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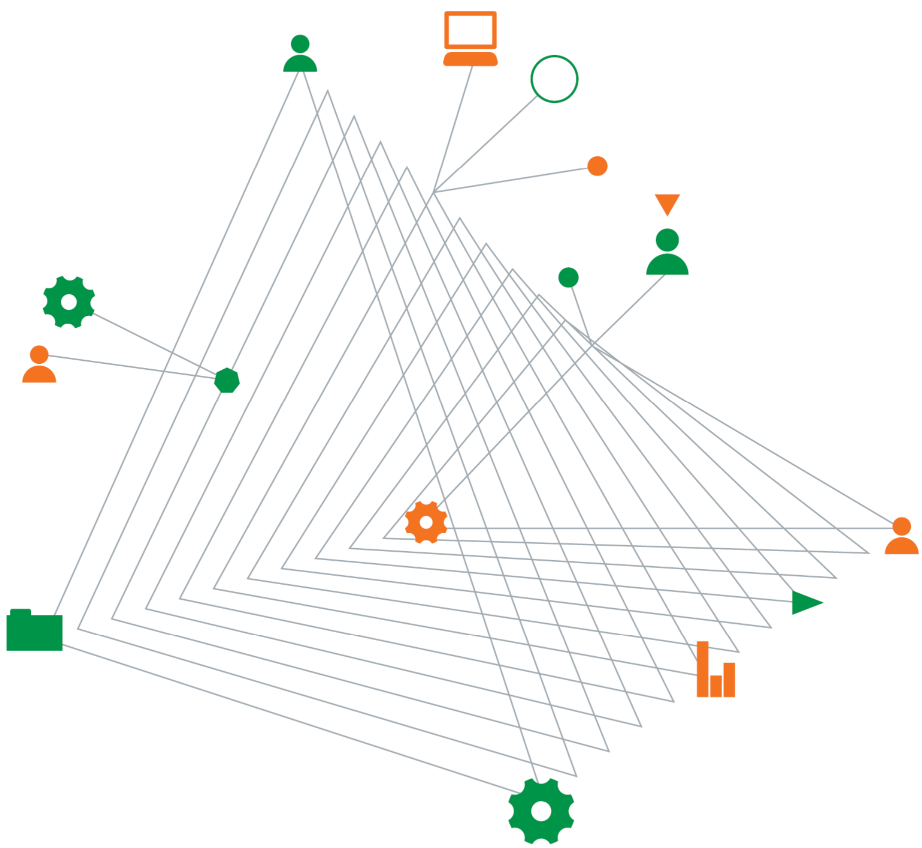
Art Gallery of NSW

Preliminary Acid Sulfate Soil Management Plan

Art Gallery of NSW Expansion Project– Sydney Modern
Art Gallery Road, Sydney NSW

25 September 2017



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Preliminary Acid Sulfate Soil Management Plan

Prepared for
Art Gallery of NSW

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Abbreviations

AGNSW	Art Gallery of New South Wales
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ASS	Acid Sulfate Soils
ASSMP	Acid Sulfate Soils Management Plan
bgs	below ground surface
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
EC	Electrical Conductivity
ENV	Effective Neutralisation Value
FOS	Factor of Safety
GME	Groundwater Monitoring Event
HSSE	Health, Safety, Security and Environment
LEP	Local Environmental Plan
NATA	National Association of Testing Authorities
NEPC	National Environmental Protection Council
NEPM	National Environment Protection (Assessment of Site Contamination) Measure
NSW EPA	Environmental Protection Authority of New South Wales
PAH	Polycyclic Aromatic Hydrocarbon
PID	Photoionisation Detector
QASSIT	Queensland Acid Sulfate Soils Investigation Team
QASSTM	Queensland Acid Sulfate Soils Technical Manual
SEAR	Secretary's Environmental Assessment Requirements
SCR	Chromium Reducible Sulfur
SDS	Safety data Sheet
SWL	Standing Water Level
TDS	Total Dissolved Solid
TOC	Total Organic Carbon
TRH	Total Recoverable Hydrocarbon

1. Introduction

1.1. General

The Art Gallery of NSW proposes to undertake a major expansion of the existing art gallery adjacent to the Phillip Precinct of the Domain. The expansion, proposed as a separate, stand-alone building, is located north of the existing gallery, partly extending over the Eastern Distributor land bridge and includes a disused Navy fuel bunker located to the north east of this land bridge.

The new building comprises a new entry plaza, new exhibition spaces, shop, food and beverage facilities, visitor amenities, art research and education spaces, new roof terraces and landscaping and associated site works and infrastructure, including loading and service areas, services infrastructure and an ancillary seawater heat exchange system.

For the purposes of this project, the "site" is referred to as the land and water in the immediate vicinity of the proposed seawater heat exchange infrastructure. The site location is shown on Figure 1, and the site layout is shown on the figure in Appendix A.

The proposed seawater heat exchange infrastructure and construction works is understood to comprise:

- Two inlet pipes located in Woolloomooloo Bay;
- A plant room in the Art Gallery that would contain:
  - Pump equipment;
  - Heat exchangers;
  - A flooded chamber / dry pit;
  - Filters and strainers to assist in preventing biofouling (the accumulation of micro-organisms, plants, algae and animals); and
- Two outlet pipes located in Woolloomooloo Bay.

The volume of soil likely to require reuse and / or disposal is estimated to be approximately 1,300m^3 to 1,400m^3 (based on excavations within 40m of the sea wall).

The proposed layout of the seawater heat exchange, based on current information, is shown on the figure in Appendix A.

Reference to the Acid Sulfate Soil (ASS) risk map for the area indicates that the proposed alignment options for the seawater heat exchange system pass through land classed as 'Disturbed Terrain', between 2m and 4m AHD elevation, where there is a likelihood of ASS being present due to historical filling or ground disturbance activities. ASS may potentially be present within fill or may be present as in-situ marine sediments ('bottom sediments') below filled ground. There is a high probability of ASS being present as natural marine 'bottom sediments' below the water level in Woolloomooloo Bay. Disturbance or dewatering of these materials may present an unacceptable environmental risk if not adequately managed during construction activities.

Due to the potential for disturbance and / or dewatering of the above materials as part of the construction works, the NSW Planning Department has indicated that an Acid Sulfate Soil Management Plan (ASSMP) would be required, to address the relevant requirements of the following planning conditions:

- Clause 36 - Development on land comprising acid sulfate soils - Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005; and

- Clause 7.14 - Acid Sulfate Soils – City of Sydney Local Environmental Plan 2012.

In addition, Section 14 of the Secretary's Environmental Assessment Requirements (SEARs) notes that the following must be provided for the project:

- Details of the scheduled, liquid and non-liquid wastes and quantities, storage, treatment and disposal or re-use of waste generated; and
- An assessment of the waste impacts and their management during construction and operation, including consideration of the assessment and management of ASS.

AGNSW has therefore requested Coffey Geotechnics Pty Ltd (Coffey) to prepare an ASSMP for the proposed development.

Coffey notes that ASSMPs are typically prepared after ASS assessments have been carried out, identifying the location and nature of ASS if present. At this stage, Coffey understands that an ASS assessment has not been carried out at this site. As such, this ASSMP is preliminary only, and provides generic guidance on the management of ASS. This ASSMP should be reviewed and updated (if required) following the results of future ASS assessments. A recommended ASS assessment scope is provided as part of this ASSMP.

This ASSMP has been prepared in accordance with the relevant sections of the following references which outlined industry standards/practices in NSW and Australia:

- QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines; and
- ASSMAC (1998) Acid Sulfate Soils Manual; and
- NSW EPA (2014) Waste Classification Guidelines: Part 4 – Acid Sulfate Soils.

This report must be read in conjunction with the attached sheet entitled *"Important Information about your Coffey Environmental Report"*.

1.2. Objectives

The objectives of this ASSMP are to:

- Provide a scope of work to assess the nature and extent of ASS at the site (an ASS assessment);
- Provide general guidance on the management of excavations, including separation of ASS from other soils;
- Provide guidance on the management of ASS, including treatment and analysis requirements; and
- Provide guidance on dewatering, including analysis and disposal requirements.

2. Site description

2.1. Site location and identification

General site information is provided below in Table 1.

Table 1 –Summary of site details

Site Address:	Lincoln Crescent, Woolloomooloo, Sydney, NSW 2000. The site location also includes land to the north and east of Lincoln Crescent as well as part of Woolloomooloo Bay. The site location is shown on Figure 1.
Total Site Area:	Approximately 1.9 hectares, covering the proposed seawater heat exchange areas only.
Title Identification Details:	The site of the proposed seawater exchange system occupies parts of the following lots: • Lots 34 to 36 DP 39586 • Lot 51 DP 47732; • Lot 7007 DP 93650; and • Lot 9 DP 1007565 The site also occupies part of Lincoln Crescent ad part of the bed of Sydney Harbour.
Current Zoning:	The proposed seawater heat exchange area is currently zoned as RE1 Public Recreation under the Sydney LEP 2012, and W6 Scenic Waters Active Use under the Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005.
Current Site Use:	Parkland, wharves and Woolloomooloo Bay
Proposed Site Use:	Subsurface - Seawater heat exchange including discharge pipes and subterranean plant room. Above ground – Continued use as parkland, wharves and Woolloomooloo Bay
Adjoining Site Uses:	• The Royal Botanic Garden and Woolloomooloo Bay to the north; • Woolloomooloo Bay to the east; • The Royal Botanic Garden, the existing art gallery and proposed gallery Expansion Area, the Cahill Expressway and the Cowper Wharf Roadway to the south; and • Art Gallery Road and the Royal Botanic Garden to the west.
Site Co-ordinates:	The centre of the site is located at approximately 33°51’59”S, 151°13’10”E.

