Esso Highlands Limited

Papua New Guinea LNG Project

Environmental and Social Management Plan Appendix 15: Acid Sulfate Soils Management Plan

PGGP-EH-SPENV-000018-017

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TABLES

ATTACHMENTS

1.0 OBJECTIVES

Esso Highlands Limited (Company) has developed this Acid Sulfate Soils Management Plan as part of its Environmental and Social Management Plan (ESMP).

The Acid Sulfate Soils Management Plan outlines the strategies to be used in the management of acid sulfate soils when these are encountered.

Contractor shall develop a Site-Specific Acid Sulfate Soils Management Plan based on preliminary investigation data prior to the commencement of works.

The objectives of Company's Acid Sulfate Soils Management Plan are to:

1. Protect the local environment from adverse impacts arising from the disturbance of actual acid sulfate soils and potential acid sulfate soils
2. Identify measures to avoid or minimise the disturbance of acid sulfate soils and to contain, mitigate and minimise the impacts of disturbed acid sulfate soils.

Performance Criteria include the following:

- Compliance with specified regulatory requirements. In the absence of international acid sulfate soils guidelines, the Queensland regulations have been adopted as most appropriate (see Section 3.2 below)
- Significant degradation to the environment is not to result from acid sulfate soils disturbance/treatment associated with the work activities.

The Acid Sulfate Soils Management Plan should be read in conjunction with the following Company documents:

- Water Management Plan
- Hazardous Material Management Plan
- Erosion and Sediment Control Management Plan
- Dredging Management Plan.

2.0 LEGAL AND OTHER REQUIREMENTS

Legal and other requirements applicable to this plan are identified in Attachment 1.

3.0 SURVEYS

Contractor shall confirm that any surveys described in the plans listed above have been completed. Additional surveys may be required as detailed in this plan.

3.1 Background to Acid Sulfate Soils

Acid sulfate soils are soils which contain iron sulfides (pyrite). If pyritic acid sulfate soils are undisturbed in anaerobic conditions, the pyrite is stable and there are no impacts. Under aerobic conditions, the pyrite oxidises to form sulfuric acid in runoff. The acid can cause the degradation of aquatic flora and fauna in the receiving environment and corrode structural elements (e.g., concrete and iron) in a development. In severe cases, ecosystems can be permanently destroyed by runoff from disturbed acid sulfate soils and the acidic conditions have contributed to failure of bridges, culverts and other structures.

The formation of acid sulfate soil requires the presence of iron (naturally available from sediments), sulfur (usually present in sediments of marine origin) and organic matter.

Acid sulfate soils are thus formed under specific environmental conditions. They typically occur in recent Holocene-age alluvial soils.

In marine coastal environments the acid sulphate soils are thus found predominantly below RL 5 metres above mean sea level (AMSL) (the height of the seas during the Holocene) and they are usually only present in unconsolidated sediments.

The specific conditions under which acid sulfate soils are formed (as outlined above) allow investigations to be concentrated at sites where they are likely to occur with only minor confirmatory investigations required in areas where acid sulfate soils are less likely to occur.

Furthermore, acid sulfate soils are only an environmental hazard if they are changed from an anaerobic to an aerobic environment such as by excavating the soils or lowering the water table. Thus, there are no environmental management reasons to investigate areas where soils will remain in anaerobic conditions.

3.1.1 Guidelines for Acid Sulfate Soils Investigation, Assessment and Management

There are no relevant PNG or international guidelines on acid sulfate soils investigation, assessment and management.

The requirements of the Queensland Government's State Planning Policy 2/02: Planning and Managing Development Involving Acid Sulfate Soils (SPP2/02) may be used for guidance. SPP2/02 has attendant guidelines published by the Queensland Acid Sulfate Soils Investigation Team (QASSIT), these being:

- Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland (1998)
- Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines (2002)
- Acid Sulfate Soils Laboratory Methods Guidelines (2003)

SPP 2/02 and its attendant guidelines represent best practice within Australia and have been developed for use in tropical littoral environments such as those that occur in Papua New Guinea.

The purpose of the acid sulfate soils investigation and assessment is to allow environmental risks associated with acid sulfate soils to be comprehensively evaluated and to provide a basis for the development of a management plan to mitigate potential negative impacts arising from the disturbance of such soils.

3.1.2 Acid Sulfate Soil Investigation and Assessment

An acid sulfate soils investigation and assessment is required to:

- Collect sufficient soil samples and laboratory analyses data to delineate the extent and severity of potential acid sulfate soils on the site
- Generate estimates of soil volumes that may require management under the Site Specific Acid Sulfate Soil Management Plan
- Provide input data to the Site Specific Acid Sulfate Soil Management Plans
- Identify areas where engineering controls may be required to ensure protection of the environment from acid runoff and to ensure the integrity of facility infrastructure in contact with acid sulfate soils.

4.0 MANAGEMENT AND MONITORING

Table 1 presents a summary of potential impacts related to acid sulfate soils together with mitigation and management measures to avoid or reduce these impacts.

Examples of field sampling protocols are provided in Attachment 2.

Contractor shall develop a Site-Specific Acid Sulfate Soils Management Plan, which will as a minimum incorporate the measures described in Table 1 but shall not be limited to these measures.

