



State Planning Policy 2/02 Guideline



Planning and Managing Development involving Acid Sulfate Soils



Queensland Government

Department of Local Government and Planning
Department of Natural Resources and Mines

STATE PLANNING POLICY 2/02 GUIDELINE

Acid Sulfate Soils

Version 2

Addendum Note:

Pages 9, 10, 31, 32 and 33 in the Planning Guideline Acid Sulfate Soils have been amended. The addendum corrects the advice on devising detailed planning scheme measures.

TABLE OF CONTENTS

1.	Purpose of the Guideline	1
2.	Introduction	1
	About acid sulfate soils	2
3.	Application of the SPP	3
	Effect of the SPP	3
	Development assessment	3
	Making or amending planning schemes	3
	Designating land for community infrastructure	3
	Area and development to which the SPP applies	3
	Other considerations	4
4.	Development outcomes and development assessment	5
	Achieving development outcome 1	5
	Information requirements	5
5.	Making or amending planning schemes	7
	Identification of high probability areas	7
	Planning strategies to avoid or minimise disturbance	8
	Detailed planning scheme measures	8
6.	Identification and investigation of acid sulfate soils	10
	Introduction	10
	Step 1: Desktop assessment, site investigation and soil sampling	11
	Step 2: Sample selection and laboratory analysis	15
7.	Investigation of groundwater prior to disturbance	19
	Introduction	19
	Information requirements	19
	Using the information	20
8.	Investigation relating to filling activities	21
	Introduction	21
	Fill quality assessment	21
	Assessment of potential disturbance to <i>in situ</i> ASS from filling	21
9.	Treatment	22
	Introduction	22
	Determining the ‘level of treatment’	23
10.	Treatment and management of surface and drainage waters from disturbed acid sulfate soils	27
	Introduction	27
	Water quality criteria	27
	Neutralising acid leachate and drainage water	28
	Calculating the quantity of neutralising agent	28

Appendix 1: Devising detailed measures for development assessment	31
Appendix 2: Soil and water field indicators	34
Appendix 3: Interpreting soil field pH tests	35
Appendix 4: Environmental management plans	37
Appendix 5: Texture-based acid sulfate soil ‘action criteria’	39
Appendix 6: References	40
Appendix 7: Special acid sulfate soils maps	42
Appendix 8: Glossary	44

1. PURPOSE OF THE GUIDELINE

- 1.1 The purpose of this Guideline is to provide advice and information on interpreting and implementing State Planning Policy 2/02: *Planning and Managing Development Involving Acid Sulfate Soils* (SPP 2/02).
- 1.2 SPP 2/02 declares this Guideline to be ‘extrinsic material’ under the *Statutory Instruments Act 1992*, thereby giving the Guideline legal status in assisting in the interpretation of SPP 2/02.

2. INTRODUCTION

- 2.1 While the primary purpose of the *State Planning Policy 2/02 Guideline: Acid Sulfate Soils* (the SPP 2/02 Guideline) is stated above, the Guideline may also be used as a source of general advice on investigation and management of acid sulfate soils (ASS) for situations outside the scope of SPP 2/02. This Guideline is divided into two main parts as outlined below.

Sections 3 to 5 give guidance on the implementation of SPP 2/02 in development assessment and how local governments could appropriately reflect this SPP in their planning schemes under the *Integrated Planning Act 1997*.

Sections 6 to 10 give general guidance on the level of investigation required to support a development application and general guidance on defining the level of treatment required should ASS be disturbed. Sections 6, 7 and 8 deal with investigations and Sections 9 and 10 deal with treatment and management. Further information that is relevant to each section is included in appendices. The information contained in Sections 6 to 10 and the appendices is not technically exhaustive and therefore should be used in consultation with more detailed information.

- 2.2 The latest version of the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland* (referred to in this Guideline as the *Queensland Sampling Guidelines*) should be consulted for more detailed information on how to conduct an ASS investigation.
- 2.3 The Department of Natural Resources and Mines was reviewing and updating the *Queensland Sampling Guidelines* at the time of printing. Additionally, the Queensland Government, the Queensland Acid Sulfate Soils Management Advisory Committee (QASSMAC), and other stakeholders were developing the *Queensland Acid Sulfate Soil Technical Manual* at the time this SPP Guideline was published. The revised *Queensland Sampling Guidelines* will be incorporated into the *Queensland Acid Sulfate Soil Technical Manual*. The manual will also include chapters on management and treatment options for ASS, guidance on environmental management plans, examples of industry best practice, laboratory analysis of ASS, legislation and policy, and management options for treating acid water. When completed, the *Queensland Acid Sulfate Soil Technical Manual* should be consulted for current best-practice treatment and management of ASS in Queensland.
- 2.4 Appendix 6 of this SPP Guideline lists sources of further detailed information on the treatment and management of ASS.

- 2.5** The Department of Natural Resources and Mines' website (www.nrm.qld.gov.au) is a source of ASS information and other material may be available from NR&M district offices or some local governments.

About acid sulfate soils

- 2.6** ASS cover approximately 2.3 million hectares of land in Queensland and occur naturally along the coast usually where land elevation is less than 5 metres AHD. These soils affect urban, transport, tourism, agricultural and industrial land uses. The exposure of ASS to oxygen (e.g. by drainage, excavation or filling) results in production of sulfuric acid and toxic quantities of aluminium and other heavy metals, in forms that can be commonly released into waterways. The acid corrodes concrete and steel infrastructure and, together with the metal contaminants, can kill or damage fish, other aquatic organisms, native vegetation and crops.
- 2.7** Under anaerobic conditions maintained by permanent groundwater, iron sulfides are stable and the pH is often weakly acid to alkaline. ASS only becomes a problem when they are disturbed and exposed to air. Typically, excavating or otherwise removing soils or sediments, extracting groundwater or filling land, causes disturbance of ASS. These activities can occur during construction of, for example, canal estates, golf courses, swimming pools, agricultural drainage systems, roads and other infrastructure. The extraction of sand and gravel can also result in the disturbance of ASS.
- 2.8** When iron sulfides are oxidised, sulfuric acid forms and the soil becomes strongly acidic (usually below pH 4). The acid can mobilise the naturally occurring metals in the soil. These actual ASS, and any subsequent leachate, can potentially have significant adverse effects on the natural and built environments, the economy and human health due to the presence of abundant acid, iron, aluminium, manganese and possibly other heavy metals. For example:
- the release of acid and metal contaminants into the environment can have significant adverse effects on the ecology of wetlands and shallow freshwater and brackish aquifer systems by degrading water quality, habitat, and dependant ecosystems. Acidified waters may result in the killing or disease of fish and other aquatic organisms;
 - the presence of actual ASS and any release of leachate can have significant adverse economic consequences upon crop productivity and commercial and recreational fisheries;
 - the leachate can corrode concrete and steel infrastructure, such as culverts, pipes, bridges and buildings, reducing their functional lifespan; and
 - ground and surface waters containing toxic concentrations of acid and metal contaminants can cause dermatitis, and dust from disturbed ASS may cause eye irritation.

3. APPLICATION OF THE POLICY

Effect of the SPP

- 3.1 Under the *Integrated Planning Act 1997* (IPA), SPP 2/02 has the following effects.

Development assessment

- 3.2 In the local government to which SPP 2/02 applies, the policy applies to assessable development, except building work only assessable under the *Standard Building Regulation*¹, in the following ways:
- i) *IPA Planning Schemes*: Where an IPA planning scheme is in force, the assessment manager must have regard to SPP 2/02 when assessing development applications under IDAS².
 - ii) *Transitional Planning Schemes*: Where a transitional planning scheme is in force, the assessment manager must have regard to SPP 2/02 when assessing development applications requiring a development approval under the planning scheme.

Making or amending planning schemes

- 3.3 SPP 2/02 should be appropriately reflected in planning schemes for those local governments to which SPP 2/02 applies to ensure the State's interests are interpreted in the local context when planning for future development and making decisions on development applications.
- 3.4 SPP 2/02 is appropriately reflected when it is integrated with those planning schemes to the extent that the State's interests are not adversely affected. Essentially, this means that the planning scheme seeks the same outcomes as SPP 2/02 to an extent that satisfies the Minister for Local Government and Planning (acting for the State Government on the advice of the Department of Natural Resources and Mines and the Department of Local Government and Planning), and all aspects of the planning scheme are consistent with those outcomes.

Designating land for community infrastructure

- 3.5 SPP 2/02 must be considered when designating land for community infrastructure. Community infrastructure is defined in the IPA, which also prescribes the designation process.