2.2. Site observations

Site observations, based on previous site walkovers carried out by Coffey on 14 May 2016, are summarised below.

- The proposed seawater heat exchange area is relatively flat and incorporates Lincoln Crescent in the south and public open space in other areas.
- The area of public open space to the north of Lincoln Crescent comprises asphalt footpaths and grassed areas.
- The public open space in the east (in the vicinity of the proposed pipeline alignment) is present to the east of an apartment complex and comprises a timber and concrete pedestrian walkway. The southern section of the walkway appears to be partially suspended over Woolloomooloo Bay with a seawall assumed to be present beneath. A seawall was observed to the north, adjacent to the east and northeast of the northern end of the apartment complex.
- A marina is present to the east within Woolloomooloo Bay and the water in this area appeared to be deeper than 2m at the time of the walkover.
- Sandy marine sediments and sandstone cobbles and boulders were observed in the bay adjacent to the seawall to the north (in the vicinity of the proposed pipeline alignment). The floor of the bay in the vicinity of the proposed pipeline alignment was not observed due to water depth but likely comprises finer grained sediments due to the deeper water and lower energy depositional environment.
- Sandstone outcrops were observed to the west from in the vicinity of the proposed subterranean plant room to the north of Lincoln Crescent and adjacent to the land to the north. The sandstone appeared to have been quarried in places and sandstone bedrock is likely present at shallow depth in these areas. A former fuel bunker is located to the west of Lincoln Crescent (where the seawater heat exchanges pipes are proposed to connect to the Sydney Modern development). The bunker was constructed by excavating into sandstone bedrock.
- An Ausgrid substation is present to the west of the northern end of Lincoln Crescent.

2.3. Site topography and drainage

Reference to the Sydney 1:25,000 Topographic Map indicates that the surface of the site is relatively flat but the land to the west slopes down towards Woolloomooloo Bay to the north and east. Site survey information indicates that the site lies at an elevation of approximately 2-3m Australian Height Datum (AHD) in the vicinity of Lincoln Crescent.

Woolloomooloo Bay is the closest waterway to the site, located in the eastern part of the site. Woolloomooloo Bay is part of Sydney Harbour. Surface water flow across the site during periods of heavy rainfall is anticipated to flow to the east and drain via drainage networks to Woolloomooloo Bay.

2.4. Geology and soils

2.4.1. Regional geology and soils

Review of the 1:100,000 Sydney Geological map indicates that the site is underlain by Hawkesbury Sandstone of the Wianamatta Group. Hawkesbury Sandstone is described as medium to coarse grained quartz sandstone with very minor shale and laminate lenses.

The Sydney 1:100,000 Soil Landscape Series Sheet 9130 (Soil Conservation Service of NSW, 1989) indicates that the site is in an area underlain by 'Gymea' soils which are typically associated with the rolling and low hills of Hawkesbury Sandstone.

2.4.2. Site specific geology

Previous geotechnical investigations carried out by Coffey in 2014 indicated that the subsurface conditions beneath the proposed Art Gallery Expansion Area to the west of the site generally comprised fill material overlying sandstone bedrock, to the maximum depth of investigation (approximately 20m bgs). The fill thickness was recorded from approximately 0.6m to approximately 3.2m.

2.4.3. Acid sulfate soil risk mapping

Reference to the ASS risk map for Prospect / Parramatta River (Department of Land and Water Conservation, Sheet 91 30N3) indicates the following:

- The bottom sediments of Woolloomooloo Bay are considered to have a high probability of ASS being encountered;
- The areas of the site to the east of Lincoln Crescent are located in an area of low probability of ASS being encountered; and
- The areas to the west of Lincoln Crescent are located in an area of no known ASS occurrence.

Figure 1 below shows the ASS risk mapping from CSIRO Land & Water's Atlas of Australian Acid Sulphate Soils (available from http://www.asris.csiro.au). Figure 1 shows that the seawater heat exchange system will enter the area of high probability of ASS being encountered in Woolloomooloo Bay.

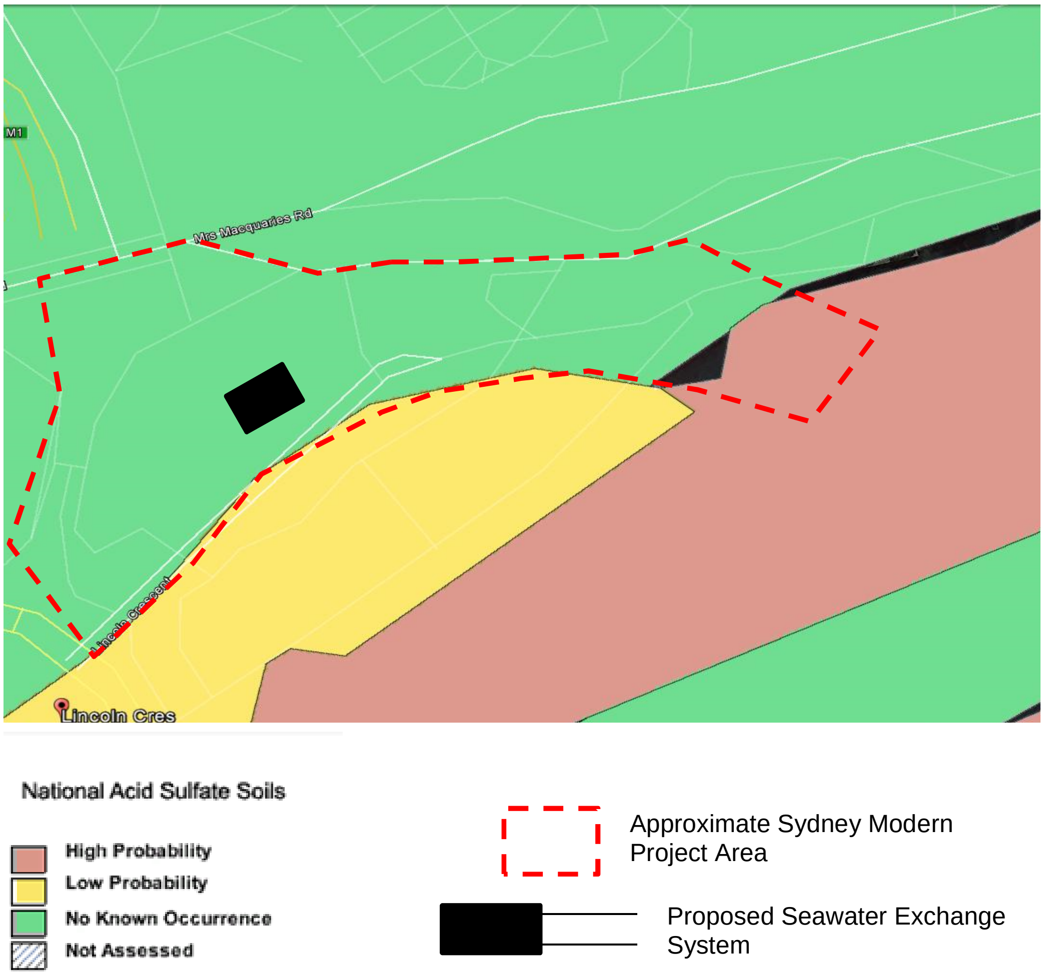


Figure 1: Acid sulfate soil risk map (http://www.asris.csiro.au)

Reference to the Sydney LEP ASS Map (Sheet ASS_021) indicates the following:

- Some areas in the southern section of the site between Lincoln Crescent and Woolloomooloo Bay (where the seawater exchange system travels under Lincoln Crescent from the new building) are designated as consisting of "Class 2" ASS; and
- On-land sections of the site (along the Woolloomooloo Bay foreshore) are designated as consisting of "Class 5" ASS.

Figure 2 below shows the ASS classes as shown in the Sydney LEP.