Due to differing scopes of work and work locations, not all management and mitigation measures in the Acid Sulfate Soils Management Plan are applicable to all Contractors. Company's Environmental and Social Mitigation Register defines which management and mitigation measures are applicable to each Contract scope of work.

Mitigation and management commitments contained in the PNG LNG Project Environmental Impact Statement (EIS) are identified by a code commencing with an 'M' in the 'Mitigation Item Reference Number' column. Some mitigation measures have been reworded to provide further clarity or more detailed information regarding required measures. In these instances, the code is displayed in italics, and these reworded measures supersede what is in the EIS.

Other mitigation and management commitments required by Company are identified with a code commencing with an 'A'.

Monitoring required as part of the Acid Sulfate Soils Management Plan is shown in Table 1.

Contractor shall develop site-specific procedures for the monitoring program, to be agreed by Company.

The management of acid sulfate soils during the construction works shall mitigate impact by incorporating appropriate strategies that minimise environmental harm.

Contractor's Site-Specific Acid Sulfate Soils Management Plan shall adopt the hierarchy of management principles set out in the Queensland Acid Sulfate Soil Technical Manual Soil Management Guidelines (2002).

These include, as the preferred method of mitigation, avoidance of acid sulfate soils disturbance where practicable.

When not practicable, procedures include:

- Minimization, mitigation and management measures for disturbance
- Neutralization strategies for excavated acid sulfate soils
- Hydraulic separation in conjunction with dredging
- The strategic reburial of acid sulfate soils below the permanent groundwater table, (although this may not be suitable for soils where there is significant existing activity without additional mitigation measures)
- Higher risk management strategies including stockpiling, filling and large scale dewatering or drainage.

Details of these management strategies are outlined below.

4.1 Avoidance

The preferred method of management is to avoid disturbance of the acid sulfate soils. Those persons involved in the design of the works shall be fully informed of the location and severity of acid sulfate soils on the site and shall take due consideration of the costs and environmental risks associated with acid sulfate soils disturbance within the project area.

The proposed design shall be reviewed to determine if disturbance of the acid sulfate soils can be practically and economically avoided by:

- Relocating works.
- Decreasing the depth of works.
- Modifying the design to avoid excavation of acid sulfate soils.
- Modifying the design so that dewatering in acid sulfate soils is not required.

Records shall be kept of such design reviews.

Filling activities may disturb in situ acid sulfate soils by:

- Bringing actual acid sulfate soils into contact with the groundwater
- Displacing or extruding previously saturated potential acid sulfate soils above the water table
- Raising acidic groundwater tables with the short-term release of acid into waterways.

Contractor shall conduct geotechnical investigations to allow the calculation of likely settlement, shear failure and heave associated with the proposed works in acid sulfate soil profiles.

Contractor shall prepare a geotechnical report setting out the likely settlements and the area and magnitude of any likely heave.

4.1.1 <u>Minimisation</u>

Where avoidance is not possible, Contractor shall design and construct the works as far as reasonably possible to minimise the disturbance of acid sulfate soils and the exposure to air of pyrite.

Once fully informed of the location and severity of acid sulfate soils on the site, Contractor shall review the potential for disturbance of acid sulfate soils to be practically and economically minimised by:

- Decreasing the depth of works
- Minimising the extent of works potentially interacting with acid sulfate soils
- Minimising the periods of dewatering of any in situ potential acid sulfate soils
- Modifying the design so that dewatering in acid sulfate soils is not required.

Contractor shall design structures, fill platforms and embankments so as to minimise subsidence, settlement and heaving.

Contractor shall minimise disturbance of the natural drainage systems by maintaining existing surface and groundwater flow paths.

Contractor shall limit changes to water table levels by minimising changes to the drainage systems and any tidal influences.

Contractor shall devise construction methods to minimise acid sulfate soils risks by:

- Planning and conducting the work in stages to minimise exposure time of any acid sulfate soils disturbed by the works
- Keeping exposed acid sulfate soils surfaces moist by irrigation or the use of appropriate covers to restrict oxygen diffusion into the soil
- Ensuring buffers, bunds or barriers are used to separate the works areas from adjacent acid sensitive areas
- Establishing defined treatment areas which can be bunded and lined to contain any acid generated during holding and treatment periods
- Containing of any acid affected waters until it can be treated and checked prior to the controlled release to the environment.

Contractor shall include details of such management strategies in the Site-Specific Acid Sulfate Soils Management Plan.

4.1.2 Neutralisation

Fine grained agricultural lime (or similar neutralising agents) shall be the prime neutralisation agent of disturbed actual acid sulfate soils and potential acid sulfate soils on the site where avoidance is not practical.

Disturbance from dredging, excavations, exposed batter cuts and soil displacement by heaving in acid sulfate soils profile shall require effective neutralisation at the nominated treatment rate.

4.1.3 Liming Rate Testing

All soils to be excavated within nominated potentially affected areas shall be tested for acid generating potential at the rate of 1 test per 1000 cubic metres. Unless otherwise agreed, the testing shall be by the chromium reducible sulfur (S_{CR}) method plus actual and retained acidity (TAA and S_{NAS}). Acidity shall be defined as the sum of the TAA plus S_{CR} plus S_{NAS}.