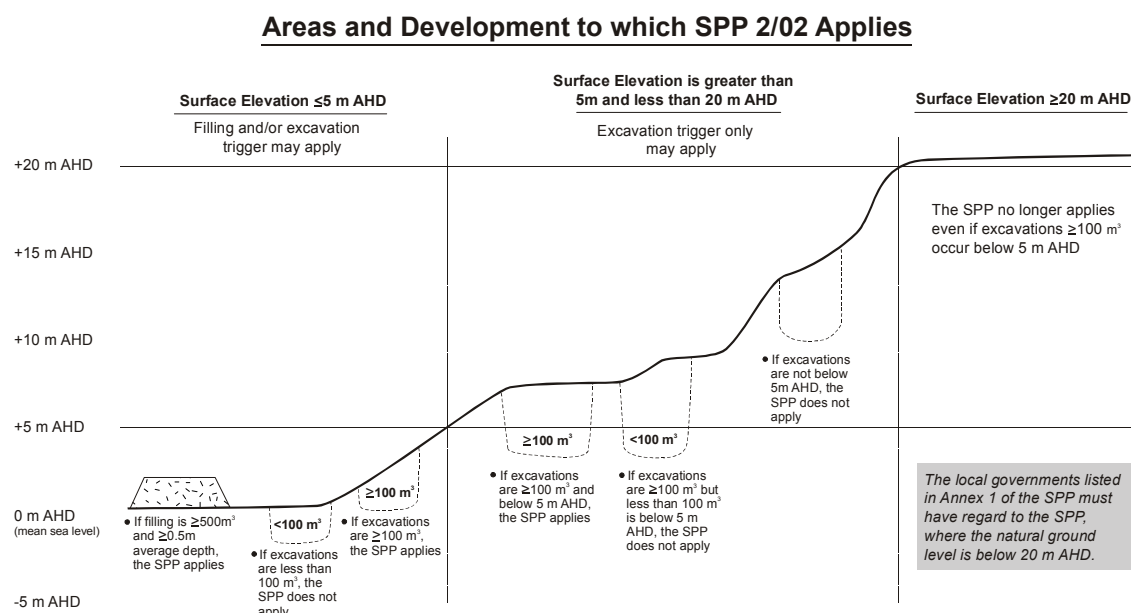
Area and development to which the SPP applies

- 3.6 SPP 2/02 applies to all land, soil or sediment at or below 5 metres AHD where the natural ground level is below 20 metres AHD in the local governments listed in Annex 1 of SPP 2/02. The SPP applies to development that would result in:
- the excavation of, or otherwise removing, 100 m³ or more of soil or sediment; or
 - filling of land involving 500 m³ or more of material with an average depth of 0.5 of a metre or greater.

¹ See paragraph 5.1 of SPP 2/02.

² See Appendix 8, Glossary.

3.7 The following diagram illustrates how SPP 2/02 applies.



3.8 While ASS occur predominantly in low-lying coastal areas, they can also occur some distance from the existing coastline in situations where historic low-lying coastal areas have been covered by younger geological material. SPP 2/02 therefore assumes, based upon the precautionary principle that all land to which SPP 2/02 applies may contain ASS unless compelling geological/geomorphic evidence indicates otherwise. Sections 5 and 6 of this Guideline provide more information on this issue.

Other considerations

3.9 SPP 2/02 sets out the expected development outcomes for the issues it addresses. However, a local government, in consultation with its local community, may choose to adopt higher standards in the planning scheme. For example, where accurate information establishes that ASS may be present above 5 metres AHD, it is recommended that local governments adopt measures that are appropriate for their local circumstances, even though such measures are not required by the SPP.

NB: Generally, planning schemes should not adopt lower excavation and filling ‘triggers’ for development assessment than the 100 m³ for excavation and 500 m³ filling. To do so would make a significant proportion of building work assessable against the planning scheme as well as the *Standard Building Regulation*, and the potential environmental harm would not justify the extra regulation involved.

However, in areas where there is clear evidence of ASS at concentrations requiring very high levels of treatment (eg. from detailed site data), planning schemes could adopt excavation and filling ‘triggers’ lower than that recommended by SPP 2/02.

4. DEVELOPMENT OUTCOMES AND DEVELOPMENT ASSESSMENT

Achieving development outcome 1

- 4.1** This section provides advice on achieving Outcome 1 of SPP 2/02. Compliance with Outcome 1 is achieved by avoiding the release of acid and associated metal contaminants into the environment in one of the following ways:
- not disturbing ASS when excavating or otherwise removing soil or sediment, extracting groundwater or filling land; or
 - managing/treating any disturbed ASS to prevent the potential impacts of that disturbance.
- 4.2** The disturbance of ASS can be avoided by:
- not excavating or removing soil and sediment identified as ASS;
 - not permanently or temporarily extracting groundwater that results in the aeration of previously saturated ASS; or
 - not filling land with material to an extent and thickness that results in:
 - actual ASS being moved below the watertable; and
 - previously saturated ASS being aerated.
- 4.3** If the disturbance of ASS cannot be avoided, the potential impacts of that disturbance must be treated and managed to:
- neutralise existing acidity and prevent the generation of acid and metal contaminants; and
 - avoid releasing surface or groundwater flows containing acid and metal contaminants into the environment.

NB: While it is preferred that disturbed ASS should be treated on-site, this may not always be possible. Therefore, untreated ASS should not be taken off-site unless it is to an approved alternative location for appropriate treatment. Untreated ASS cannot be considered as ‘clean fill’.

- 4.4** Because both methods of achieving the development outcome require detailed knowledge on the location of ASS to be effective, specific site investigations are required to support achieving the solutions. Section 6 of this Guideline set out the types and levels of information required for the majority of circumstances.

Information requirements

- 4.5** SPP 2/02 assumes that all land, soil and sediment to which the SPP applies³ may contain ASS, unless site-specific information is available confirming the contrary. This sub-section describes the information necessary to establish whether the SPP applies and if so, the information required to assess development applications against Outcome 1 of SPP 2/02.

³ See paragraph 3.6 of this Guideline.

Does the SPP apply?

- 4.6** If a proposed development involves excavation or filling, the assessment manager will need the following information to establish whether a development application will be subject to SPP 2/02:
- the lowest point in metres AHD of the proposed excavation, together with the maximum volume of excavation below 5 metres AHD; and
 - the height in metres AHD of land to be filled, together with volume and thickness of the fill to be placed on land below 5 metres AHD.

Are acid sulfate soils present?

- 4.7** Where it has been determined that SPP 2/02 applies, the applicant is expected to provide the assessment manager (and other agencies where relevant) with a detailed ASS investigation report to determine whether ASS are present in the area to be disturbed. If such soils are present, the report needs to define the location, depth and existing/potential acidity of ASS relative to the proposed disturbance.

What treatment and management measures are proposed?

- 4.8** If ASS are to be disturbed by the proposed development, the applicant is also expected to provide a comprehensive ASS management strategy outlining how the proposed development will achieve Outcome 1 of SPP 2/02.

Information standards

- 4.9** The information in both the ASS investigation report and any proposed management strategy should be of sufficient detail for the assessment manager and any referral agencies to be satisfied that the development outcomes required by SPP 2/02 will be met. Applicants should provide the information in accordance with the relevant parts of Sections 6 to 10 and associated appendices of this Guideline.

Information requests

- 4.10** If the appropriate information is not provided with the application, the assessment manager should make the information the subject of an information request under IDAS.

5. MAKING OR AMENDING PLANNING SCHEMES

- 5.1 In order to meet Outcome 2 of SPP 2/02, planning schemes should identify particular information and contain appropriate planning strategies and development assessment measures.

Identification of high probability areas

- 5.2 The identification of relevant information in the planning scheme is a necessary step in devising planning strategies that contribute to the achievement of SPP 2/02's Outcome 1. The SPP does not require local governments to undertake detailed mapping of ASS areas. However, when considering future land use options, the planning scheme should identify areas that have a high probability of containing ASS.
- 5.3 Currently, high probability areas can be identified from existing *Special Acid Sulfate Soil Maps*⁴ available from the Department of Natural Resources and Mines.
- 5.4 In areas where *Special Acid Sulfate Soil Maps* are not available, the identification of areas with a high probability of containing ASS can be determined using the following geomorphic and site description criteria:
- land with elevation less than 2 metres AHD;
 - soil and sediment of recent geological age (Holocene);
 - marine or estuarine sediments and tidal lakes;
 - low-lying coastal wetlands or back swamp areas, waterlogged or scalded areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes;
 - coastal alluvial valleys⁵;
 - areas where the dominant vegetation⁶ is tolerant of salt, acid and/or waterlogging conditions e.g. mangroves, saltcouch, swamp-tolerant reeds, rushes, grasses (e.g. *Phragmites australis*), paperbarks (*Melaleuca spp.*) and swamp oak (*Casuarina spp.*); and
 - areas identified in geological descriptions or in maps as:
 - bearing sulfide minerals;
 - coal deposits or marine shales/sediments (geological maps and accompanying descriptions may need to be checked); and
 - deep older estuarine sediments below ground surface of either Holocene or pre-Holocene age.
- 5.5 All available information from the above list should be used to identify high probability areas. Generally the outer boundary of the overlays used will identify high probability areas. Where only one source of information is available it may be sufficient to identify high probability areas.