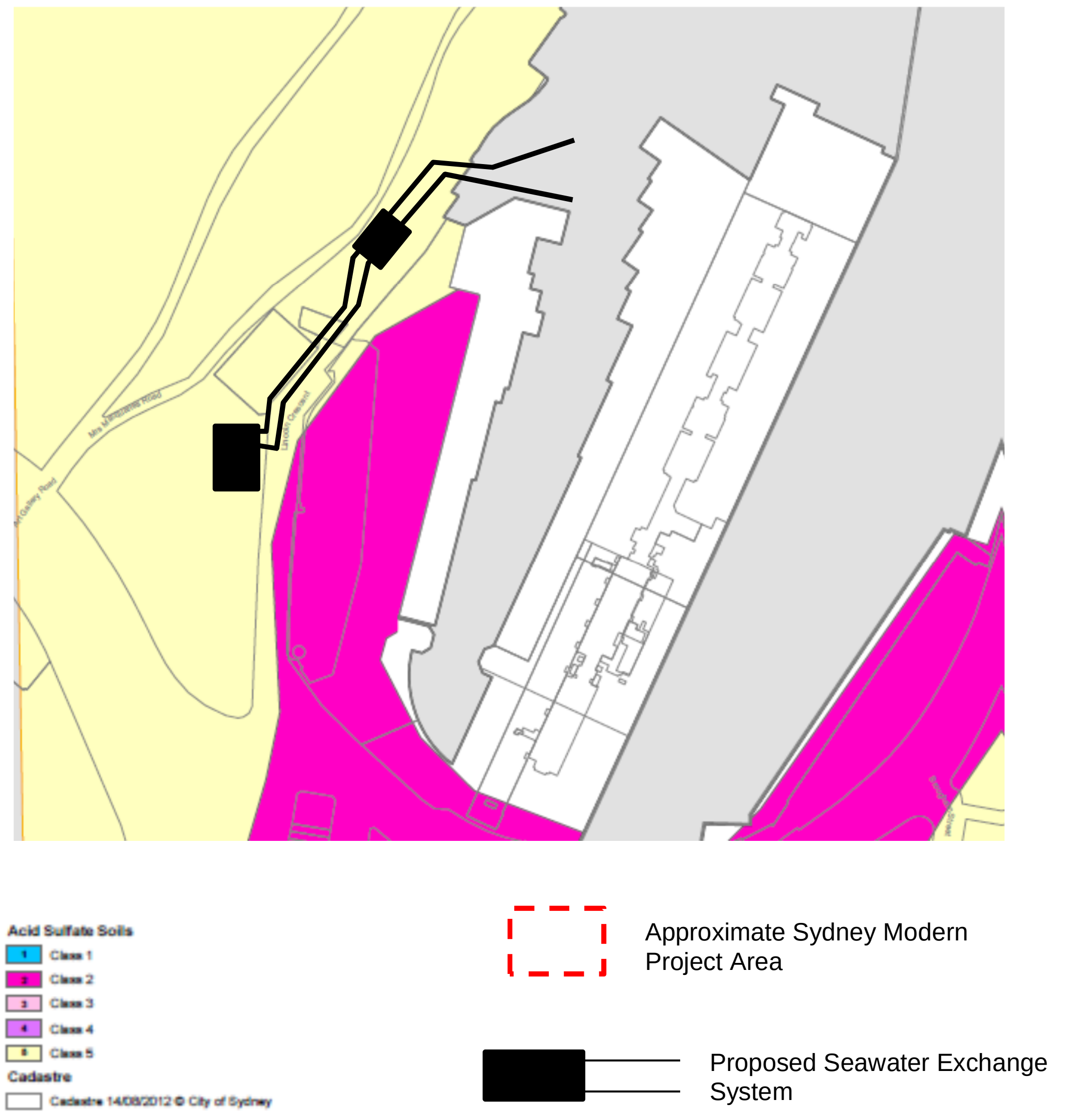


Figure 2: Acid sulfate soil class map (Sydney LEP, 2012)

Based on the current design plans, Coffey considers it likely that ASS, if present, may be disturbed during the proposed seawater heat exchange development. As a result, an ASSMP is required as part of the development application (refer to Section 3.2 below).

2.5. Regional hydrogeology

Based on the hydrology of the surrounding area, it is expected that regional groundwater would flow in a broadly north-easterly direction toward Woolloomooloo Bay.

Coffey carried out a Groundwater Monitoring Event (GME) at the site in 2016 (Coffey, 2016). The GME involved sampling from two groundwater monitoring wells adjacent to the former fuel bunker area to the south and west of the proposed seawater heat exchange infrastructure. Standing Water Levels (SWLs) were recorded between approximately 1.6m bgs and 2.0m bgs in April and May 2016. The groundwater elevation at these locations was estimated to range between approximately 0.4m and 1.3m Australian Height Datum (AHD) based on available nearby survey data.

A search of groundwater bore licences was undertaken in April 2014 and May 2016 by Coffey using the NSW Natural Resources Atlas (http://www.nratlas.nsw.gov.au). The results of the search indicated that there are three registered groundwater bores within an approximately 1km radius of the site. Two bores are registered for domestic purposes, and one is registered for monitoring purposes.

3. Background information and previous reports

3.1. Background information on acid sulfate soils

3.1.1. Coastal acid sulfate soils

Coastal ASS are soils which contain significant concentrations of iron sulfide or pyrite which, when exposed to oxygen in the presence of sufficient moisture, oxidises, resulting in the generation of sulfuric acid. Unoxidised pyritic soils are referred to as potential ASS. When the soils are exposed, the oxidation of pyrite occurs and sulfuric acids are generated, and the soils are said to be actual ASS.

Pyritic soils typically form in waterlogged, saline sediments rich in iron and sulfate. Typical environments for the formation of these soils include tidal flats, salt marshes and mangrove swamps below about RL 5m AHD. They can also form as bottom sediments in coastal rivers and creeks.

Pyritic soils of concern on low lying NSW and coastal lands have mostly formed in the Holocene period, (i.e. 10,000 years ago to present day) predominantly in the 7,000 years since the last rise in sea level. It is generally considered that pyritic soils which formed prior to the Holocene period (i.e. >10,000 years ago) would already have oxidised and leached during periods of low sea level which occurred during ice ages, exposing pyritic coastal sediments to oxygen. There is still some potential for these older soils to contain stored acidity that could be released on exposure.

WSP – Parsons Brinckerhoff Pty Ltd (WSP) carried out a Marine Impact Assessment for the Sydney Modern Project in 2016 (Reference 2270096A-ENV-REP-001 RevA dated July 2016). The assessment included a desktop review of ASS risk mapping. WSP noted that there was a high risk of encountering Class 2 ASS on the land to the south of the proposed construction footprint, and a low risk of encountering Class 5 ASS to the west of the proposed construction footprint. WSP concluded that, due to these areas not bordering the proposed construction footprint, there was negligible risk for marine sediments in Woolloomooloo Bay to be ASS generating.

3.1.2. Significance of coastal acid sulfate soils

Disturbance or poorly managed development and use of coastal ASS can generate significant amounts of sulfuric acid, which can lower soil and water pH to extreme levels (generally <4) and produce acid salts, resulting in high salinity.

The low pH, high salinity soils can reduce or altogether preclude vegetation growth and can produce aggressive soil conditions which may be detrimental to concrete and steel components of structures, foundations, pipelines and other engineering works.

Generation of the acid conditions often releases aluminium, iron and other naturally occurring elements from the otherwise stable soil matrices. High concentrations of some such elements, coupled with low pH and alterations to salinity can be detrimental to aquatic life. In severe cases, affected waters flowing off-site into aquatic ecosystems can have a detrimental effect on aquatic ecosystems.

3.2. Summary of previous ASS assessment

In 2016, Coffey was requested by AGNSW to confirm the proximity of the proposed Expansion Area to land potentially containing ASS. The scope involved a desktop study of available ASS maps for the area around the Expansion Area only. Coffey referred to the ASS map published by City of Sydney Council as part of the Sydney Local Environmental Plan 2012 (reference: Sheet ASS_021), as well as Clause 7.14 of the Sydney LEP (2012).

Based on the ASS map, Coffey note that the proposed Expansion Area development would be located on “Class 5” land, and that development would be subject to Clause 7.14 ‘Acid Sulfate Soils’ of the Sydney LEP (2012).

Coffey noted the following would apply:

- Clause 7.14 of the Sydney LEP (2012) indicates that development consent would be required for the carrying out of works within 500m of adjacent Class 1, 2, 3 or 4 land that is below 5m AHD and by which the water table is likely to be lowered below 1m AHD on adjacent Class 1, 2, 3 or 4 land.
- Development consent could not be granted under this clause for the carrying out of works unless an ASSMP has been prepared for the proposed works in accordance with the ASSMAC (1998) *Acid Sulfate Soils Manual* and has been provided to the consent authority.
- Development consent would not be required under this clause for the carrying out of works if:
  - A preliminary assessment of the proposed works prepared in accordance with the Acid Sulfate Soils Manual indicates that an ASSMP is not required for the works, and
  - The preliminary assessment has been provided to the consent authority and the consent authority has confirmed the assessment by notice in writing to the person proposing to carry out the works.
- Clause 7.14 of the Sydney LEP (2012) indicates that, as the seawater heat exchange system will extend under Lincoln Crescent (which is on Class 2 ASS land), and the works will be below the natural ground surface, development consent will be required for the proposed works with respect to acid sulfate soils, unless:
  - The works involve the disturbance of less than 1 tonne of soil, and
  - The works are not likely to lower the water table.

Coffey advised AGNSW that an ASSMP may be required if proposed construction on the Expansion Area was likely to result in lowering of groundwater levels beneath the former fuel bunker below 1m AHD. The seawater heat exchange system was subsequently added to the proposed development, and is located adjacent to the east of the Expansion Area. The site is located on Class 2 land below 5m AHD. Disturbance of more than one tonne of soil and / or lowering of the water table would be expected. An ASSMP is therefore required.