Where testing has shown that the soils contain greater than the threshold limits of 18 moles per tonne acidity (or other criteria to indicate Potential acid sulfate soils/Actual acid sulfate soils), the liming rate to neutralise the potential acid shall be calculated. The liming rates shall be calculated on the basis of TAA plus S_{CR} plus S_{NAS} with a 1.5 factor of safety.

The location and depth of all tests for acid sulfate soils shall be accurately marked on a plan of the works area. Where identified acid sulfate soils are removed to a treatment area, a stake bearing the ID number of the relevant soil samples shall be placed in the area in which the fill has been placed.

4.1.4 Treatment Areas and Lime Treatment Method

Acid sulfate soils shall be stored and treated at strategically located soil storage and handling areas (to be identified in the site specific Acid Sulfate Soil Management Plan). All acid sulfate soils are to be stored and treated in these prepared areas.

Treatment areas shall be constructed in accordance with Section 8.3.6 of the Soil Management Guidelines (Dear, 2002), which include:

- Perimeter bunds of impermeable non acid sulfate soils around the storage area.
- An internal perimeter drain grading to a central sump that shall be constructed inside the bund where any run off can be collected, checked for pH and treated if necessary.
- The base of the treatment area to be constructed from non acid sulfate soils.

A guard layer of fine agricultural lime or similar shall be applied to the base and bunds of the storage areas at a minimum rate of 10 kilograms per square metre.

The treatment area shall be located at a minimum distance of 30 metres from waterways. Alternatively, the area shall be enclosed in two sets of parallel bunds.

The soils requiring treatment shall be:

- Spread in layers of 300mm loose (maximum) depth and each layer shall be treated with fine agricultural lime (or similar) at the nominated calculated rate.
- The lime shall be thoroughly mixed through the soil by discing, harrowing or rotary hoeing.
  - The soils may require drying and must be worked several times to ensure thorough mixing.
  - Sampled and laboratory tested for to confirm the effectiveness of the treatment.

Where actual acid sulfate soils and potential acid sulfate soils occur in cut batter faces, the soils on the batter faces shall be treated with fine agricultural lime (or similar) at the nominated calculated rate (with a minimum rate of 10 kilograms per square metre).

The lime shall be incorporated in the batter face by tyning or other mechanical means.

4.1.5 Validation Testing

Verification testing of treated actual acid sulfate soils and potential acid sulfate soils at the rate of 1 test per 500 cubic metres shall be undertaken to confirm the effectiveness of the lime treatment.

The treatment shall be deemed successful when the treated soils have a post oxidation pH greater than 6.5 and the excess acid neutralising capacity determined by back titration (ANCbt) is more than 1.5 times the acid generating potential determined by the SCR method.

Contractor shall include the required details of laboratory test certificates, lime receipts and monitoring records in Contractor's Site-Specific Acid Sulfate Soils Management Plan.

4.1.6 Hydraulic Separation

Dredging is proposed for the gas pipeline Right of Way from onshore to offshore.

The separation of pyritic fines using hydrosluicing is a measure for acid sulfate soils management during dredging of potential acid sulfate soils.

This measure is only effective where the dredge materials are predominantly sands with not more than 20% clay and silt fines. To enhance the removal of pyritic fines during sluicing,

Contractor shall ensure:

- A turbulent flow is achieved by incorporating tight bends in the dredge pipe
- The length of residence time in the pipeline is increased as far as possible
- The discharge return flow drains are kept relatively small and steep to ensure high water velocities and turbulent conditions so that the pyritic fines remain in suspension and do not settle out and concentrate near the discharge point

- An excavator continually works and shapes the discharge area, keeping the pyritic fines overflow in one well defined steep, fast flowing channel all the way to the point discharge into the pyritic storage dams established for the period of dredging
- Maintain the discharge point to prevent the build up of fines ‘fans’ that drain through previously washed sands, leaving pyritic fines buried in the fill.

Hydraulic separation does not normally remove all pyritic fines. The effectiveness depends on the proportion of silt and clay fines in the dredged materials.
Rigorous site management, including the use of guard layers, water pH control, in-line dosing and neutralising procedures, which may be required if hydraulic separation is proposed by Contractor as an acid sulfate soils management strategy.

Contractor shall include details of the proposed management measures in Contractor’s Site-Specific Acid Sulfate Soils Management Plan.

4.1.7 Strategic Reburial

Strategic reburial involves the placement of potential acid sulfate soils below the permanent water table.

Should strategic reburial of potential acid sulfate soils be deemed necessary, it may be adopted under the conditions outlined in the Soil Management Guidelines (Dear, 2002).

Reburial shall only be permitted:

- In company approved areas a minimum of 0.5 metres below the lowest recorded permanent water table level
- Where the buried materials are capable of supporting a capping layer 0.2 to 0.5 metres thick of a non acid sulfate soils material
- Where limnological studies indicate that there is no risk of the pyritic fines being re-suspended in the water column
- For soils with TAA plus retained acidity below 0.03% oxidisable sulfur (the Qacid sulfate soils IT threshold) or soils which have been treated to neutralise their actual acidity.

Soils proposed for strategic reburial shall be sampled and tested for TAA and retained acidity prior to any excavation.

A safety factor of 1.5 shall be used in liming rate determinations to treat the actual acidity in soils allocated for strategic reburial.