⁴ See Appendix 8, Glossary.

⁵ Most ASS sediments are associated with coastal landforms that have surface elevations below 5 metres AHD. Older estuarine sediments (Holocene or pre-Holocene age) have been found deep below ground surface with surface elevations up to 20 metres AHD. These occurrences, such as those found in upper alluvial valleys, are mainly an issue if deep excavation or drainage is required. Areas such as Central Queensland with large tidal variations or tropical areas subject to cyclonic storm surges may also have ASS occurring above 5 metres AHD.

⁶ ASS can also occur associated with other vegetation types eg. in Central Queensland, ASS have been found in deep sandy soils supporting ironbark communities.

- 5.6** In the absence of mapping available from the Department of Natural Resources and Mines, a local government can consider undertaking more detailed investigations in selected areas to help evaluate options for their planning scheme's land use strategy. Priority areas for further investigation could include those where the presence of ASS is likely to have a significant effect on the viability of the particular types of development being considered in the land use strategy options.
- 5.7** The Department of Natural Resources and Mines can provide some of the information identified in paragraphs 5.3 and 5.4 above and assist local governments in interpretation of other available information.

Planning strategies to avoid or minimise disturbance

- 5.8** In keeping with the principle that avoidance is better than treatment, the planning scheme should give preference where practicable to future land uses and development requirements that avoid or minimise the disturbance of ASS.
- 5.9** Where areas with a high probability of containing ASS are identified, the potential implications of disturbing these soils should be carefully considered when devising planning strategies. Where there are compelling social, economic or other environmental arguments in the local context for favouring land uses that are likely to disturb ASS, the planning strategies should also make clear the need for development to treat and manage those disturbances in accordance with the requirements of SPP 2/02.
- 5.10** Land uses such as extractive industries, golf courses, marinas, canal estates, agriculture uses requiring drainage systems and land uses with car parking, storage etc. below ground level which are likely to result in significant amounts of excavation or filling, should be avoided in high probability areas. However, where the Department of Natural Resources and Mines' information indicate ASS occur at a significant depth, the above land uses may be appropriate if they are unlikely to result in the disturbance of acid sulfate soil layers.
- 5.11** When considering land use strategies, it should be recognised that some ancillary uses (e.g. large residential swimming pools) may result in the disturbance of ASS at depths or volumes the primary use is unlikely to disturb. In such cases and subject to other planning considerations, it may be preferable to select a different primary use for areas where the information indicates a high likelihood of ASS being present. Alternatively, the planning scheme could make it clear that those ancillary uses will be subject to requirements regarding ASS by appropriate conditions on development permits.

Detailed planning scheme measures

Preparing a code(s)

- 5.12** SPP 2/02 requires planning schemes to include a code(s) against which to assess developments with the potential to disturb ASS. Including specific development standards as assessment criteria in a code(s) will ensure that all relevant development can be assessed against those standards, irrespective of the assessment process prescribed by the planning scheme. The code(s) may be a specific issue-related code or a code(s) that includes the above mentioned assessment criteria as one of its components.

- 5.13** The code(s) should make clear the area to which it applies by identifying the relevant information described in paragraph 5.16 and Tables 1 and 2 below, and should contain assessment criteria that are consistent with the advice in Section 4 on achieving appropriate development outcomes. Appendix 1 provides detailed advice on devising assessment criteria that are consistent with those outcomes. Any criteria need to be integrated with other scheme measures to achieve consistency, so examples are not necessarily appropriate as ‘models’ for all planning schemes.
- 5.14** When developing a code(s) to manage development involving ASS, a local government should obtain advice from the Department of Natural Resources and Mines.

Making development assessable

- 5.15** The planning scheme should seek to ensure that development achieves Outcome 1 of the SPP by making any relevant development assessable against specific development code(s) addressing the disturbance of ASS.
- 5.16** The planning scheme should identify in map form (eg. on an overlay) areas within which assessable development will be subject to the code(s) containing ASS assessment criteria. Table 1 describes the areas that should be identified on the overlay(s), depending on the contour information available in the particular local government area.

Table 1. Overlay information where the 5 metre contour information is available

Available Information	Area 1	Area 2
If the 5 metre contour is available	All land at or below the 5 metre contour	All land above the 5 metre contour but below the 20 metre contour

- 5.17** With regard to an overlay based upon Table 1, the planning scheme will be expected to make the following types of development assessable against the planning scheme’s code(s) containing ASS assessment criteria:
- works** (not associated with a material change of use) on land within **Area 1** and where such **works** involve:
 - excavating or otherwise removing 100 m³ or more of soil or sediment; or
 - filling of land involving 500 m³ or more of material with an average depth of 0.5 of a metre or greater;
 - works** (not associated with a material change of use) on land within **Area 2** where such **works** involve excavating or otherwise removing 100 m³ or more of soil or sediment **at or below 5 metres AHD**; and
 - material changes of use** on land within **Area 1** or **Area 2** where any associated **works** as described by a) and b) above are an intrinsic component of the use.

Table 2. Overlay information in other circumstances

Available Information	Overlay
If the 10 or 20 metre contour is the lowest available	All land below the 20 metre contour
If the 20 metre contour is not available use the lowest available contour, eg. the 50 metre contour	All land below the lowest available contour, eg. the 50 metre contour

- 5.18** With regard to an overlay based upon Table 2, the planning scheme will be expected to make the following types of development assessable against the planning scheme's code(s) containing ASS assessment criteria:
- a) **works** (not associated with a material change of use) where such **works** involve:
 - excavating or otherwise removing 100 m³ or more of soil or sediment **at or below 5 metres AHD**; or
 - filling of land **at or below the 5 metre contour** involving 500 m³ or more of material with an average depth of 0.5 of a metre or greater; and
 - b) **material changes of use** on land identified by **the overlay** where any associated **works** as described by a) above are an intrinsic component of the use.

NB: Such **works** (described in 5.17 and 5.18) should include:

- building works;
- extracting clay, gravel, rock, soil or other material from a place where it occurs naturally or from other premises;
- operations that allow taking, or interfering with, water under the *Water Act 2000*.

Such **uses** (described in 5.17 and 5.18) could include canal estates, marinas, extractive industry, service stations and other uses where below ground car parking, storage or infrastructure is an unavoidable consequence of the use.

Specifying the information expected to be provided with development applications

- 5.19** SPP 2/02 requires the planning scheme or supporting planning scheme policy(s) to specify the information the assessment manager needs to assess a development application adequately⁷. The scheme or planning scheme policy should also make it clear that when this information does not accompany the development application, it will be made the subject of an information request under IDAS. In this way, prospective development proponents are forewarned about the information that will be sought by the assessment manager, thereby increasing the likelihood of such information being provided with the development application.

6. IDENTIFICATION AND INVESTIGATION OF ACID SULFATE SOILS

Introduction

- 6.1** The objective of this Section is to provide information on the level of investigation required to:
- identify the presence or absence of ASS in areas to be disturbed by a proposed development; and if present,
 - define the location of ASS and the maximum amount of existing and potential acidity in order to determine the appropriate treatment and management response as outlined in Section 9.
- 6.2** ASS and the associated hydrology are a complex environmental issue. To assess the presence or absence of ASS accurately, it is necessary to drill or auger holes and conduct field soil tests. Where field tests indicate ASS may be present, it is necessary for the maximum amount of existing plus potential acidity to be quantified by laboratory analysis of samples.
- 6.3** To achieve the objective, a two-step investigation process will usually be required. These steps are:
- Step 1: Soil sampling supported by desktop assessment and site investigation; and
- Step 2: Sample selection and laboratory analysis (supported by Step 1).

⁷ Paragraphs 4.6–4.9 describe the information that an assessment manager may need to for an adequate assessment.