In addition, Coffey notes that Clause 36 of the Sydney Regional Environmental Plan (SREP) (Sydney Harbour Catchment) 2005 applies to Foreshores and Waterways areas including Zone W6 (which the seawater heat exchange system will enter. Clause 36 states that:

- Subclause 2 – *“Works that involve the excavation, dredging, filling or contouring of land to which this clause applies, or the extraction of soil or other extractive material from such land, may be carried out only with development consent”.*
- Subclause 3 – *“Despite subclause (2), such works may be carried out without development consent if:*

  - *(a) a copy of a preliminary assessment of the proposed works undertaken in accordance with the Acid Sulfate Soils Assessment Guidelines has been given to the consent authority, and*
  - *(b) the consent authority has provided written advice to the person carrying out the works confirming that results of the preliminary assessment indicate the proposed works need not be carried out pursuant to an acid sulfate soils management plan prepared in accordance with the Acid Sulfate Soils Assessment Guidelines".*
- Subclause 4 – *"The consent authority must not grant development consent as required by this clause unless it has considered:*
  - *(a) the adequacy of an acid sulfate soils management plan prepared for the proposed development in accordance with the Acid Sulfate Soils Assessment Guidelines, and*
  - *(b) the likelihood of the proposed development resulting in the discharge of acid water".*
- Subclause 5 – *"This clause requires development consent for the carrying out of works:*
  - *(a) by councils or county councils (within the meaning of the Local government Act 1993), or*
  - *(b) by private drainage boards (within the meaning of the Water Management Act 2000),*

  despite any other provision of this plan".
- Subclause 6 – *"This clause does not apply to or in respect of works carried out by or on behalf of the Maritime Authority of NSW or Sydney Ports Corporation".*

In relation to Subclause 4, Coffey considers that there is a relatively low likelihood of the proposed development resulting in the discharge of acid water when this management plan is implemented.

4. Management of acid sulfate soils

4.1. Typical management strategy

The strategy to be adopted for the management of ASS will typically involve:

- Establishment of a treatment pad;
- Visual assessment of excavated soils, including separation of ASS from other materials excavated from the site;
- Stockpiling of ASS at a designated treatment pad;
- Neutralisation of ASS by mixing with lime;
- Monitoring of treated soils to assess if neutralisation has been achieved; and
- Placement of treated soils at a designated location.

At this stage, Coffey understands that an ASS assessment has not been carried out at the site. Coffey recommends this assessment be carried out as a first step of the ASS management process, prior to excavation works. The results of the ASS assessment should be used to assess the nature and extent of ASS (if present), and confirm the management strategy. This ASSMP should be reviewed and updated if required based on the results of the ASS assessment.

The steps typically involved in ASS management are discussed in detail in Section 4.2 below. These steps should be carried out or supervised by a suitably experienced environmental or geotechnical consultant.

4.2. Proposed management plan

4.2.1. Step 1 – Acid sulfate soil assessment

Prior to excavation, an ASS assessment should be undertaken in the proposed areas of soil, sediment and / or groundwater disturbance by a suitably experienced environmental or geotechnical consultant. The objectives of the ASS assessment would be to identify the nature and extent of ASS (if present), and confirm the management procedures provided in this ASSMP are appropriate.

The ASS assessment should include the following works:

- A review of published geological, topographical and ASS risk mapping (as summarised in this ASSMP).
- Soil sampling, as outlined below:
  - Soil sampling should target the areas of the site recorded as “high probability” or “low probability” according to the ASS risk mapping that are within areas where soil disturbance or groundwater drawdown below 1m AHD may occur as a result of the construction works. For this site, this is likely to be the areas to the north and east of Lincoln Crescent within approximately 5m of the proposed excavations. Coffey understands that the intake and discharge pipework within Woolloomooloo Bay will be installed below water level and sediments will be retained within the bay below water level. If sediments are proposed to be brought to the surface or potentially exposed to air, then assessment of the sediments in the vicinity of the proposed pipes will also be required prior to construction works;
  - The parts of the site where excavations are proposed have an area of approximately 3,000m^2. Coffey recommends that samples be collected approximately every 25 linear metres

along the proposed alignment of the seawater heat exchange infrastructure, with a minimum of eight sampling locations within potential ASS / PASS soils (i.e. fill and / or marine sediments rather than sandstone bedrock).

  - The sampling locations should target the proposed excavation and construction areas such as the proposed pipeline trenches and subterranean plant room;
  - The sampling locations should be extended at least 1m below the proposed depth of excavation or potential dewatering. Sampling is not required below the depth of sandstone bedrock;
  - The samples can be collected by mechanical methods (drill rigs or excavators), or by hand if appropriate. Samples should be collected at approximate 0.5m depth intervals until the target depth at each location is reached;
  - If bay sediments may potentially be brought to the surface during construction works (not expected based on current pipe installation methodology) then sampling will be undertaken using a piston sampler or sediment sampler operated from a boat. Alternatively, samples could be collected by trained divers operating vibracoring equipment. Samples should be collected at approximate 0.5m depth intervals until the target depth at each location is reached;
  - Samples should be placed into airtight sample bags within minimal air space inside, and kept in cold storage after collection. If samples are kept for more than 24 hours after collection before being analysed, they should be frozen;
  - A clean pair of disposable nitrile gloves should be worn when collecting each sample; and
  - Care should be taken to minimise the potential for cross-contamination of samples. This includes decontamination of sampling equipment if practical.
- Laboratory analysis, including the following:
  - ASS field screening of each sample collected. The field screening should be carried out as soon as practical after sample collection, in accordance with the procedure outlined in Appendix 1 of the Assessment guidelines in the ASSMAC (1998) Acid Sulfate Soils Manual; and
  - Laboratory analysis of samples, selected based on the field screening results. The laboratory testing should consist of the Chromium Reducible Sulfur (S_{CR}) method, and provide liming rates.
- Preparation of an ASS assessment report, including updating this ASSMP as required. If significant changes to the project scope are required, a new ASSMP may need to be prepared. The action criteria provided in Table 4-1 of the QASSIT (2014) guidelines should be referenced when assessing the laboratory results. A copy of Table 4-1 is provided in Appendix B.

4.2.2. Optional step – Disposal of untreated acid sulfate soils

Coffey understands that untreated potential ASS may be able to disposed offsite at the Besmaw Pty Ltd facility in Kurnell, NSW, if it is disposed of within 24 hours of excavation and placed below the water table at the Kurnell facility. If this option is to be considered by AGNSW or the civil contractor, the facility must be contacted prior to disposal to confirm acceptance of the material and to identify specific handling, transport and disposal requirements (if any). Material tracking records, and possibly field pH testing, may be required for material being disposed of in this fashion.

If materials is not disposed directly to the Kurnell facility in accordance with the facility license conditions then subsequent steps outlined below must take place.

4.2.3. Step 2 – Establishment of a treatment pad

A treatment pad should be established on a suitable area of the site. Selection of a treatment pad location should be based on:

- Area required for stockpiling (based on likely volumes of ASS to be excavated);
- Proximity of the treatment pad to the proposed excavation areas; and
- Slope of the ground surface (should be <1°).

Based on the topography of the site, suitable treatment pad locations may include:

- Flat areas of the proposed Expansion Area (e.g. on top of the former fuel bunker); or
- The foreshore along Woolloomooloo Bay adjacent to the proposed subterranean plant room.

The treatment pad should be constructed as per Figure 3 below.

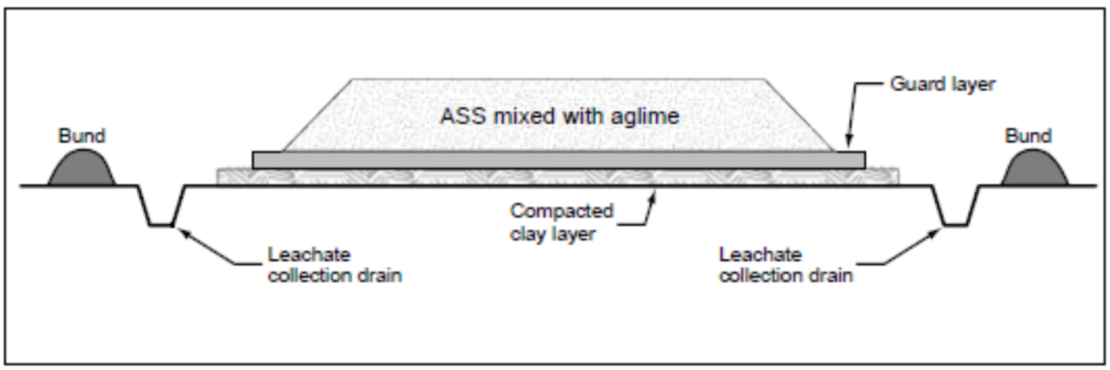


Figure 3**:** Typical treatment pad design, based on QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines

The typical procedure for establishment of the treatment pad is as follows:

- A temporary fence, approximately 2m high, should be constructed around the treatment pad to prevent unauthorised access. Shadecloth should be attached to the temporary fence to minimise dust exiting the treatment area.
- A "separation" layer (referred to as 'compacted clay layer' on the drawing above) should be constructed at the treatment pad location. This can be constructed from non-ASS materials excavated from the construction area (such as weathered sandstone), or from imported Virgin Excavated Natural Material (VENM) or Excavated Natural Material (ENM), or other impermeable materials. The base should be constructed to a minimum of 100mm above the surrounding ground surface. This will minimise the need to excavate into the ground surface and potentially exposing additional ASS material.
- A "guard" layer, consisting of a geotextile material, should be placed on top of the separation layer.