Any soils proposed for reburial must be:

- Reinterred within 72 hours of excavation.
- Kept moist by sprinkler irrigation to reduce oxygen diffusion into the soils when excavated and waiting to be reburied.

Details of the limnological studies, reburial areas, reburial area design and proposed management measures for strategic reburial of potential acid sulfate soils shall be set out in Contractor’s Site-Specific Acid Sulfate Soils Management Plan.

4.1.8 Higher Risk Management Strategies

Stockpiling

Due to the local climatic conditions only short term stockpiling of acid sulfate soils is recommended (3 days maximum).

All stockpiles shall be appropriately contained by limed guard layers, bunds and leachate collection systems.

Untreated acid sulfate soils stockpiles shall be located at a minimum distance of 30 metres from waterways. Alternatively, the area shall be enclosed in two sets of parallel bunds.

<u>Exposed Batters in Acid Sulfate Soils Profiles</u>
Contractor shall plan the works program in such a way as to minimize the time of exposure of any cut batter faces in acid sulfate soils.

This may involve the staging of works or the use of a larger workforce to complete sections of the work which involves the exposure of acid sulfate soils.

Where periods of prolonged exposure cannot be avoided, precautionary measures shall be adopted for exposure periods in excess of 3 days and these may involve:

- Applying a surface coating of fine agricultural lime to the batter face
- Maintaining the surface of the cut batter in a moist condition to restrict the diffusion of oxygen into the soil. This may be done by irrigation of the batter. Alternatively, the batter may be covered with plastic sheeting to reduce drying and restrict oxidation
- Isolating the exposed acid sulfate soils from adjacent areas and waterways by the used of bunds or appropriately designed drains
- Collection and retention of runoff from exposed acid sulfate soils so that it can be checked and treated if necessary prior to release.

<u>Large scale dewatering or drainage</u>
Large scale dewatering or drainage in acid sulfate soils profiles may disturb in situ potential acid sulfate soils through the lowering of the groundwater table.

The management of any proposed disturbance of in situ Potential acid sulfate soils shall incorporate:

- Minimizing the exposure time of the soil surfaces to be recovered
- Keeping exposed surfaces moist/covered
- Minimising the period of dewatering by excavating soils above the water table initially and dewatering only for the excavation of the deeper soils below the water table
- Dewatering to the minimum depth required to allow the works to proceed
- Where feasible, undertaking excavation and dewatering in stages so that the period of dewatering in any one area is minimised
- Limiting the extent of the drawdown of the water table in the vicinity of the dewatering by the using aquifer recharge techniques such as recharge trenches or recharge spear
- Regular and frequent irrigation of soils overlying a dewatered aquifer should be undertaken so that, as far as possible, the overlying soils are maintained in a near saturated condition to restrict the diffusion of oxygen into the soils
- Maintaining an elevated pH level (in the range 7.5 to 9.0) in any recharge and/or irrigation waters in the range 7.5 to 9.0) to help minimise any acid formed.

Water from dewatering operations, accumulations in large excavations and bunded treatment areas shall be discharged only when quality parameters are within specified acceptable limits.

Water from dewatering operations may be treated with in line treatment systems with release quality parameters monitored not less than once per hour while discharging.

Alternatively, water from dewatering operations may be held in storage until it has been tested and treated as necessary prior to release. All water from the excavations (infiltration, rainfall runoff, construction water) shall be retained in the excavation and/or bunded areas until it has been tested for quality and satisfies the criteria detailed in Table 2.

Specific groundwater management strategies will be necessary if prolonged periods of dewatering are required.

A minimum of three monitoring bores shall be used in each area where acid sulfate soils occur and prolonged dewatered is required. Details of the proposed management measures shall be set out in Contractor's Site-Specific Acid Sulfate Soils Management Plan.

Details of the hydrological conditions, geolimnological studies, reburial areas, reburial area design and proposed management measures for strategic reburial of Potential acid sulfate soils shall be set out in the site specific Acid Sulfate Soil Management Plan.

4.1.9 Potential Disturbance of Acid Sulfate Soils

Construction activities which may disturb soils with acid sulfate potential include:

- dredging of the pipeline RoW from onshore to offshore
- excavations from bored or drilled piles for jetty or fencing works
- stripping and excavations for roads, pipelines, structures and civil works
- stockpiling of acid sulfate soils within the Project area
- dewatering for pipeline trenches, civil trenches and basement construction.

Table 1: Management and Monitoring

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Source of Impact	**Potential Impact and Relevant Management Plan Objective**[†]	**Mitigation and Management (Design Feature/Specific Measure)**	**Mitigation Item Reference Number**	**Monitoring**	**Minimum Monitoring Frequency**	**Responsibility**
Dredging of the pipeline RoW	Dredged Potential acid sulfate soils placed in aerobic conditions may generate sulfuric acid and leach sulfuric acid and dissolved metals into the environment.	Lime neutralization Hydraulic Separation Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2.	Contractor
Bored or drilled pile excavations	Excavated acid sulfate soils may be placed in aerobic conditions and any untreated acid sulfate soils may generate sulfuric acid and leach sulfuric acid and dissolved metals into the environment. Exposure of soils, surface water and groundwater to acid sulfate soils and acid leachate resulting in reduced quality.	Lime neutralization Strategic Reburial Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2.	Contractor