- 6.4** Step 1 is necessary for all investigations and involves a desktop assessment and a site visit to identify indicators of ASS, followed by soil sampling. Soil sampling involves augering or drilling boreholes, describing the soil profile, undertaking field tests and collecting and storing soil samples.
- 6.5** In certain circumstances, results from field soil testing and other information gathered from Step 1 may provide strong evidence that ASS are absent from the areas to be disturbed. The applicant may submit this evidence to support *non-completion of Step 2*. (For details of these circumstances and the nature of the evidence required, see Section 6.26 below).
- 6.6** For all other (being the majority of) situations, laboratory analysis as outlined in Step 2 will be necessary. The results from laboratory analyses together with the volume of disturbance are then used to rate the level of treatment required for the disturbance.
- 6.7** Borehole intensities, sampling intensities and guidance for staged sampling for disturbances greater than 1000 m³ or linear disturbances are detailed in the most recent edition of the *Queensland Sampling Guidelines*. As stated earlier the Department of Natural Resources and Mines was reviewing and updating the *Queensland Sampling Guidelines* at the time of printing and incorporating the revised document into the *Queensland Acid Sulfate Soil Technical Manual*. When completed the Manual should be consulted for current best-practice sampling procedures. For non-linear disturbances less than 1000 m³, a reduced number of boreholes (and therefore of sampling and laboratory analysis) is required by comparison with those in the 1998 *Queensland Sampling Guidelines*⁸. These are detailed in Table 2 below. However, if initial laboratory results based on these reduced sampling rates indicate that high⁹ levels of existing or potential acidity in the soil or sediment may be disturbed, then further laboratory analysis of stored samples will be needed. Additional boreholes, soil sampling and laboratory analysis may also be needed in these circumstances.
- 6.8** The bottom-line is that applicants will need to provide enough information in their ASS investigations and subsequent management strategies to enable authorities to make an informed decision about their application. The assistance of a qualified professional may not be necessary to undertake investigations for simple non-linear disturbances up to 1000 m³ that do not disturb groundwater. However, for disturbances greater than 1000 m³, linear disturbances, and for disturbances affecting groundwater it is recommended that a suitably qualified person experienced with ASS conduct the investigation and develop the management plan. Such a suitably qualified person would be a professionally accredited soil scientist.

Step 1: Desktop assessment, site investigation and soil sampling

Introduction to step 1

- 6.9** Step 1 involves a desktop assessment and a site visit to identify indicators of ASS, followed by soil sampling. The location of boreholes for soil sampling should be guided by a desktop assessment and general site investigation.

⁸ Sampling rates for disturbances less than 1000 m³ will be incorporated into the revised *Queensland Sampling Guidelines*.

⁹ A high level of existing or potential acidity is determined by the combination of volume of material being disturbed and the highest laboratory analysis that would result in a 'very high' or 'extra high' level of treatment, as defined in Table 4, Section 9.

Desktop assessment and site investigation

- 6.10** The desktop assessment should define and document the general parameters of the proposed works and document the potential disturbance of ASS (if present) on the proposed site. The information should include copies of relevant site maps, air photos and descriptions and/or diagram(s) on the:
- nature of the disturbance (excavation, filling or groundwater extraction);
 - specific location or locations of disturbance;
 - total area of the site (in m² or hectares) to be disturbed;
 - volume of material to be disturbed; and
 - maximum depth of disturbance with reference to metres AHD (including any underground service pipes such as sewerage or drains).
- 6.11** At an early stage in the ASS investigation, it is important to consider any potential groundwater issues, particularly if groundwater is likely to be disturbed beyond normal seasonal fluctuations. The investigation of groundwater issues is discussed in Section 7.
- 6.12** The desktop assessment should check the location of the proposed development against suitable ASS maps (e.g. NR&M *Special Acid Sulfate Soils Maps*¹⁰) or other broad scale information if available. The most recent version and most detailed ASS map should be used (e.g. 1:25 000 scale is preferred to 1:100 000 scale). This information may be available from the Department of Natural Resources and Mines or from local governments. If ASS maps are not available the applicant should undertake an investigation to determine whether there is a known ASS problem in the area (e.g. recorded in adjacent sites) and check if the site meets the geomorphic or site description criteria outlined below.
- 6.13** ASS maps at a broad scale (i.e. 1:100 000, 1:50 000 and even 1:25 000 scale) are designed for planning purposes. Whilst information from these maps should form part of the information presented in an investigation report, they cannot be used alone at the property scale to confirm absence of ASS, or define the amount of existing or potential acidity for a disturbance.

Geomorphic and site description criteria

- 6.14** The following geomorphic or site description criteria should be used to determine if ASS are likely to be present:
- land with elevation less than 5 metres AHD;
 - soil and sediment of recent geological age (Holocene);
 - marine or estuarine sediments and tidal lakes;
 - low-lying coastal wetlands or back swamp areas, waterlogged or scalded areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes;
 - coastal alluvial valleys¹¹;

¹⁰ See Appendix 8, Glossary.

¹¹ Most ASS sediments are associated with coastal landforms that have surface elevations below 5 metres AHD. Older estuarine sediments (Holocene or pre-Holocene age) have been found deep below ground surface with surface elevations up to 20 metres AHD. These occurrences, such as those found in upper alluvial valleys, are mainly an issue if deep excavation or drainage is required. Areas such as Central Queensland with large tidal variations or tropical areas subject to cyclonic storm surges may also have ASS occurring above 5 metres AHD.

- areas where the dominant vegetation¹² is tolerant of salt, acid and/or waterlogging conditions e.g. mangroves, saltcouch, swamp-tolerant reeds, rushes, grasses (e.g. *Phragmites australis*), paperbarks (*Melaleuca spp.*) and swamp oak (*Casuarina spp.*); and
- areas identified in geological descriptions or in maps as:
 - bearing sulfide minerals;
 - coal deposits or marine shales/sediments (geological maps and accompanying descriptions may need to be checked); and
 - deep older estuarine sediments below ground surface of either Holocene or pre-Holocene age.

Soil sampling

- 6.15** After assessing the available broad scale information and calculating the dimensions of the proposed disturbance, a site visit with soil sampling is required. The desktop assessment and site investigation for geomorphic and other indicators can be used to help define the location of boreholes for soil sampling. Appendix 2 lists soil and water indicators that can be used (as a result of either site investigations or field soil tests) to identify if ASS are present. As many of the indicators for actual and potential ASS are quite different, the site inspection should investigate for the presence of both types of soil. Also note that it is common to have an actual ASS that also contains some un-oxidised iron sulfides or potential acidity.
- 6.16** Care should be taken especially on sites with more than one type of geomorphological unit, or clearly different land surface elevations, so that sampling is representative of the area.
- 6.17** The number of boreholes required is dependant on the volume of ASS disturbance or for disturbances greater than 1000 m³, the area (m² or hectares) to be disturbed. Table 2 summarises the minimum number of boreholes to be drilled, described, field tested and sampled for non-linear disturbances.

Table 2: Minimum number of boreholes required for ASS investigations based on volume of disturbance for non-linear disturbances

Volume of disturbance ¹³ (m ³)	Minimum number of boreholes
≤250	2
251 to 1000	3
>1000	4 or more See <i>Queensland Sampling Guidelines</i>

¹² ASS can also occur associated with other vegetation types eg. in Central Queensland, ASS have been found in deep sandy soils supporting ironbark communities.

¹³ For linear disturbances, for example drains, trenches, pipelines etc., see the *Queensland Sampling Guidelines* for borehole requirements.

- 6.18** Soil sampling involves going to the site, drilling or augering investigative boreholes to at least 2 metres depth, or at least 1 metre below the maximum depth of disturbance (whichever is the greater¹⁴), describing and undertaking field soil tests¹⁵ on the soil profiles retrieved and finally collecting and storing samples for laboratory analysis. The information gathered from this step will be required to assist in selecting appropriate samples for laboratory analysis and enable both the applicant and the reviewer of the application to interpret the results.
- 6.19** The information that will need to be collected and documented as part of the soil sampling procedure includes:
- the full grid reference of each borehole;
 - the exact location of each borehole shown on an appropriately scaled map;
 - an exact description of the vertical dimensions of the borehole relative to surface AHD;
 - a brief description of the equipment and/or methods used to retrieve the samples;
 - a field description for each soil profile including soil texture¹⁶, colour, mottling and other diagnostic features (e.g. jarosite, shell);
 - results from field soil tests (field pH (pH_F), pH after oxidation with hydrogen peroxide (pH_{FOX}) and reaction with peroxide) at 0.25 metre vertical intervals to the base of the soil profile (see Appendix 3 for notes on how to interpret these tests); and
 - collect samples at a maximum of 0.5 metre intervals down the soil profile e.g. 0–0.5 m, 0.51–1.0 m, 1.01–1.5 m, 1.51–2.0 m etc, ensuring each horizon is sampled.
- 6.20** Once boreholes have been dug, the profile described and soil field tests conducted, soil samples must be collected from each profile at a vertical maximum of 0.5 metre intervals. In deciding the appropriate sampling intervals, the operator should refer to the field description notes and identify any significant changes with depth down the profile in field description properties (such as a change in pH, colour, texture etc.). Samples with clearly different physical, visual or chemical properties should not be ‘bulked’ together, as this will reduce the precision of future laboratory results.
- 6.21** When collecting samples in the field it is important to prevent oxidation of the soil as much as possible. This can be achieved by immediately placing the sample in plastic bags or other suitable containers, excluding air, then placing in a field freezer or with ice in an esky. The samples should be carefully marked (using a waterproof pen) with borehole number and depth for easy identification, and be frozen or specially dried within 24 hours of collection.