- The treatment pad should be suitably bunded to prevent stormwater from entering or leaving the treatment pad. The bund should consist of an earth bund approximately 0.5m high, or sand bags or hay bales. The bund material should not comprise treated ASS or material that has the potential to be contaminated.
- An acid resistant tank should be installed to collect runoff. The tank should be placed downslope of the treatment pad.
- A tank designed to capture runoff from a 1 in 10 year, 1 hour storm duration event, should be installed.
- Leachate and sediment removed from the tank should be assessed for pH levels prior to disposal.
- Stormwater diversion drains should be excavated on the upgradient side of the treatment pad to prevent stormwater run-on. The diversion drains should be created so that runoff flows towards the tank.
- The construction of the treatment pad should be visually assessed by the environmental or geotechnical consultant prior to excavation works to ensure it has been constructed appropriately.

4.2.4. Step 3 – Visual assessment of excavated soils

The third step of the proposed management strategy would typically involve the visual assessment of excavated soils involving the following process:

- Excavated soils should be visually assessed for material type, colour and consistency.
- ASS soil types will need to be assessed based on the results of the ASS assessment (refer to Step 1 above). Based on our current understanding of potential ASS conditions at the site, ASS may include:
  - Fill soils overlying the weathered sandstone in the “low probability” ASS risk area to the east of Lincoln Crescent (due to possible dredged sediments used in filling);
  - Bottom sediments beneath fill associated with the former Woolloomooloo Bay shoreline; and
  - Bottom sediments within Woolloomooloo Bay. However, Coffey understand that these sediments will not be removed or exposed to air by the construction works.
- The environmental or geotechnical consultant should visually assess the material excavated and should provide guidance to the contractors as to which material will require transport to the designated treatment pad.
- A record of material tracking is to be maintained by the earthworks contractor, including details on the volume of excavated material transported to the treatment pad.

4.2.5. Step 4 – Placement of excavated acid sulfate soils in treatment pad

The fourth step of the proposed management strategy would typically involve placing the excavated ASS into the treatment pad using the following process:

- Excavated ASS should be immediately transported to the treatment pad. No temporary stockpiling outside of the treatment pad should occur.
- If ASS is treated inside the excavation area, it should be transported to the stockpile pad immediately after treatment.
- Where practicable, heights within the treatment pad should not exceed the height of the temporary fence.

- If treatment is not undertaken immediately after stockpiling, stockpiles should be bunded and covered with plastic to help slow the oxidation process.
- The environmental or geotechnical consultant should observe the placement of the ASS to ensure stockpiling is undertaken appropriately.

Bottom sediments excavated from Woolloomooloo Bay that contain ASS are likely to be saturated. However, Coffey understand that these are not proposed to be exposed to air as they will remain below water level. If bottom sediments are proposed to be excavated then in order to reduce the potential for leachate runoff, where possible the sediments should be processed through a filtering device to filter out the sediments from water, prior to the sediments being transported to the treatment pad. The water that is left over should be transferred to holding tanks for further assessment (refer to Section 5 below).

4.2.6. Step 5 – Treatment (neutralisation) of acid sulfate soils

Liming rate

The liming rate to be applied for the neutralisation of ASS should calculated using the following formula:

per m^3 of soil = $\frac{\%S\, x623.7}{19.98}\ x\ \frac{100}{ENV\ (\%)} \times D \times FOS$

where %S is average for sulphidic layer (about 0.3%Scr)

D is bulk density of soil (1.8 tonnes/m^3)

FOS Factor of safety (1.5)

ENV is Effective Neutralisation Value (usually 90% to 95% for agricultural lime)

The liming rate should be provided in the laboratory analysis carried out in the ASS assessment (refer to Step 1 above). The liming rate will typically be reported in kg $CaCO_3$/tonne or similar measurement, and will typically include a safety factor of 1.5.

Liming methodology

A suitable supply of lime should be available on site during the construction works to enable efficient neutralisation of ASS. A lime register should be maintained by the contractor in order to record the amount of lime delivered to the site. Lime should only be handled by contractors trained in the safe application of lime, and a Safety Data Sheet (SDS) for the lime should be kept on site.

In order to demonstrate that appropriate quantities of lime have been used, a lime register should be maintained by the earthworks contractor. The register shall list the quantities of lime delivered to the site, verified by delivery dockets, and where the lime has been used. The lime usage shall quantify areas limed and soil volumes treated, liming rates and quantities of lime used. The lime register shall be a verifiable performance indicator and extracts may be used in a final environmental report.

The type and amount of lime to be applied should be such that a neutralising value (NV) of 90 to 100 can be achieved. NV relates to the purity of the lime and an NV of 100 is required to ensure that the lime is effective in neutralising the potential acid. Fine powdered agricultural lime ($CaCO_3$) generally has an NV of 90% to 100% whilst other manufactured forms of lime can have an NV as low as 80%. Where NV is below 100, the factor of safety, hence the amount of lime, will have to be adjusted accordingly.

Liming should be undertaken inside a treatment pad constructed as outlined above in Step 2. The following liming procedures (or other equivalent) should be undertaken:

- Spreading of the soil in thin (<200mm) layers within the treatment pad; and
- Addition of lime followed by mixing, using backhoe bucket or equivalent.

4.2.7. Step 6 – Monitoring of treated soils to be reused on site

The sixth step of the proposed management strategy for soils that are to be reused on site would typically involve monitoring of the ASS as it is being treated. This would typically involve the following process:

- The pH levels of the treated soils should be monitored regularly by the earthworks contractor or the environmental or geotechnical consultant (every 2-3 days) for up to four weeks. The pH levels should remain above pH 6.5 (QASSTM, 2014). This monitoring period could potentially be reduced as advised by the environmental or geotechnical consultant if consistent results indicating the ASS is being effectively neutralised are obtained.
- Monitoring records should be maintained by the earthworks contractor, including the day, time and pH levels recorded.
- The pH levels of treated soils are to be monitored by measuring the pH of soil mixed with distilled water at a ratio of 1:5 soil/water.
- Should the pH fall below 6.5 additional lime would be required.
- The monitoring frequency may be revised based on the results of the monitoring.
- Verification testing of the soil, using chromium suite analysis, should be carried out, four weeks after the treatment programme. QASSTM recommends a testing frequency of 1 test per 1,000m^3 where the %S equivalent is less than 0.5%. Composite sampling is preferred rather than a single grab sample (QASSTM, 2014). Sampling for the verification testing should be carried out by the environmental or geotechnical consultant and should include at least one sample per batch of treated soils.
- QASSTM (2014) indicates that verification test results should show net acidity below the Action Criteria (as outlined in Table 4-1 reproduced in Appendix B).
- Material may be reused on site once the above criteria are met.

If soils are to be disposed offsite to a licensed facility, then disposal can be undertaken after Step 5, without the requirement for monitoring as outlined in Step 6.

4.2.8. Step 7 – On-site reuse or offsite disposal of treated soils

Once treated, the soils can either be reused on-site (subject to monitoring of treated soils as per Step 6) or disposed offsite.

On-site reuse

- Treated material can be re-used on the site (e.g. to backfill excavations).
- Records should be maintained by the earthworks contractor, including the volume of treated material moved and the final destination of treated material.
- Treated material may also need to be assessed from a contamination and geotechnical perspective for on-site reuse.

- The treated material, once placed, can be capped with a turf cover or reseeded, assuming pH levels are suitable for grass growth.
- ASS testing should be undertaken on the treated soils approximately two weeks after placement, to assess if re-oxidation has occurred.
- Treated material is not to be removed from the site unless it has been waste classified in accordance with the NSW EPA (2014) Waste Classification Guidelines.

Placement of untreated material below water table

Depending on the timing of the works, stockpiled ASS could be returned to the excavations provided the following management procedures are followed:

- Visual assessment of temporary stockpiling and pH monitoring does not show evidence of oxidation;
- The excavated ASS can be returned to below the water table within the excavation in a timely manner (two days).

Off-site disposal

Once treated with lime the soils may be disposed of to an appropriately licensed landfill following a waste classification. The waste classification and disposal should be undertaken by a suitably qualified environmental consultant in accordance with the NSW EPA (2014) Waste Classification Guidelines.

5. Management of dewatering activities

If dewatering exceeding 24 hours is required in areas containing potential ASS, such activity may result in drawdown of the groundwater table and may enhance oxidation of the potential acid sulfate soils in the area. This is considered unlikely in areas where sandstone bedrock is present at shallow depths above the groundwater table.

The contractor should install and/or employ appropriate groundwater control systems to minimise the ingress of groundwater into excavations such that the surrounding groundwater table will be maintained. The surrounding groundwater level should be monitored regularly by the contractor or the environmental consultant. The contractor should also endeavour to minimise the length of dewatering where possible.

If the groundwater level is lowered below the depth of potential ASS for >2 days, then the environmental consultant must be contacted for advice in relation to assessment and possible excavation and treatment of soils in accordance with the procedure outlined in Section 4.

