidance regarding the appropriate liming rates for ASS material soils at different locations within the site, instead it provided a generic liming rate based on the maximum sulfide content identified in the soil investigations undertaken by Coffey.

Risks associated with this work included oxidation of ASS material material by exposing it to air through dewatering and excavation and the discharge of acidic runoff from stockpiled ASS material.

The management plan provides guidance on the following:

- excavation management to minimise the potential risk of oxidising acid sulfate soils;
- Stockpile management;
- Identification of ASS material during construction;
- Neutralisation of ASS material identified during construction. The proposed liming rate was based on the maximum reported sulfide content identified in Coffey, 2010;
- Dewatering management.

Prior to construction a bunded stockpiling area was prepared within the larger temporary stockpile site and the contractor had Aglime on hand for use during construction. However, no field indicators where observed during construction and all spoil excavated from areas identified as low risk of occurrence (ASRIS) was found to consist of fill material rather than natural soils. Due to this, neutralisation of soils (stockpiled and In situ) was not considered necessary. All excavated spoil was stored at the temporary stockpile site for soil classification in accordance with EPA and NEPM criteria for on-site reuse, off-site reuse and disposal.

A trench showing newly laid service conduits beneath existing conduits; a groundwater drawdown system for dewatering running parallel to a service trench; close up of one of the spear inlets on the groundwater.

ASS Case Study 3 - Seaford Rail Extension Project

Project description

The Seaford Rail Extension project is a 5.7km dual track electrified passenger railway extension from Noarlunga Centre to Seaford. The project included:

- A station and park and ride facilities at Seaford Meadows;
- A station, park and ride facilities and bus/train interchange at the Seaford rail terminus;
- Construction of a depot at Seaford Meadows for rail car stabling and commissioning;
- Construction of a 1.2km dual track elevated bridge (viaduct) over the Onkaparinga River and River Road and a rail bridge over Old Honeypot Road;
- Construction of road bridges over the new rail rack at Goldsmith Drive, Seaford Road and Lynton Terrace;
- Provision of new pedestrian and cyclise access pathways;
- Urban design and landscaping where appropriate.

Planning investigations

As part of the geotechnical and contamination investigations undertaken by Sinclair Knight Mertz (SKM) during the planning phase of the project in 2009, it was identified that ASS material may exist at the site, specifically within the vicinity of the former SA Water sludge lagoon areas. Further work undertaken by Coffey Geotechnics Pty Ltd (Coffey) in 2010 identified the presence of ASS material adjacent to the sludge lagoon areas and the nearby Onkaparinga River.

The successful Construction Contractor, Thiess MacDow Joint Venture (TMDJV), then decided to engage Golder Associates to assess the extent of the PASS soils within the area of the site where soils are proposed to be excavated during pier construction. The majority of the piles in the floodplain used the continuous flight auger (CFA) method.

TMDJV investigations

The work that Golder Associates undertook were shallow soil investigations at all 21 pier locations to a depth of 2.7m below ground level (bgl). A push tube and hand auger were used however not all boreholes could reach the full depth given the soil characteristics. Of the 186 ASS material field tests completed, 60 were assigned a ‘low’ acidification potential, 120 were assigned a ‘medium’ and 6 were assigned a ‘high’ acidification potential.

Further testing was undertaken in a NATA accredited lab and these results indicated that of the 51 samples tested in the lab, 6 samples were had oxidised to be sulfuric material (with pH<4). A further 27 of the samples tested were inferred to be hypersulfidic material (by Acid Base Accounting (ABA) methods) and would be expected to acidify if oxidised (i.e. unverified by incubation testing).

ABA results indicated that some of the hypersulfidic samples had sufficient ANC to buffer the acid generated in the event that sulfides in the soil were oxidised. However because 20 of these samples did not have sufficient ANC for this purpose, all sulfuric and hypersulfidic soils were treated with the liming rates calculated from Net Acidity (minus ANC). The calculated liming rates ranged from 1.6kg agricultural lime/m3 dry soil to 70.1kg agricultural lime/m3 dry soil.

Based on the results, Golders Associates believed that for the soil excavated and exposed at 5 of the pier locations, TMDJV would need to managed the soil for the presence of ASS materials. This was also the case if soil disturbance depth was increased below 1.7m.

Management of the AAS materials

As a result of the Golders investigations, there was a need for a management plan to be prepared to document the procedures for excavation, storage and treatment of the soils disturbed during excavations for pier construction. The procedure included the background and objectives, risks, location of stockpile, methodology for activities on site, liming rates and monitoring requirements.

<u>Activities on site to manage AAS material</u>

<u>Find stockpile/treatment location</u>

The location of the stockpile for the excavated soil was one of the SA Water sludge lagoons that had been capped with clay as part of the rehabilitation works undertaken by SA Water. TMDJV negotiated the use of the lagoon area with SA Water and certain conditions were placed on the Contractor by SA Water and DPTI. The area was chosen as it was already a bunded area, adequate size to contain stormwater (should a 1 in 10 year ARI, 6 hour storm event occur), clay lined and very close to the pile cap locations and therefore limited the amount of movement of the material. There was also another lagoon area that could be used as a contingency. The area was lined with 100mm of agricultural lime to buffer any potential acid generation during storage and treatment. Sumps were constructed for the collection and sampling of water draining from the affected soil.

Management of material

The material was spread out in a thin layer to dry, prior to applying and mixing the lime with an excavator/loader bucket. The material excavated was kept in different stockpiles for each pier and was also divided into treated and waiting sampling and drying out still requiring treatment.

Results of testing material

Following treatment of the material, Golders Associates were brought in to undertake testing to confirm the soils have been adequately neutralised and required no further management. Quite early in the excavation of the soils Golders attended site to undertake sampling of a stockpile that had been treated with agricultural lime, at a rate as per the procedure. Golders also tested a stockpile that had not been treated with lime. The results from the lab indicated that the material had enough ANC to require no further lime treatment. The existing buffering capacity of the soil was considered sufficient to neutralise acid produced upon oxidation of the sulfides. It is suspected that the soils were effectively mixed during the CFA process and during transportation to the stockpile location.

From this point on, the stockpiled material was still segregated, spread thin in order to dry out and placed within the nominated location which was still lined with 100mm of the lime. Golders continued to test each stockpile and the results continued to come back with no requirement for treatment.

Use of material from pier excavations

As part of the Golders testing, the material was confirmed to meet waste fill classification and geotechnical requirements. It was then:

- stockpiled in the SA Water lagoons for the rehabilitation works that SA Water have planned for the area once the Seaford Rail Extension project was completed;
- used as backfill material for the pier works;
- used as fill within the project site.

Monitoring/Communications/Reporting

The procedure and requirements were communicated to the people undertaking the works in the floodplain zone through toolbox meetings, pre-start meetings and JSEAs. Regular inspections by the TMDJV Environment Manager and the DPTI Environment Manager to ensure the material was being managed in accordance with the procedure were undertaken. Golders Associates continued to attend site to take samples and undertake testing in the field and in the lab. Any issues were discussed during the joint TMDJV /DPTI weekly inspections and meetings as well as when required. The process ran very smoothly and there were few issues to discuss. DPTI have received all the Golders testing results and reports.

The bridge pier locations in the Onkaparinga river valley were assessed for ASS

Lime placed at base of stockpile site

Stockpile site for ASS to be treated with lime