¹⁴ Where hard rock is intercepted then this may be accepted as the base of drilling and sampling for soil investigation purposes. Mechanical equipment may be necessary to investigate material below indurated sands (e.g. ‘coffee rock’) as existing and/or potential acidity has been found in some coffee rock. Marine muds (containing iron sulfides) have also been found below coffee rock in some areas.

¹⁵ See the *Queensland Sampling Guidelines* for information on how to conduct the field tests, and Appendix 3 for details on how to interpret field tests.

¹⁶ Soil texture is required for determining the *Action Criteria* used for ASS treatment and management (see Appendix 5).

- 6.22** All samples should be retained in storage (frozen or specially dried) until the field investigation report and any related ASS management strategy has been assessed for the purposes of the development, i.e. approval given. Further laboratory analysis may be required by the reviewer to clarify results, or provide a more accurate understanding of the soil for management purposes. Re-drilling is expensive.
- 6.23** Further information on how to conduct sampling is contained in the latest version of the *Queensland Sampling Guidelines*.
- 6.24** It is important to note that there are Occupational Health and Safety issues related to soil collection and field-testing, particularly in regard to handling hydrogen peroxide, digging soil inspection pits and dangers associated with hydrogen sulfide gas poisoning.

Using information gathered in step 1 to make a decision

- 6.25** Appendix 3 outlines how to interpret field pH (pH_F) and field peroxide pH (pH_{FOX}) results. These tests are essential for indicating whether ASS are likely to be present or absent. If the applicant concludes that the desktop assessment, site and field indicators and pH test results all show that ASS are absent then this should be clearly stated.
- 6.26** Irrespective of the field test results, Step 2 (confirmatory laboratory analysis) is required in the majority of situations. The exception is when a non-linear disturbance up to 1000 m³ which does not involve activities that may alter groundwater, is planned in one of the following situations:
- the area is mapped as low probability of ASS on a NR&M *Special Acid Sulfate Soils Map* and the conclusions of Step 1 show that ASS are absent. The applicant may submit the results of Step 1 for assessment without undertaking Step 2; and/or
 - compelling geomorphic and geologic evidence (e.g. soils developed on basalt) supported by field pH tests on the soil provides strong evidence that ASS are absent from the areas to be disturbed. The applicant may submit this evidence (i.e. photographs, soil description and results from Step 1) to support non-completion of Step 2. Due to the technical nature of such evidence this situation would normally require assessment by a qualified professional soil scientist.

NB: All soil samples should be retained until the application is approved. The assessor may call upon one or more of the samples to be confirmed by laboratory analysis.

Step 2: Sample selection and laboratory analysis

Introduction to step 2

- 6.27** Step 2 outlines the selection of soil samples for laboratory analysis required to either prove that ASS are absent, or to quantify the maximum amount of existing and potential soil acidity that will require treatment and management. Sample selection for laboratory analysis should be guided by the field results obtained in Step 1 (particularly the field pH and field pH peroxide tests).

NB: The reviewer will likely compare the laboratory results with the field results and if dissatisfied with the sample selection, may request that additional samples be analysed.

Sample selection

For non-linear disturbance up to 1000 m³

- 6.28** The sampling protocol outlined below, together with Table 3, should be used as a guide to selecting samples for laboratory analysis where a non-linear disturbance up to 1000 m³ is proposed. Use of this protocol assumes that high quality field investigations have been undertaken as outlined in Step 1.
1. Use Table 2 to determine the minimum number of boreholes required (based on the maximum volume of disturbance).
 2. Collect samples at the required interval and collate field information (see Step 1).
 3. Using the field results from Step 1, select the *soil profile* most likely to contain ASS¹⁷.
 4. From this soil profile, and using the field results as a guide, select one sample that is most likely to contain ASS from *each metre interval*.
 5. Using the field results, select a single (one) sample most likely to contain ASS from *each* additional soil profile.
 6. Submit the selected samples for laboratory analysis, and store the remaining samples frozen or specially dried for possible future use^{18 & 19}.

All other disturbances

- 6.29** For disturbances that are greater than 1000 m³, linear disturbances and activities involving alteration to groundwater, consult the *Queensland Sampling Guidelines* when selecting samples for laboratory analysis.

Table 3: The minimum number of samples[#] to be initially selected for laboratory analysis for non-linear disturbances less than 1000 m³

	Maximum disturbance depth [*]			
	<1 m	1–2 m	2–3 m	3–4 m
	(Borehole depth 2 m)	(Borehole depth 3 m)	(Borehole depth 4 m)	(Borehole depth 5 m)
Volume of disturbance (m ³) ≤250	3	4	5	6
251–1000	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 depth must be 1 metre below maximum depth of disturbance.

¹⁷ See Appendix 3 on interpreting field pH and peroxide pH results.

¹⁸ If the field tests results indicate considerable existing or potential acidity then the applicant may choose to undertake analysis of all samples immediately rather than waiting for the initial laboratory results from minimal analysis to confirm this.

¹⁹ See Section 6.32–6.37 for situations when more laboratory analyses are required.

Laboratory analysis selection

- 6.30** Once the appropriate samples have been selected, the applicant will need to submit samples to a laboratory for analysis. The existing acidity and potential acidity of the soil will need to be analysed. Potential acidity can be determined by Chromium Reducible Sulfur (S_{CR}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOS}). For samples with $pH_F < 5.5$, the existing acidity must also be determined by appropriate laboratory analysis e.g. Titratable Actual Acidity (TAA). Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis. The latest version of the *Queensland Sampling Guidelines* (or the *Queensland Acid Sulfate Soil Technical Manual*) contains further information on approved laboratory methods e.g. Titratable Potential Acidity (TPA) and the full Suspension Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS) method (McElnea *et al.* 2002a and b).
- 6.31** Different laboratory analyses provide different types and levels of information on the chemistry of the soil. Therefore certain laboratory techniques will be more suitable for certain soil samples. A combination of analyses may be required if a more detailed knowledge of the soil chemistry is necessary e.g. to determine the most appropriate neutralising agent or management technique, or if the applicant wants to minimise the amount of neutralising agent used (often economical for larger scale disturbances). Professional advice on the appropriate laboratory methods should be sought before analysis commences.

Using laboratory results from Step 2

For all disturbances

- 6.32** If no single laboratory results exceed the texture-based ASS *Action Criteria* in Appendix 5 (i.e. absence of ASS has been confirmed), then the applicant can submit the application with the supporting information.
- 6.33** If any one of the laboratory results exceed the texture-based ASS *Action Criteria*, indicating that existing and potential acidity must be managed, then the appropriate level of treatment [low (L), medium (M), high (H), very high (VH) or extra high (XH)] can be determined using the highest single laboratory result and the total volume of disturbance together with Table 4 in Section 9. If the level of treatment is very high (VH) or extra high (XH) then additional laboratory analysis will normally be required to give a better quantification of the location, the maximum amount of existing plus potential acidity and volume of ASS to be disturbed.

For non-linear disturbances up to 1000 m³

- 6.34** If the combination of the disturbance volume and the highest laboratory result applied to Table 4 indicate that a very high (VH) or extremely high (XH) level of treatment is required, additional samples will need to be analysed in accordance with the full requirements of the *Queensland Sampling Guidelines* (i.e. one sample per 0.5 metre interval analysed). Treatment and management are discussed in Section 9 and Appendix 4. The results from these additional analyses can then be used to calculate average existing plus potential acidity content for each depth interval and develop a more refined cost-effective treatment plan.

Adequacy of sampling intensities

- 6.35** Care should be exercised when defining liming rates. The preliminary sampling intensities in Table 3 do not provide sufficient detail on the existing and potential acidity required for using different liming rates with different soil layers. Therefore, the total volume of soil to be disturbed will need to be limed at a single rate based on the sample with the greatest amount of potential plus existing acidity.
- 6.36** Further analysis of the stored samples and/or more detailed justification will be required if the applicant wants to neutralise different layers of the soil with different amounts of neutralising agent, or use the average of all laboratory analyses as the basis for lime application rates. In such cases, more detailed calculations involving weight (using volume and bulk density) will be necessary—consult the latest version of the *Queensland Sampling Guidelines*.
- 6.37** There may be situations where ASS are found at the construction stage of a development even though the ASS investigation (undertaken in accordance with this Guideline) indicated otherwise. If such a situation occurs, the disturbed ASS would still require treatment and management to minimise adverse environmental impacts.