If dewatering is required, it may be undertaken using a spear point and pump system or other method where appropriate. The water should be pumped into a temporary holding tank for monitoring and possible treatment prior to discharge, as outlined in Section 6.1 below.

6. Management of water

6.1. Management goals

The broad management goal, with respect to collected water, is to monitor the water collected on the site during construction works to ensure it is removed from the site in a suitable manner.

6.2. Proposed management strategy

For the purposes of this preliminary ASSMP and based on the proposed construction works, and the anticipated groundwater level, it is anticipated that disposal of water will be required. Water may be present in the form of:

- Groundwater accumulating in open excavations;
- Leachate collected in the stockpile treatment area; or
- Water left over following filtering of sediments excavated from Woolloomooloo Bay (although this is not expected to occur as sediments will remain below water level).

Therefore, the strategy to be adopted for the management of water would typically involve the following:

- Placement of extracted water in an acid-resistant holding tank;
- Sampling and analysis of the extracted water;
- pH adjustment (if required); and
- Disposal of the water via land irrigation or used as dust suppression, or
- Disposal to local sewerage systems, nearby water bodies or to a licensed liquid waste disposal facility.

These steps are discussed further in the sections below.

If there is a potential for the groundwater table to be lowered for a considerable period of time (several weeks or months) the earthworks contractor should install and/or employ an appropriate groundwater control system to minimise the ingress of groundwater into open excavations such that the surrounding groundwater table will be maintained. The surrounding groundwater level should be monitored regularly by the earthworks contractor, and this would involve monitoring from nearby existing and / or new monitoring wells. The earthworks contractor should also endeavour to minimise the length of dewatering where possible.

6.2.1. Step 1 – Placement of water in a holding tank

- Water to be removed from the site should be placed in an acid-resistant holding tank or pond.
- Records should be maintained by the earthworks contractor, including the location of the holding tank, and the volume of liquid placed into the tank.

6.2.2. Step 2 – Sampling and analysis of water

- Water stored in the tank should be sampled and analysed by a suitably qualified environmental consultant to assess appropriate disposal options.

- Samples should be dispatched to a NATA-accredited laboratory for analysis. The analysis required will depend on the proposed disposal option and may include:
  - pH;
  - Electrical Conductivity (EC);
  - Heavy Metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese);
  - Alkalinity;
  - Sulfate, Chloride, Fluoride, Ammonia and Nitrate;
  - Calcium, Magnesium, Potassium and Sodium;
  - Total Suspended Solids (TSS);
  - Total Organic Carbon (TOC) and Biochemical Oxygen Demand (BOD);
  - Polycyclic Aromatic Hydrocarbons (PAH);
  - Total Petroleum Hydrocarbons (TPH); and / or
  - Benzene, Toluene, Ethylbenzene and Total Xylenes (BTEX).
- If the water is to be disposed of at a wastewater disposal facility, the water should be analysed for heavy metals, TRH, BTEX and PAH (as a minimum).
- In addition, if the water is to be disposed to sewer, sample may also need to be analysed for Turbidity and Oil & Grease (depending on Sydney Water requirements). A trade waste agreement may need to be obtained from Sydney Water for disposal to sewer.
- Where applicable, the results should be compared to adopted assessment criteria derived from:
  - ANZECC (2000) Australian and New Zealand Water Quality for Fresh and Marine Waters; and
  - NEPC (2013) National Environmental Protection (Assessment of Site Contamination) Measure (ASC NEPM).

6.2.3. Step 3 – pH adjustment (if required)

- Groundwater pH values have previously been recorded by Coffey to be between approximately 5.80 and 6.77, indicating that groundwater is mildly acidic.
- Additionally, leachate collected in the treatment pad or left over after filtering of sediments may also be acidic depending on the ASS status of stockpiled soils and bottom sediments.
- If the pH levels from the sampling undertaken in Step 2 (above) indicate pH is below 6.5 (the ANZECC criteria for discharge), pH adjustment may be required (depending on the preferred disposal option).
- If pH adjustment is required, a neutralising agent such as agricultural line ($CaCO_3$) or Sodium Hydroxide (NaOH) should be added to the water at a rate assessed from the results of the testing and Table 7.1 of the Management Guidelines in the ASSMAC (1998) Acid Sulfate Soils Manual. A copy of this table is provided in Appendix B.
- Following treatment, the water should be re-sampled and tested again for pH, EC and possibly metals.
- The results of the monitoring should be maintained by the earthworks contractor throughout the duration of the project.

6.2.4. Step 4 – Disposal of water

Extracted water can be disposed offsite (after pH adjustment, if required). The disposal option will be dependent on a number of factors, including:

- The volume of water to be disposed;
- Cost and timeframe implications;
- The quality and concentrations of contaminants in the water; and
- Council, Sydney Water and/or NSW EPA requirements (if any).

Options for disposal of extracted water include:

- Land irrigation;
- Disposal to Woolloomooloo Bay;
- Disposal to local sewer systems; and
- Offsite disposal to a wastewater disposal facility.

Depending on the volume of water to be disposed, the most effective option is considered to be land irrigation (e.g. use of water as dust suppression during earthworks). This would assist in maintaining groundwater levels, no specific permission from Council or other regulatory authorities would be required, and pH adjustment would not be required, provided the irrigation does not migrate to Woolloomooloo Bay.

Disposal of water to local sewer systems will likely require approval from Sydney Water. Additional sampling and treatment of water may be required in order to obtain a trade waste consent.

Offsite disposal via tanker to a wastewater disposal facility would not require specific permission from Council or other regulatory, or pH adjustment. However, if significant volumes of water are to be disposed, the cost and timeframes of implementing this option may not be practical.

Regardless of the disposal option selected, records of disposal should be maintained by the earthworks contractor, including the method and location of disposal, and the volume of water disposed.

7. Contingency plan

A contingency plan is outlined in Table 2, listing potential events that may arise during the fieldwork and actions that can be undertaken if unexpected conditions occur.

Table 2 – Contingency plan

Unexpected Condition	Action
ASS extends further than expected.	Options include excavating soils further, or potentially altering the design of the seawater heat exchange.
Water (rainwater and/or groundwater) fills excavation pits and visual and olfactory observations suggest that contamination could be present.	Sample water and assess options for disposal. Options could include disposal to sewer or removal by a licensed liquid contractor following sampling and analysis.
Identification of contaminants in excavated soil or water during excavation works	Managed in accordance with the Unexpected Finds Procedure included as Appendix A in the Remedial Action Plan (Coffey, 2017c). This would likely involve sampling soil or water for the potential contaminants of concern and assessing options for management. Options could include on-site remediation or management or offsite disposal.
Other (e.g. significant groundwater drawdown)	Other unexpected events which may affect the outcome of the investigation should be notified to the AGNSW and the Principal Contractor and managed in consultation with the environmental consultant.

8. Limitations

It is the nature of contaminated site investigations that the degree of variability in site conditions cannot be known completely and no sampling and analysis program can eliminate all uncertainty concerning the condition of the site. Professional judgement must be exercised in the collection and interpretation of the data.

In preparing the management plan, current guidelines for assessment and management of acid sulfate soils and contaminated land were followed. This work has been conducted in good faith in accordance with Coffey's understanding of the client's brief and general accepted practice for environmental consulting.

This management plan was prepared for the Art Gallery of NSW with the objectives of providing a scope of work to assess the nature and extent of ASS at the site (an ASS assessment), providing general guidance on the management of excavations, including separation of ASS from other soils, providing guidance on the management of ASS, including treatment and analysis requirements, and providing guidance on dewatering, including analysis and disposal requirements. No warranty, expressed or implied, is made as to the information and professional advice included in this report. Anyone using this document does so at their own risk and should satisfy themselves concerning the applicability of its application and where necessary should seek expert advice in relation to the particular situation.

This plan should be read in conjunction with the attached "Important Information about your Coffey Environmental Report".

9. References

Acid Sulfate Soil Management Advisory Committee (1998) *Acid Sulfate Soils Manual*.

ANZECC/ARMCANZ (2000) Australian Water Quality Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, October 2000.

Coffey (2014) Groundwater Monitoring Adjacent to Bunker Fuel Tank Site, Art Gallery of NSW. GEOTLCOV25037AA-AH. 2 July 2014.

Coffey (2016) Sydney Modern Project – Groundwater monitoring adjacent to former fuel bunkers. GEOTLCOV25037AC-L01a. 19 May 2016.

Coffey (2017a) Geotechnical Investigation, Sydney Modern Project, Art Gallery Road, Sydney, NSW. GEOTLCOV25037AA-AF Rev 2. September 2017.

Coffey (2017b) Art Gallery of NSW, Sydney Modern Project, Revised Stage 1 Preliminary Environmental Study. GEOTLCOV25037AC-R01 Rev2, September 2017.

Coffey (2017c) Art Gallery of NSW, Remedial Action Plan, Sydney Modern Project, Art Gallery Road, Sydney, NSW. GEOTLCOV25037AC-R03 Rev 3, September 2016.

Geological Survey of NSW (2007) 1:100,000 Sydney Geological Map, First Edition, Map Number SI 56-5.

Land and Property Information (2001) 1:25,000 Sydney Topographic Map, Edition 3, Map 9130-2N.