Table 1: Management and Monitoring						
Source of Impact	**Potential Impact and Relevant Management Plan Objective†**	**Mitigation and Management (Design Feature/Specific Measure)**	**Mitigation Item Reference Number**	**Monitoring**	**Minimum Monitoring Frequency**	**Responsibility**
Stripping and excavations for roads, pipelines, structures and civil works	Excavated acid sulfate soils may be placed in aerobic conditions and any untreated acid sulfate soils may generate sulfuric acid and leach sulfuric acid and dissolved metals into the environment. Changes to surface runoff patterns may speed the release and transport of acids and dissolved metals to the environment. Exposure of soils, surface water and groundwater to acid sulfate soils and acid leachate resulting in reduced quality. Acid corrosion to facility infrastructure resulting from direct contact with acid sulfate soils.	Avoidance Minimization Lime neutralization Higher Risk Strategies Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2	Contractor

Table 1: Management and Monitoring

Source of Impact	Potential Impact and Relevant Management Plan Objective[†]	Mitigation and Management (Design Feature/Specific Measure)	Mitigation Item Reference Number	Monitoring	Minimum Monitoring Frequency	Responsibility
Stockpiling of Acid Sulfate Soils	Uncontrolled surface runoff from acid sulfate soils stockpiles may leach any untreated acid and dissolved metals.	Lime neutralization Higher Risk Strategies Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2	Contractor
Fill placement	Placement of fill over weak alluvial soils may result in settlement or heaving adjacent to the loaded area. Settlement may cause Actual acid sulfate soils to come in contact with the groundwater. Heaving may result in Potential acid sulfate soils being elevated to an aerobic situation causing the formation and leaching of sulfuric acid	Avoidance Minimisation Lime neutralization Higher Risk Strategies Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2	Contractor

Table 1: Management and Monitoring						
Source of Impact	**Potential Impact and Relevant Management Plan Objective†**	**Mitigation and Management (Design Feature/Specific Measure)**	**Mitigation Item Reference Number**	**Monitoring**	**Minimum Monitoring Frequency**	**Responsibility**
Dewatering	Long term dewatering (greater than three days) may cause the drawdown of the water table within a cone of depression associated with the dewatering. The depression of the water table may result in the aeration of in situ Potential acid sulfate soils, the oxidation of pyrites and the subsequent leaching of acids and dissolved metals Water discharged during dewatering activities in acid sulfate soils areas may not be compliant with government legislations, standards and water quality guidelines. Therefore any uncontrolled discharge of these waters may result in the degradation of the receiving water body	Avoidance Minimisation Lime neutralization Higher Risk Strategies Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2	Contractor

Table 1: Management and Monitoring

Source of Impact	Potential Impact and Relevant Management Plan Objective[†]	Mitigation and Management (Design Feature/Specific Measure)	Mitigation Item Reference Number	Monitoring	Minimum Monitoring Frequency	Responsibility
Re-use of Acid Sulfate Soils for vegetation strata (topsoil)	Reuse of any untreated acid sulfate soils can lower soil pH and may severely limit vegetation growth in such areas and result in the leaching of acids and dissolved metals.	Lime neutralization Adopted management strategies to be defined in Contractor's Site Specific Acid Sulfate Soils Management Plan.	M28	Monitoring requirements are to be set out in Contractor's Site Specific Acid Sulfate Soils Management Plan, which shall document sources and volumes of acid sulfate soil and outline the monitoring required to demonstrate the effectiveness of the mitigation measures.	Refer to Table 2	Contractor

[†] See Section 1

5.0 ROLES AND RESPONSIBILITIES

Contractor shall ensure sufficient resources are allocated on an ongoing basis to achieve effective implementation of Contractor's Site-Specific Acid Sulfate Soils Management Plan.

Contractor's Site-Specific Acid Sulfate Soils Management Plan shall describe the resources allocated to and the responsible personnel for the execution of each task and requirement contained therein, and shall describe how roles and responsibilities are communicated to relevant personnel.

Company shall ensure sufficient resources are allocated on an ongoing basis to achieve effective implementation of Company's responsibilities in the Acid Sulfate Soils Management Plan.

6.0 TRAINING AND AWARENESS REQUIREMENTS

Contractors Site-Specific Acid Sulfate Soils Management Plan shall describe the training and awareness requirements necessary for its effective implementation.

Contractor's training activity associated with the Site-Specific Acid Sulfate Soils Management Plan shall be appropriately implemented by means of a training needs assessment, training matrix/plan and by keeping records of training undertaken.

Company shall ensure that all Company personnel responsible for the execution of Company's tasks and requirements in the Acid Sulfate Soils Management Plan are competent on the basis of education, training and experience.

Company's training activity associated with the Acid Sulfate Soils Management Plan shall be appropriately documented by means of a training needs assessment, training matrix/plan and records of training undertaken.

7.0 PERFORMANCE INDICATORS

Table 2 outlines indicators for measuring and verifying performance in relation to acid sulfate soils.