7. INVESTIGATION OF GROUNDWATER PRIOR TO DISTURBANCE

Introduction

- 7.1** The objective of this Section is to outline broad principles regarding the investigation of groundwater. ASS and the associated hydrology are a complex environmental issue and more detailed groundwater guidelines will be developed in the future and incorporated into the *Queensland Acid Sulfate Soil Technical Manual*.
- 7.2** The hydrological regimes that operate in an area affect the behaviour of ASS and the transport of oxidation products. ASS which are permanently waterlogged remain benign, but if the groundwater level is lowered (either temporarily or permanently) then oxidation may occur and acid and associated products can be produced. Vertical and horizontal groundwater flows transport oxidation products (acid, toxic by-products) to other areas and adjacent subsoil. Information relating to both aspects is needed to assess risk. It is also vital to keep in mind that groundwater treatment *in situ* is usually not feasible. A suitably qualified professional person experienced in assessing and managing ASS and groundwater issues should undertake all investigations.
- 7.3** Information gathered from an investigation of groundwater prior to disturbance should be used to demonstrate:
- the presence or absence of acidic groundwaters prior to works that may result in the release of such waters;
 - that the proposed development will not result in previously saturated ASS being aerated through groundwater extraction or filling; and
 - that if previously-saturated ASS will become aerated (as a result of the proposed development), this information will be used to assist in the production of effective treatment and management plans. Also see Section 10 for treatment of waters.

Information requirements

- 7.4** Prior to on-site works, the groundwater investigation should include a description of water quality, including seasonal variations where applicable. Essential information that will need to be collected and documented as part of the groundwater investigation will include (but is not limited to):
- field measurements of pH, electric conductivity and dissolved oxygen. If field measurement of water pH is less than 6.5 additional investigations on calcium, magnesium, total iron, dissolved iron, dissolved manganese, filtered aluminium, bicarbonate, carbonate, chloride, sulfate, and colour should be conducted;
 - determine the depth to the watertable with an indication of the seasonal variation. The greater the groundwater depth, the less likely is the potential for impacts on the groundwater or for watertable levels to change as a result of the proposal;
 - identify adjoining on- and off-site groundwater related environments (e.g. wetlands, springs, rivers and creeks) and any likely recharge areas (e.g. areas of waterlogging). Sites that contain surface water linkages to the groundwater increase the likelihood of groundwater being affected; and
 - identify any adjoining existing groundwater users, density of water extraction bores and uses of groundwater extraction.

- 7.5 Using the above information, the applicant should demonstrate that there would be negligible effect on adjoining groundwater users and related environments as a result of the proposed activity. If this cannot be demonstrated, the applicant should conduct a full groundwater investigation including:
- the hydraulic characteristics of any aquifer (e.g. thickness, type, porosity, transmissibility);
 - groundwater gradient and flow direction;
 - soil permeability and attenuation/sorption characteristics (soils with high permeability increase the potential for infiltration to the groundwater); and
 - pumping tests.
- 7.6 Additionally, a full groundwater investigation should include sampling and laboratory analysis of pH, electric conductivity, dissolved oxygen, calcium, magnesium, total iron, dissolved iron, dissolved manganese, filtered aluminium, bicarbonate, carbonate and colour. A soluble chloride: soluble sulfate ($\text{Cl}^-:\text{SO}_4^{2-}$) ratio should also be calculated.

NB: Analysis of groundwater or drain water for the soluble chloride: soluble sulfate ($\text{Cl}^-:\text{SO}_4^{2-}$) ratio can indicate that sulfidic material in the vicinity of the site is being, or has been, oxidised. In order to undertake this test, water samples should be submitted for laboratory analysis. The location of each borehole or sampling site should be clearly marked on a map, with grid references and elevation (m AHD) for each sample site recorded.

As seawater has a SO_4^{2-} concentration of approximately 2700 mg/L and a Cl^- concentration of approximately 19 400 mg/L, the ratio of $\text{Cl}^-:\text{SO}_4^{2-}$ on a mass basis is 7.2. As the ratios of the dominant ions in saline water remain approximately the same when diluted with rainwater, estuaries and coastal saline creeks can be expected to have similar ratios to the dominant ions in seawater. Where the analysis indicates that there is an elevated level of sulfate ions relative to the chloride ions, these results may indicate the presence of ASS in the landscape. A $\text{Cl}^-:\text{SO}_4^{2-}$ ratio by mass of less than four, and certainly a ratio less than two, is a strong indication of an extra source of sulfate from previous sulfide oxidation (Mulvey 1993).

Caution should be exercised in interpreting $\text{Cl}^-:\text{SO}_4^{2-}$ ratio results. The $\text{Cl}^-:\text{SO}_4^{2-}$ ratio becomes less predictive as the water becomes less brackish (as indicated by electrical conductivity (EC) results). Care should also be taken with the interpretation of data in tropical areas during the wet season or where large freshwater inputs occur. With groundwater, as the layer supplying most of the water within a hole will influence the final analysis outcomes, properly installed 'nested' piezometers, accessing particular strata or horizon/depth intervals, will assist in overcoming sampling limitations and improve the reliability of results.

- 7.7 All groundwater sampling should be undertaken in accordance with the *Murray Darling Basin Groundwater Quality Sampling Guidelines, August 1997, Technical Report No. 3*, Groundwater Working Group, Murray Darling Basin Commission. Further information can be found in Alexander DG (ed) (2000). *Hydrographic Procedure Water Quality Sampling*, May 2000. Department of Natural Resources, Brisbane and in Environmental Protection Agency (1999). *Water Quality Sampling Manual*, December 1999. Environmental Protection Agency, Brisbane.

Using the information

- 7.8 If groundwater investigations indicate that existing groundwaters do not conform to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000a) water quality criteria, then any extracted groundwater must be contained and treated in accordance with the ANZECC guidelines before release.

- 7.9** If groundwater investigations indicate that existing groundwaters are acceptable by the ANZECC guidelines water quality criteria:
- daily monitoring for pH is still required prior to any release of waters to ensure that there is no deterioration of water quality standards since previous measurements; and
 - weekly monitoring for pH is still required if an on-site water storage (greater than 100 m³ or 0.1 megalitre) interacts with groundwater to ensure that there is no deterioration of water quality standards since previous measurements. If the above monitoring indicates a pH result outside the acceptable range of the ANZECC guidelines, waters must be treated in accordance with Section 10 to mitigate the potential for environmental damage should the structure fail.

8. INVESTIGATION RELATED TO FILLING ACTIVITIES

Introduction

- 8.1** Filling is an activity involving the placement of soil, sediment and/or other material to raise the elevation of the land surface. It may also involve ‘preloading’ unconsolidated sediments in preparation for the ‘load’ of built structures. Both the material to be used as fill, and the potential impacts on *in situ* ASS need to be considered prior to filling.

Fill quality assessment

- 8.2** Soil or sediment above the texture-based ASS *Action Criteria* (see Appendix 5) is not suitable for use as fill if not adequately treated. Sections 6 and 9 outline the approach for investigating, treating and managing ASS.

Assessment of potential disturbance to *in situ* ASS from filling

- 8.3** Filling activities may disturb *in situ* ASS by:
- 1) bringing actual ASS (AASS) into contact with the groundwater (and thus potentially mobilising and transporting existing acidity out of the AASS into the groundwater); and/or
 - 2) displacing or extruding previously saturated potential acid sulfate soil (PASS) above the watertable and aerating these soils or sediments²⁰.
- 8.4** To determine the potential for *in situ* ASS to be disturbed by filling, the applicant will need to:
- define the nature (both physical and chemical properties) of the underlying soil and sediment;
 - determine the magnitude and direction of forces that will be exerted on the underlying soil and sediment by the fill material; and
 - predict any changes to watertable/groundwater levels that may occur and the interactions of groundwater with underlying soil and sediment.

²⁰ For example, aeration may occur at the margins of the filling area if the weight of fill exceeds the failure limit of the underlying soil or sediment.

- 8.5** Having regard to the site and nature of the filling activities, the following information should be collected and presented to assist in determining whether *in situ* ASS are likely to be disturbed by the proposed filling. See Sections 6 and 7 for further guidance relevant to conducting ASS and groundwater investigations. The information should include (but is not limited to):
- mass or volume, basal area and thickness of fill;
 - proximity of filling activities to open excavation faces, cavities or watercourses (eg. canals, drains (including agricultural drainage systems), rivers);
 - depth to any PASS and/or AASS layer(s)²¹;
 - thickness of any PASS layer and/or AASS layer(s)²¹;
 - soil physical and chemical characteristics including texture, moisture content and existing plus potential acidity of underlying soil and sediment²¹;
 - underlying strata (eg. consolidated bedrock, coffee rock); and/or
 - groundwater dynamics²².
- 8.6** If, based on the above information, it is considered likely that disturbance to *in situ* ASS will occur as a result of filling, then the applicant will need to predict any resulting physical and chemical changes to the underlying soil and sediment. Any potential environmental impacts, both on and off-site will need to be considered and managed.
- 8.7** It should be noted that a geotechnical assessment by a suitably qualified geotechnical engineer or engineering geologist may be required to adequately define the risks associated with filling.