NEPC (2013) National Environmental Protection (Assessment of Site Contamination) Measure, National Environment Protection Council 1999, amended 2013.

NSW EPA (2014) Waste Classification Guidelines.

Queensland Acid Sulfate Soils Investigation Team (2014) Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.

Soil Conservation Service of NSW (1989) 1:100,000 Sydney Soil Landscape Map, Edition 1, Map Number 9130.

Soil Conservation Service of NSW (1995) 1:25,000 Prospect-Parramatta River Acid Sulfate Soil Risk Map.

WSP – Parsons Brinckerhoff Pty Ltd (2006) Marine Impact Assessment, Sydney Modern Project, Harbour Heat Rejection System, Reference 2270096A-ENV-REP-001 RevA dated July 2016.

Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice,

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept appraised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

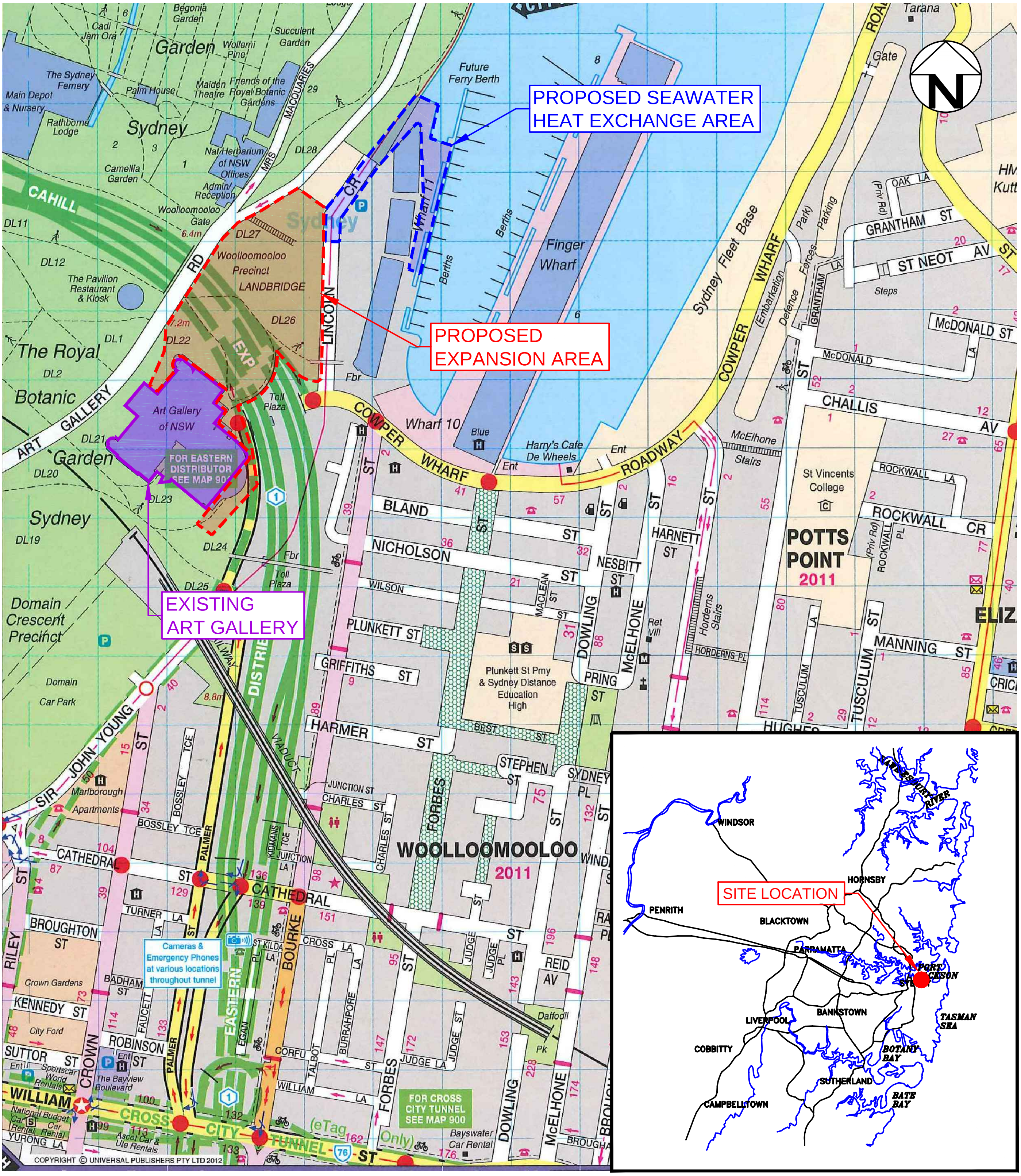
The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.

Figures



GENERAL AREA MAP

SOURCE:UBD STREET DIRECTORY GREGORYS
SYDNEY, NEW SOUTH WALES
48TH EDITION, 2013, MAP:J

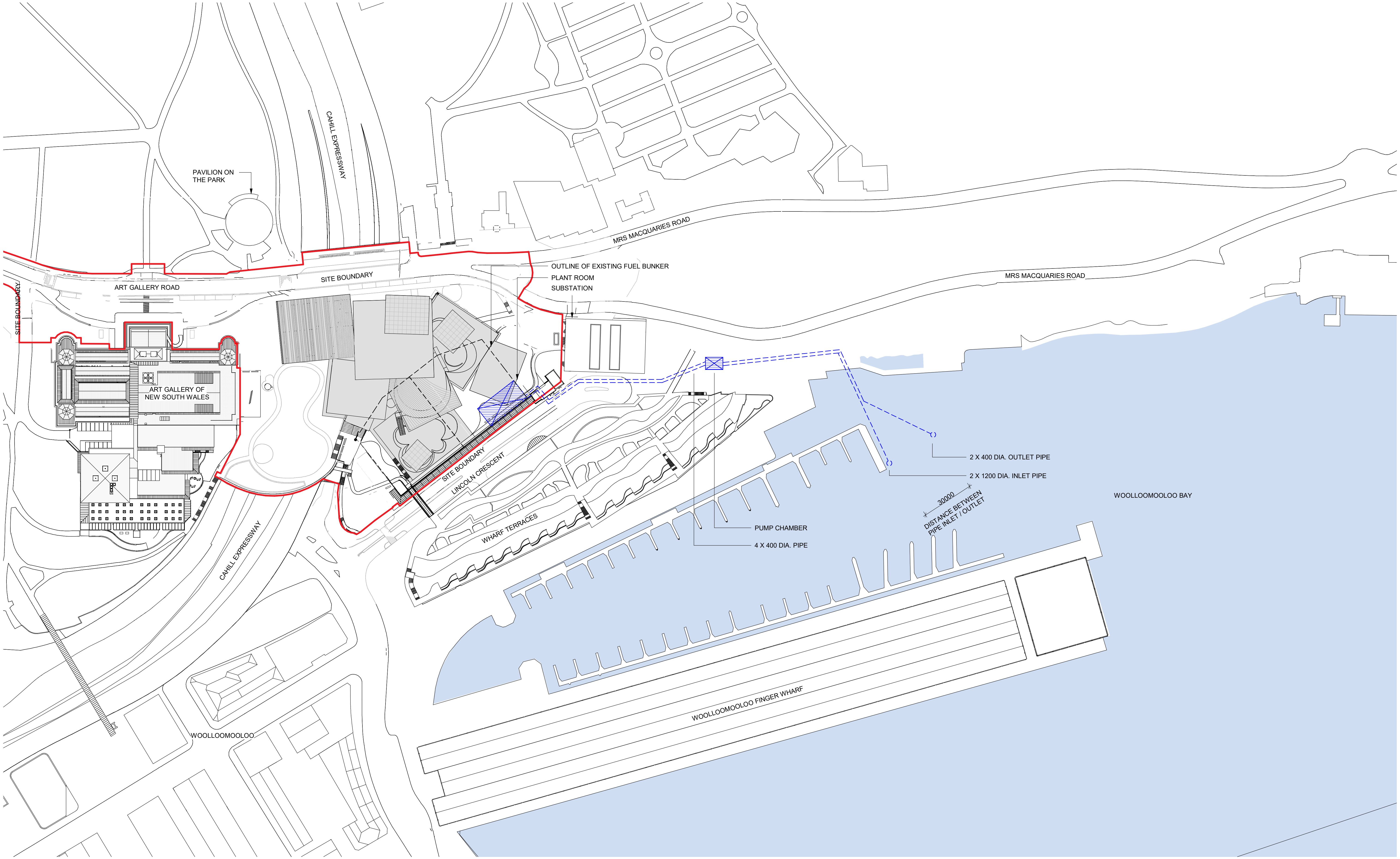
50 0 50 100 150 200 250

Scale (metres) 1:5000

drawn	CQ / AW	coffey A TETRA TECH COMPANY	client:	ART GALLERY OF NSW
approved	-		project:	SYDNEY MODERN PROJECT ART GALLERY ROAD, SYDNEY, NSW
date	31 / 05 / 16			
scale	AS SHOWN		title:	SITE LOCATION PLAN
original size	A4		project no: GEOTLCOV25037AC-R04	figure no: FIGURE 1 rev: A

PLOT DATE: 31/05/2016 3:13:05 PM DWG FILE: F:\GEOTECHNICS\1.PROJECTS\GEOTLCOV25037AC ART GALLERY NSW CONTAMINATION ASSESSMENT\DRAWINGS\GEOTLCOV25037AC-R03.DWG

Appendix A - Proposed Seawater Heat Exchange Infrastructure Options and Information



1 Plan

Scale: 1 : 1000

Revision	Description	Date
A	SSDA DRAFT	06 10 2017
B	SSDA Issue	19 10 2017
C	SSDA Issue	03 11 2017

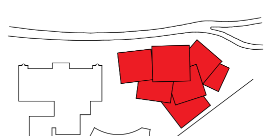
Scale: 0 10 20 30
1:1000 @ A1
1:2000 @ A3

checked LJ/JW/JJ

drawn Architectus project no 140419

Do not scale drawings.