Table 2: Performance Indicators

ID #	Performance Indicator	Measurement	Internal Assessment Frequency	Relevant Management Plan Objective[†]
1	Surface Water Quality	pH within 6.5 to 8.5	pH hourly when discharging	As determined by specific onsite surface water treatment areas outlined in the site specific Acid Sulfate Soil Management Plan
		DO >5.0mg/l or background whichever is lesser Turbidity <20 NTU or background	Daily when discharging	
		Dissolved Al <100µg/l or background Dissolved Fe <500µg/l or background	Weekly when discharging	
2	Groundwater Monitoring	Groundwater level variation ± 0.2m pH variation±0.5	Weekly when dewatering	As outlined in the site specific Acid Sulfate Soil Management Plan (if required minimum of x3
		Maintain baseline levels for: Electrical Conductivity, Redox	Weekly when dewatering	

ID #	Performance Indicator	Measurement	Internal Assessment Frequency	Relevant Management Plan Objective†
		Sulfates, Chlorides, Titratable Acidity		bores)
		Maintain baseline levels for dissolved Fe, Mn and Al ions	Monthly when dewatering	
		Trace elements Zn, Cu, Pb		
Performance Indicators to be further developed and agreed between Contractor and Company				

† See Section 6

8.0 REPORTING AND NOTIFICATION

Notification and reporting requirements will be defined by Company following the completion of the acid sulfate soils surveys as part of the development of Contractor's Site Specific Acid Sulfate Soils Management Plan.

Attachment 1: Legal and Other Requirements

LEGAL AND OTHER REQUIREMENTS

Contractor shall comply with applicable Papua New Guinea Laws and Regulations, applicable International Finance Institution (IFI) requirements and International Treaties and Conventions (where applicable).

Papua New Guinea Laws and Regulations

The Environment Act 2000 contains numerous provisions that promote environmental protection, regulate environmental impacts associated with development activities, and safeguard the life supporting capacity of air, water land and ecosystems.

Attachment 2: Field Sampling Protocols

INTRODUCTION

The following protocol presents the recommended minimum sampling requirements as described in the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998* (October 1998, Revision 4.0) prepared by the Queensland Acid Sulfate Soils Investigation Team (QASSIT Guidelines).

Additional sampling is recommended to support a quality control and quality assurance system additional samples may or may not be used for analysis.

With justification and approval from Company, variations in sampling methodology may be acceptable to represent site specific conditions.

BOREHOLE DENSITY

Profile intensity is dependant on the volume and area of Acid Sulfate Soils disturbance and whether the disturbance is non-linear or linear.

Non-linear Disturbances

For sites involving <1000m^3 of soil disturbance the number of profile sampling required is illustrated in the following table:

Minimum number of profile sampling (boreholes or test pits) based on volume of disturbance for non linear disturbances

Volume of Disturbance (m^3)	Number of holes
≤250	2 holes
251 to 1000	3 holes
> 1000	Refer to Table 2

For sites involving disturbances >1000m^3 the number of profile sampling required is illustrated in the following table:

Minimum number of profile sampling (boreholes or test pits) for sites involving disturbances >1000m3

Area of Site	Number of holes
Up to 1 ha	4 holes
1-2 ha	6 holes
2-3 ha	8 holes
3-4 ha	10 holes
> 4 ha	2 holes/ha

Linear Disturbances
For linear (eg. trenching, roads) disturbances, conduct profile sampling at 50 metre intervals along the length of disturbance.

SAMPLING SOIL FOR ACID SULPHATE ANALYSIS

1. Identify and record the borehole or test pit location and elevation. The use of a GPS unit or survey equipment may be necessary to attain the full grid reference of each hole (the accuracy of the equipment used must also be specified).
2. Drill or auger boreholes to at least two metres depth, or at least one metre below the maximum depth of disturbance (whichever is greater).
3. Log borehole or test pit using the Unified Soil Classification System, including soil texture, colour, mottling and other diagnostic features (e.g. jarosite, shell, sulfur odor)
4. Record watertable depth below surface and if groundwater disturbance is proposed collect water sample.
5. Collect a minimum of 40g soil samples at 0.25m depth intervals. Ensure at least one sample is taken from each soil horizon.
6. The soil sample should be placed in a zip lock polythene storage bag. Preferably use bags with a white panel. Use a black permanent marker to write on the sample bag. Exclude air from the bag before sealing.
7. Store the bags ASAP in an esky with ice or freezer blocks.
8. On return to the office freeze the samples solid (overnight) and courier as soon as possible to the testing laboratory. All samples should be retained in storage until the report has been assessed and approved. If delays in the assessment are expected arrange longer holding times with the laboratory.

SAMPLE SELECTION AND LABORATORY ANALYSIS

Soil Testing

Laboratory testing of the soil samples is undertaken in two parts. Part 1 is the field screen (pH_F and pH_{FOX}) testing, these tests indicate whether Acid Sulfate Soils are likely to be present or absent.

Part 2 of the QASSIT Guidelines recommend using a peroxide screen test on all samples and the more definitive quantitative laboratory testing of one sample per 0.5 m depth intervals. The volume of analyses and testing may be reduced by directing analyses at the strata of concern without compromising the validity of the investigation. This method requires written authorization from the project. The scope of analyses recommended would be determined by the criteria below:

- Undertake testing on samples of unconsolidated (soft) sediments.
- Undertake testing on a limited number of samples of stiffer sediments and residual soils to confirm their non-acid sulfate soils status.
- Confirmation that representative samples of all possible acid sulfate soils strata are tested but do not redundantly test numerous samples of each strata.
- Select appropriate analytical methods that will provide certainty of assessment and allow the development of the most environmentally and cost effective management options.