9. TREATMENT AND MANAGEMENT OF DISTURBED ACID SULFATE SOILS

Introduction

- 9.1** The preferred management approach to deal with ASS is to avoid disturbance wherever possible. However, ASS that have been or will be disturbed require treatment and management to prevent acid generation and neutralise existing acidity.
- 9.2** This Section provides an approach to defining the level of treatment that would be required to neutralise the existing plus potential acidity associated with the disturbance of ASS, and outlines the levels of management and reporting that might be expected for these given levels of treatment.
- 9.3** A range of strategies and options are available to manage ASS disturbances. Further technical guidance should be sought before considering the use of these options. The most common strategies include:
- Avoidance;
 - Minimisation of disturbance;
 - Neutralisation;
 - Strategic reburial (or reinterment); and
 - Hydraulic separation techniques.

²¹ Prior to disturbing ASS, an ASS investigation should be conducted, see Section 6 for further guidance.

²² Prior to disturbing groundwater, a groundwater investigation should be conducted, see Section 7 for further guidance.

- 9.4** A range of other strategies may be considered but these can pose an unacceptably high environmental risk. More detailed management and treatment guidelines will be developed in the future and incorporated into the *Queensland Acid Sulfate Soil Technical Manual*.
- 9.5** With all levels of treatment and management, the information provided to the assessment manager and any required referral agencies should include details of the preliminary investigations and the ASS investigation report including disturbance dimensions, volume calculations, field soil test results and laboratory analysis results. The level of detail provided will depend on the size and complexity of the project and the level of treatment associated with the proposed works, the level of certainty associated with the proposed management strategy, and the sensitivity of the environment likely to be affected. For simple non-linear disturbances less than 1000 m³, the minimum level of site and soil investigation is given in Section 6. For all other disturbances an ASS investigation involving laboratory analysis must be undertaken in accordance with the latest version of the *Queensland Sampling Guidelines* as outlined in Section 6.

Determining the ‘level of treatment’

- 9.6** Table 4 has been developed to assist in identifying the level of treatment required to treat all existing and potential acidity. The levels of treatment defined in this table are based on laboratory results and the volume of material to be disturbed. There are additional factors that will also influence the level of treatment required including the nature of the works to be undertaken, the soil characteristics (e.g. variability of sulfide concentrations, soil bulk density, physical characteristics such as texture and inherent neutralising capacity), the surface and sub-surface hydrology, the sensitivity of the surrounding environment and the past history of the site.
- 9.7** Table 4 can also be used to define the amount of fine agricultural lime²³ (aglime, CaCO₃) required to neutralise the total existing plus potential acidity of a particular volume of soil. Neutralisation agents other than aglime can be used to treat ASS. Factors to consider when choosing a neutralising agent include pH, solubility, neutralising value, fineness/coarseness of the product, spreading and transport costs and chemical composition and purity of the agent. If agents other than aglime are being used, the figures in Table 4 will need to be adjusted accordingly.
- 9.8** The tonnes of lime required for treating the total mass of ASS can be read off Table 4 at the intersection of the mass (tonnes) [row] and the existing plus potential acidity (converted to equivalent S% units) [column]. Potential acidity can be determined by Chromium Reducible Sulfur (S_{CR}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOS}). For samples with pH <5.5, the existing acidity must also be determined by appropriate laboratory analysis e.g. Titratable Actual Acidity (TAA). Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis. The latest version of the *Queensland Sampling Guidelines* (or the future *Queensland Acid Sulfate Soil Technical Manual*) contains further information on approved laboratory methods.

²³ Fine agricultural lime is sometimes called ground limestone. It should not be confused with hydrated lime Ca(OH)₂.

9.9 The treatment levels determined from Table 4 are outlined below²⁴.

Low level of treatment – (Category L)

9.10 For disturbances of ASS requiring treatment at a rate of less than 0.1 tonnes of aglime as per Table 4, the management should ensure:

- manage site runoff and infiltration; and
- treat soils according to their existing plus potential acidity with appropriate amount of neutralising agent (up to the equivalent of 0.1 tonne of fine aglime).

Medium level of treatment – (Category M)

9.11 For disturbances of ASS requiring treatment at a rate of between 0.1 and 1 tonne of aglime as per Table 4, the management should ensure:

- treat soils according to their existing plus potential acidity with appropriate amount of neutralising agent (up to the equivalent of 1 tonne of fine aglime);
- manage site runoff through bunding and prevent or treat infiltration passing through ASS to groundwater during earthworks; and
- ensure that the lime is thoroughly mixed with the soil.

High level of treatment – (Category H)

9.12 For disturbances of ASS requiring treatment at a rate of between 1 and 5 tonnes of aglime as per Table 4, (and no alteration of the permanent watertable levels are involved) management should ensure:

- more detailed plans of disturbance and detailed ASS investigation report;
- treat soils according to their existing plus potential acidity with appropriate amount of neutralising agent (up to the equivalent of 5 tonnes of fine aglime);
- ensure that the lime has been thoroughly mixed with the soil;
- provide bunding of the site using non-ASS material to collect all site runoff during earthworks;
- monitor pH of any pools of water collected within a bund (particularly after rain) and treat water to keep pH in the range of 6.5–8.5 (or as per site specific conditions); and
- prevent infiltration passing through ASS to groundwater or apply extra layer of aglime to intercept any infiltration from ASS.

²⁴ Neutralising materials other than fine agricultural lime (CaCO₃) may be used, in which case the liming rates need to be modified according to the neutralising value and fineness of the material used.

Very high level of treatment – (Category VH)

- 9.13** For disturbances of ASS requiring treatment at a rate of between 5 and 25 tonnes of aglime as per Table 4, (and no alteration of the permanent watertable levels are involved) then the proposed management should include (but not be limited to):
- more detailed plans of disturbance and ASS investigation report (using a higher laboratory analysis intensity if minimal laboratory analysis was undertaken as outlined in Section 6);
 - treat soils according to their existing plus potential acidity with appropriate amount of neutralising agent (up to the equivalent of 25 tonnes of fine aglime);
 - verification that the ASS have been appropriately treated and that lime has been thoroughly mixed with the soil;
 - provide substantial bunding of the site using non-ASS material to collect all site runoff during earthworks;
 - monitor pH of any pools of water collected within the bund (particularly after rain) and treat water to keep pH in the range of 6.5–8.5 (or as per site specific conditions);
 - prevent infiltration passing through ASS to groundwater or apply extra layer of lime to intercept any infiltration from ASS; and
 - provide a simple but adequate environmental management plan based on the requirements outlined in Appendix 4.

NB: If the assessment manager judges that the proposed works are likely to alter the watertable of the area or that the site is close to an environmentally sensitive area (even if <5 tonnes of lime treatment are required), then the disturbance may need to be treated as Extra High level of treatment (Category XH) as below, i.e. an environmental management plan may be required. Refer to Section 10 for guidance on treatment and management of surface and drainage waters.

Extra high level of treatment – (Category XH)

- 9.14** For disturbances of ASS requiring treatment at a rate of greater than 25 tonnes of agricultural lime as per Table 4 or alteration of the watertable or for disturbances affecting the groundwater, an environmental management plan must be provided. See Appendix 4 for details on the content and format of environmental management plans.
- 9.15** This plan should provide for ongoing management and monitoring of the effects of the disturbance of ASS through the construction and operation of the project and describe the construction schedules and environmental management procedures. The project should be staged so that the potential effects on any area disturbed at any one time is limited and easily managed.

Table 4: Estimating treatment levels and aglime required to treat the total weight of disturbed acid sulfate soil – based on soil analysis.

The tonnes (t) of pure fine agricultural lime (CaCO_3) required to fully treat the total weight/volume of acid sulfate soils (ASS) can be read from the table at the intersection of the weight of disturbed soil [row] with the existing plus potential acidity [column]. Where the exact weight or soil analysis figure does not appear in the heading of the row or column, use the next highest value.