Key Plan:



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project
ART GALLERY OF NSW EXPANSION PROJECT - SYDNEY MODERN

drawing
Sea Water Heat Exchange System Plan

drawing no. **DA_0056**

Revision **C**

Appendix B - QASSIT (2014) Table 4-1 and ASSMAC (1998) Table 7.1

Table 4-1: Texture-based acid sulfate soil action criteria

Type of material		Sum of existing and potential acidity			
		1−1000 t material disturbed		> 1000 t material 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 medium to heavy clays and silty clays	>40	0.1	62		
Medium Sandy loams to light clays	5 - 40	0.06	36	0.03	18
Coarse Sands to loamy sands and peats	< 5	0.03	18		
Draft action criteria for poorly buffered sands (see comments in text below table)					
Coarse sands, poorly buffered	< 5	0.01	6	0.01	6

While the first three action criteria are in common use in Australia, lower action criteria may be justifiable in specific circumstances (Western Australian Government, 2010). Disturbances of poorly-buffered sands with very low pyrite levels (<0.03% S) have led to groundwater acidification and subsequent arsenic contamination of domestic water supplies in Western Australia. The adoption of a lower action criterion of 0.01% S for such materials may be applicable to some circumstances in Queensland. Extra care is needed with laboratory determinations of low levels of existing and potential acidity and analyses need to be conducted by a laboratory that can provide very low reportable levels or specialised treatment of low analysis samples.

The highest laboratory result(s) should always be used to decide if the relevant action criterion level has been met or exceeded; using the average or mean of a set of results is not appropriate or acceptable.

Note: The action criteria are based on the existing plus potential acidity, ***not net acidity****. If a soil has some self-neutralising capacity, this may be taken into account, and a case can be made for a lower level of management (see ASS tip 17). For the purpose of ASS management according to this guideline, net acidity is defined in the latest version of the Laboratory Methods Guidelines (Chapter 3). This net acidity formula includes a 'fineness factor' which acts as a surrogate for the surface area of the neutralising material, so the formula may look different to some other net acidity formulae used in acid mine drainage management.*

4.1 Risk categorisation to guide management planning

Table 4-2 contains pre-calculated treatment amounts using pure $CaCO_3$ for disturbances of a given tonnage and laboratory-determined existing plus potential acidity. This table can be used to quickly evaluate the environmental risk posed by a planned disturbance. The table has also been divided into five risk-based treatment categories (low, medium, high, very high and extra high). Note that environmental risk increases in line with the level of treatment needed. Other factors will also

7. Neutralising acid leachate and drain water using lime

The liming rate for treating acid water should be carefully calculated to avoid the possibility of "overshooting" the optimum pH levels of 6.5 - 8.5. This can occur quite easily if more soluble or caustic neutralising agents such as hydrated lime (pH 12) or magnesium hydroxide (pH 12) are used. Overdosing natural waterways results in alkaline conditions and can impose environmental risks similar to acid conditions, with the potential to damage estuarine ecosystems (Bowman, 1993). It should be noted that when neutralising acid water, no safety factor is used. However, monitoring of pH should be carried out regularly during neutralisation procedures.

Agricultural lime (pH 8.2) is the safest and cheapest neutralising agent. It equilibrates around a pH of 8.2 that is not generally harmful to plants, stock or humans and most aquatic ecology species. The main shortcoming associated with the use of lime is its insolubility in water.
When using alkaline materials, strict protocols must be established for the use, handling and monitoring of these materials

7.1 Calculating the quantity of lime

The current pH is measured preferably with a recently calibrated pH detector. The desired pH is usually between 6.5 and 8.5 with pH 7 is normally targeted. The volume of water can be calculated by assuming 1 cu metre of acid water is equivalent to 1 kilolitre (1000 litre) and 1,000 cu metre is equivalent to 1 megalitre (ML).

> *Note: neutralising agents such as lime $CaCO_3$, hydrated lime $Ca(OH)_2$, CaO, MgO neutralise 2 mol of acidity (H^+), while sodium bicarbonate and sodium hydroxide neutralise only 1 mol of acidity.*

As a general guide, Table 7.1 shows minimum quantities of pure lime, hydrated lime or sodium bicarbonate needed to treat dams or drains of 1 ML (1,000 m^3) capacity.

Table 7.1 Quantity of pure neutralising agent required to raise from existing pH to pH 7 for 1 megalitre of low salinity acid water.

Current Water pH	*$[H^+]$ {mol/L}*	*H^+ in 1 Megalitre {mol}*	*Lime to neutralise 1 Megalitre {kg pure $CaCO_3$}*	*Hydr. lime to neutralise 1 Megalitre {kg pure $Ca(OH)_2$}*	*Pure $NaHCO_3$/ 1 Megalitre {kg}*
0.5	.316	316,228	15,824	11,716	26,563
1.0	.1	100,000	5,004	3705	8390
1.5	.032	32,000	1,600	1185	2686
2.0	.01	10,000	500	370	839
2.5	.0032	3,200	160	118	269
3.0	.001	1,000	50	37	84
3.5	.00032	320	16	12	27
4.0	.0001	100	5	4	8.4
4.5	.000032	32	1.6	1.18	2.69
5.0	.00001	10	0.5	0.37	0.84
5.5	.0000032	3.2	0.16	0.12	0.27
6.0	.000001	1	0.05	0.037	0.08
6.5	.00000032	.32	0.016	0.12	0.027

Notes on Table 7.1: *1 m^3 = 1,000 litre = 1 Kilolitre = 0.001 Megalitre*

- *Agricultural lime has very low solubility and may take considerable time to even partially react.*
- *Hydrated lime is more soluble than aglime and hence more suited to water treatment. However, as $Ca(OH)_2$ has a high water pH, incremental addition and thorough mixing is needed to prevent overshooting the desired pH. The water pH should be checked regularly after thorough mixing and time for equilibration before further addition of neutralising product.*
- *Weights of lime or hydrated lime are based on theoretical pure material and hence use of such amounts of commercial product will generally result in under treatment.*
- *To more accurately calculate the amount of commercial product required, the weight of lime from the table should be multiplied by a purity factor (100/ Neutralising Value for aglime) or (148/ Neutralising Value for hydrated lime).*
- *Calculations are based on low salinity water acidified by hydrogen ion, H^+ (acid) and do not take into account the considerable buffering capacity or acid producing reactions of some acid salts and soluble species of aluminium and iron. For example, as the pH increases towards 4, the precipitation of soluble ferric ion occurs, liberating more acid:*

  $$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$$

- *If neutralising substantial quantities of acid sulfate soil leachate, full laboratory analysis of the water will be necessary to adequately estimate the amount of neutralising material required.*

7.2 Application of lime to water

The biggest practical problem associated with using agricultural lime to treat acid water is getting it into solution so it can neutralise the acidity. Being crushed limestone, lime is difficult to dissolve. Without specialised application methods, lime has only limited effectiveness in treating acid water because of its low solubility (except at very low pH). Lime applied directly to water in a solid form will sit on the bottom and have little or no effect on the water pH.

Irrespective of the methods used to apply the agricultural lime, a change in pH will not be instantaneous. The rate of neutralisation will vary with the solubility, fineness of the lime, the application technique and the acidity (pH) of the water. The finer the lime (preferably microfine with the consistency of white dust) and the more agitated the water, the faster the lime will dissolve and become effective. The pH must be carefully monitored even after the desired pH has been reached. If the water has not reached the desired pH within two weeks, more lime may need to be added. Before additional lime is added, the lack of success should be investigated. Issues to consider may include:

- the quality of the lime being used
- the effectiveness of the application technique
- the existence of additional sources of acid leaching into the water body further acidifying the water.
- the lime has become lumpy and is sitting on the bottom

Neutralisation may be faster if higher rates are used, but is not recommended as it is expensive and resource wasteful. Moreover, over-dosing may result, though this is unlikely to be a concern with agricultural lime.

To increase the efficiency, lime should be mixed into a slurry before adding. A slurry can be prepared in a concrete truck, cement mixer or large vat with an agitator. Methods of application of the slurry include:

- spraying the slurry over the water with a dispersion pump
- pumping the slurry into the waterbody with air sparging (compressed air delivered through pipes) to improve mixing once added to water
- pouring the slurry out behind a small motorboat and letting the motor mix it in
- incorporating the slurry into the dredge line (when pumping dredge material)