The peroxide screen test uses peroxide, a powerful oxidising agent, which often leads to false positives. In this area however where soils have natural high levels of calcium carbonate, the screen test is likely to provide a good indication of acid sulfate soils.

The use of quantitative laboratory analyses is the preferred means of definitively identifying acid sulphate soils and provides data necessary for the development of an acid sulfate soil Management Plan. The QASSIT Guidelines recommend the peroxide oxidation combined acidity and sulfur (POCAS) test suite.

This has subsequently been modified to the Suspended POCAS (SPOCAS) method. This method also results in some false positives as the method does not differentiate between relatively benign organic sulfur and the harmful inorganic (pyritic) sulfur.

Potential methodologies may include a combination of three tests as set out below.

- Where pH is less than 6.5, analyse for total actual acidity (TAA) plus pre-oxidation sulfur to assess the strength and nature of the pre-existing acidity.
- Use the chromium reducible sulfur (Scr) method to measure the oxidisable inorganic (pyritic) sulfur.
- Use the acid neutralising capacity (ANC) to measure the natural neutralising capacity of the soils.

These three tests (referred to herein as the Scr suite) are regarded as the most reliable means of testing for acid sulfate soils and are recognised by QASSIT.

Non-linear Disturbances

The rate of testing required is determined by the proposed volume of Acid Sulfate Soils to be disturbed. For sites involving <1000m^3, field screen test all samples. Using the table below, calculate the minimum number of samples required for either SPOCAS or Scr analysis:

Recommended number of samples# to be initially selected for laboratory analysis for non-linear disturbances <1000m^3

	Maximum disturbance depth*			
	<1 m (Borehole depth 2m)	1-2m (Borehole depth 3m)	2-3m (Borehole depth 4m)	3-4m (Borehole depth 5m)
Volume of disturbance ≤ 250 (m^3)	3	4	5	6
Volume of disturbance 251-1000 (m^3)	4	5	6	7

Number of samples to be analysed per total volume of soil to be disturbed, not per borehole.
* Depth of disturbance from ground surface. Borehole must be 1 metre below maximum depth of disturbance.

Linear Disturbances
Field screen test all samples with half chosen for either SPOCAS or TAA SCr test analysis.

Residual Soils
If residual soils are encountered within the soil profile screen test at half metre intervals with two samples maximum chosen for either SPOCAS or Scr analysis within the residual profile to confirm their non Acid Sulfate Soils status.

Preliminary Groundwater Testing
Conduct a field test for electrical conductivity and pH. If the pH is below 6.5 then laboratory test for dissolved Ca, Mg, Fe, Mn, Al, Cl and SO4 and titratable acidity. Note this is basic suite to ascertain basic groundwater characteristics and background levels. More detailed testing can be undertaken at a later stage during the groundwater investigation if required.

EXAMPLE OF SITE SPECIFIC SAMPLING PROTOCOL ONSHORE

Depth of Sampling
The QASSIT Guidelines for Acid Sulfate Soils suggest sampling to 1 m below depth of disturbance. If driven piles are proposed, the likely soil disturbances are to be shallow, at an estimated 2 metres.

Therefore, sampling to a depth of 3 metres is recommended. If bored piers are to be used, soils will be excavated to the top of bedrock estimated at about 20 metres at the site and sampling to the full depth of the profile would be required by the Guidelines.

However, Acid Sulfate Soils occur only in alluvial soils and do not occur in rock or residual soils. Sampling of the rock is thus unnecessary. Some sampling of the residual soils would be prudent to demonstrate their non-Acid Sulfate Soils status. Sampling the full depth of the alluvial profile and 2 metres into residual soils is recommended.

Sample Frequency

The QASSIT Guidelines recommend sampling at 0.25 metre depth intervals. Geotechnical investigations normally involve standard penetration tests (SPTs) using a split tube or U50 tube sampling at 1.5 metre depth intervals. This is done with equipment held on all drill rigs doing investigations. Both SPTs and U50s provide relatively uncontaminated samples of the subsurface soils.

It is recommend that SPT tests or U50 samples are to be undertaken at 1 metre depth intervals for the upper 3 metres of the profile. As this method provides a length of about 450 mm of sample, a small soil sample for Acid Sulfate Soils testing can be obtained from both ends and the middle of the test sample. Samples for the upper 500 mm can be taken directly off the augers. This would provide samples as set out in the table below:

Acid Sulfate Soils Sampling – Upper 3 metres

Sampling Method and Depth	Samples Provided
0 – 0.5 m Off Auger	Surface Sample, 0.25 m
SPT (or U50) 0.5 to 0.95 m	Sample at 0.5 m off top of SPT Sample at 0.75 from centre of SPT Sample from 0.95 from base of SPT
SPT (or U50) 1.0 to 1.45 m	Sample at 1.0 m off top of SPT Sample at 1.25 from centre of SPT Sample from 1.45 from base of SPT
SPT (or U50) 2.0 to 2.45 m	Sample at 2.0 m off top of SPT Sample at 2.25 from centre of SPT Sample from 2.45 from base of SPT
SPT (or U50) 3.0 to 3.45 m	Sample at 3.0 off top of SPT

The table above describes a sampling regime that provides most of the samples required in the QASSIT guidelines in the upper profile.

If it is proposed to sample the full depth of the profile as discussed in the section on Depth of Sampling, then the above sampling regime may be continued down the profile until rock or residual soils are encountered. This will provide sampling at close to QASSIT frequency. Alternatively, a single sample could be obtained from each SPT (or U50) at the normal 1.5 m depth intervals used for geotechnical investigation.

While this is not as per the QASSIT Guidelines, it will allow an assessment of the depth and severity of Acid Sulfate Soil to be made and the liming rates required for neutralisation can be assessed at the construction stage. Company recommends sampling from SPTs or U50s at 1.5 metre depth intervals.

Sample Handling

The ASS samples can be collected by the technician undertaking the geotechnical field logging, testing and sampling.

Laboratory Testing

It is recommended in the QASSIT Guidelines that all samples be tested by the peroxide screen test. Selected samples, not less than 2 per metre of soil profile, should be analysed by a quantitative laboratory method.

EXAMPLE OF SITE SPECIFIC SAMPLING PROTOCOL OFFSHORE

Depth of Sampling

The QASSIT Guidelines suggest sampling to 1 m below depth of disturbance. If driven piles are proposed, the likely soil disturbances are to be shallow, at an estimated 2 m. Therefore, sampling to a depth of 3 m is recommended.[1]

If bored piers are to be used, soils will be excavated to the top of bedrock estimated at about 20 m at the site and sampling to the full depth of the profile would be required by the guidelines.

However, as acid sulfate soils occur only in soft sediments and not occur in rock, sampling of bedrock is considered unnecessary.

Some sampling of the residual soils is prudent to demonstrate their non-acid sulfate soils status.

Sampling the full depth of the soft sediment profile and 2 m into residual sediments is therefore recommended.

Sample Frequency

QASSIT Guidelines require a high frequency of test locations and down-hole sampling. The guidelines establish the test location frequency and require sampling at 0.25 m depth intervals to 1 m below the depth of disturbance is recommended in the guidelines. QASSIT Guidelines can be modified based on professional judgement depending on the site conditions and the specific circumstances of the Project.

Company's opinion is that the intent of the QASSIT Guidelines and the degree of confidence in results can be achieved with a much reduced scope of work that is specifically directed to areas of concern. The scope of investigation recommended by Company would thus be determined by the criteria below:

- Sample from boreholes below RL 5 m AHD.
- Sampling only from boreholes where the aerobic condition of soils may change as a result of disturbance associated with future project development at the site.

Geotechnical investigations normally involve standard penetration tests (SPTs) using a split tube or U50 tube sampling at 1.5 m depth intervals. Both SPTs and U50s provide relatively uncontaminated samples of the subsurface soils.

Company recommends that SPT tests or U50 samples are undertaken at 1 m depth intervals for the upper 3 metres of the profile. As this method provides a length of about 450 mm of sample, a small soil sample for Acid Sulfate Soils testing can be obtained from both ends and the middle of the test sample. Samples for the upper 500 mm can be taken directly off the augers.

[1] According to the QASSIT Guidelines, dredging to a maximum depth of 6 m would require sampling to a maximum depth of 7 m, however, in this situation the disturbance area would be characterised within the top 3 m of the profile and therefore sampling to 7 m is not considered necessary.

This would provide samples as set out in the table below:

Acid sulfate soils sampling – upper 3 m

Sampling Method and Depth	Samples Provided
0 to 0.5 m Off Auger	Surface sample, 0.25 m
SPT (or U50) 0.5 to 0.95 m	Sample at 0.5 m off top of SPT Sample at 0.75 m from centre of SPT Sample from 0.95 m from base of SPT
SPT (or U50) 1.0 to 1.45 m	Sample at 1.0 m off top of SPT Sample at 1.25 m from centre of SPT Sample from 1.45 m from base of SPT
SPT (or U50) 2.0 to 2.45 m	Sample at 2.0 m off top of SPT Sample at 2.25 m from centre of SPT Sample from 2.45 m from base of SPT
SPT (or U50) 3.0 to 3.45 m	Sample at 3.0 m off top of SPT

If it is proposed to sample the full depth of the profile as discussed above, then the above sampling regime may be continued down the profile until rock or residual soils are encountered.

This will provide sampling at close to QASSIT frequency. Alternatively, a single sample could be obtained from each SPT (or U50) at the normal 1.5 m depth intervals used for geotechnical investigation.

While this is not as per the QASSIT Guidelines, it will allow an assessment of the depth and severity of acid sulfate soil to be made and the liming rates required for neutralisation can be assessed at the construction stage.

The guidelines do not differentiate between terrestrial and marine acid sulfate soils. Company recommends sampling from SPTs or U50s at 1.5 m depth intervals.

Sample Handling

The ASS samples can be collected by the technician undertaking the geotechnical field logging, testing and sampling.

Laboratory Testing

The QASSIT Guidelines recommend using a peroxide screen test on all samples and the more definitive quantitative laboratory testing of one sample per 0.5 m depth intervals. We believe that the volume of analyses and testing can be reduced by directing analyses at the strata of concern without compromising the validity of the investigation. Refer to Section 4.0 for Laboratory sampling and analysis recommendations