Soil Analysis [#] – Potential Acidity plus Existing Acidity (converted to equivalent S% units)															
Disturbed ASS (tonnes) (≈m ³) †	0.03	0.06	0.1	0.2	0.4	0.6	0.8	1	1.5	2	2.5	3	4	5	
1	0	0	0	0	0	0.03	0.04	0.05	0.1	0.1	0.1	0.1	0.2	0.2	
5	0	0	0	0.05	0.1	0.1	0.2	0.2	0.4	0.5	0.6	0.7	0.9	1.2	
10	0	0.03	0.05	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.9	2.3	
50	0.1	0.1	0.2	0.5	0.9	1.4	1.9	2.3	3.5	4.7	5.9	7.0	9.4	12	
100	0.1	0.3	0.5	0.9	1.9	2.8	3.7	4.7	7.0	9.4	12	14	19	23	
200	0.3	0.6	0.9	1.9	3.7	5.6	7.5	9.4	14	19	23	28	37	47	
250	0.4	0.7	1.2	2.3	4.7	7.0	9.4	12	18	23	29	35	47	59	
350	0.5	1.0	1.6	3.3	6.6	10	13	16	25	33	41	49	66	82	
500	0.7	1.4	2.3	4.7	9.4	14	19	23	35	47	59	70	94	117	
600	0.8	1.7	2.8	5.6	11	17	22	28	42	56	70	84	112	140	
750	1.1	2.1	3.5	7.0	14	21	28	35	53	70	88	105	140	176	
900	1.3	2.5	4.2	8.4	17	25	34	42	63	84	105	126	168	211	
1000	1.4	2.8	4.7	9.4	19	28	37	47	70	94	117	140	187	234	
2000	2.8	5.6	9.4	19	37	56	75	94	140	187	234	281	374	468	
5000	7.0	14	23	47	94	140	187	234	351	468	585	702	936	1170	
10 000	14	28	47	94	187	281	374	468	702	936	1170	1404	1872	2340	

L Low treatment: (≤ 0.1 tonne lime)

M Medium treatment: (> 0.1 to 1 tonne lime)

H High treatment: (> 1 to 5 tonnes lime)

VH Very High treatment: (> 5 to 25 tonnes lime)

XH Extra High treatment: (> 25 tonnes lime)

Lime rates are for pure fine agricultural lime (CaCO_3) using a safety factor of 1.5. A factor that accounts for Effective Neutralising Value is needed for commercial grade lime. An approximate soil weight (tonnes) can be obtained from the calculated volume by multiplying volume (cubic m) by bulk density (t/m^3). (Use 1.7 if B.D. is not known.)

† Tonnes approximately equal m^3 (volume) for soils with Bulk Density (BD) of 1 g/cc or t/m^3 . Dense fine sandy soils may have BD up to 1.7. Thus 100 m^3 may weigh up to 170 t.

Potential acidity can be determined by Chromium Reducible Sulfur (S_{CR}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOS}). Existing acidity can be determined by Titratable Actual Acidity (TAA). Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis.

10. TREATMENT AND MANAGEMENT OF SURFACE AND DRAINAGE WATERS FROM DISTURBED ACID SULFATE SOILS

Introduction

- 10.1 Surface and groundwater flows (including to any associated water storages) coming from areas containing ASS should be treated and managed to prevent the leaching of acid and metal contaminants into the environment.
- 10.2 The preferred management approach is to prevent the generation of acid leachate during disturbance. This is particularly important for groundwaters, as neutralisation of groundwater *in situ* is very difficult.
- 10.3 While the treatment of relatively small quantities of water may be quite straightforward, applicants should seek qualified professional assistance, as the chemistry of water quality can be a complex environmental issue. Note that the requirement for monitoring and treatment of surface and drainage waters increase with the higher levels of treatment outlined in Section 9.
- 10.4 In cases where excessive iron, aluminium and other salts are present, particularly in large volumes, sophisticated and novel treatments may be required.

Water quality criteria

- 10.5 Water quality criteria should be determined using the approach defined in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000a) and with reference to the *Australian guidelines for water quality monitoring and reporting* (ANZECC and ARMCANZ 2000b).
- 10.6 The physio-chemical water quality parameters that should be considered when defining water quality criteria related to the treatment and management of surface and drainage waters from disturbed ASS includes, but is not limited to:
 - pH;
 - Electrical Conductivity;
 - Dissolved Oxygen;
 - Aluminium (Al); and
 - Total and Dissolved Iron (Fe).
- 10.7 Most natural fresh water has a pH between 6 and 7 and marine water close to pH 8.2. The natural seasonal maximum or minimum pH for freshwaters and marine waters should be considered in defining water quality criteria. As marine waters are strongly buffered, even small changes in the pH levels indicates a major change to the system. Total alkalinity of seawater is 115–120 mg/L (as CaCO₃).
- 10.8 Research has demonstrated that the chemistry of aluminium in natural waters is complex and the solubility of aluminium species is pH dependent. If the pH is at or below 5.2, the total soluble aluminium concentration increases with an increase in the range of dissolved ionic species present. Aluminium species are toxic to fish over a pH range of 4.4–5.4 and are most toxic when the pH of water is around 5.0–5.2. Under very acid conditions, the toxic effects of the high H⁺ concentrations appear to be more important than the effects of aluminium.

- 10.9** Where iron is precipitating from the acidic water, very low dissolved oxygen levels may result. Wherever possible, dissolved oxygen should be measured over the full diurnal cycle for a period of a few days to establish the diurnal range in concentration.

Neutralising acid leachate and drainage water

- 10.10** There is a range of neutralisation products available that can be used to treat acid waters. The rate of application of these products for treating acid water should be carefully calculated to avoid the possibility of ‘overshooting’. Usually the optimum water pH level is 6.5–8.5. Overshooting can occur quite easily if more soluble or caustic neutralising agents such as hydrated lime $\text{Ca}(\text{OH})_2$ (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. It should be noted that when neutralising acid water, no safety factor is used. However, the monitoring of pH should be carried out regularly during neutralisation procedures and for a suitable period afterwards to verify the appropriate pH has been achieved and maintained.
- 10.11** Agricultural lime CaCO_3 is the safest and cheapest neutralising agent. It equilibrates around a pH of 8.2 and is not generally harmful to plants, stock or humans and most aquatic ecology species. The main shortcoming associated with the use of agricultural lime is its insolubility in water (though it is more soluble in strongly acid water). As a result, trying to raise the pH of water with agricultural lime can be slow and result in wastage of lime.
- 10.12** More soluble neutralising agents are usually more effective at treating water. Sodium bicarbonate NaHCO_3 is quick to act and not subject to pH overshoot. Other cheaper fairly soluble neutralising agents such as hydrated lime $\text{Ca}(\text{OH})_2$ and quick lime CaO are difficult to manage and can result in excessively high pH. When using these strongly alkaline materials strict protocols must be established for their safe use, handling, monitoring and their effects on the receiving environment.

Calculating the quantity of neutralising agent

- 10.13** If no other means of estimating the amount of neutralising agent is available, the quantity of neutralising agent can be calculated by firstly measuring the current pH of the waterbody with a recently calibrated pH meter. The desired pH is usually between 6.5 and 8.5 (pH 7 is normally targeted). The volume of water can be calculated by assuming 1 m³ of acid water is equivalent to 1 kilolitre (1000 litres) and 1000 m³ is equivalent to 1 megalitre (ML).
- 10.14** The rate of application will vary with the solubility, fineness of the neutralising agent, the application technique and the pH of the water. As a general guide, Table 5 shows the minimum quantities of pure aglime, hydrated lime and sodium bicarbonate needed to treat dams or drains of 1 ML (1000 m³) capacity. Calculations in this table are based on low salinity water acidified by hydrogen ions (H^+) 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.
- 10.15** As ASS drainage normally contains many acidic ions other than H^+ (e.g. Fe, Al), a sample should be taken for laboratory analyses (for measurement of titratable acidity) to more accurately determine lime requirements. If this is not available, at least a field titration using the water and the proposed ameliorant may be used for estimating dosage rates.

Table 5: 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)	Aglime to neutralise 1 Megalitre (kg pure CaCO ₃)	Hydrated lime to neutralise 1 Megalitre (kg pure Ca(OH) ₂)	Sodium bicarbonate to neutralise 1 Megalitre (kg pure NaHCO ₃)
0.5	.316	316 228	15 824	11 716	26 563
1.0	.1	100 000	5004	3705	8390
1.5	.032	32 000	1600	1185	2686
2.0	.01	10 000	500	370	839
2.5	.0032	3200	160	118	269
3.0	.001	1000	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	0.012	0.027

Notes on Table 5:

- 1 m³ = 1000 litre = 1 kilolitre = 0.001 Megalitre
- Correlations between current water pH and [H⁺] (mol/L) do not account for titratable acidity. The titratable acidity component should be included in any calculations of neutralising agent requirements.
- Agricultural lime has a very low solubility and may take considerable time to even partially react. While aglime has a theoretical neutralising value of 2 mol of acidity (H⁺), this tends to be only fully available when there is excess acid. This, together with its very low solubility, means that much more aglime beyond the theoretical calculation will generally be required.
- 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 allowing sufficient time for equilibration before further addition of neutralising product.
- Weights of material given in the table above 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 neutralising agent from the table should be multiplied by a purity factor (100/ Neutralising Value for aglime) or (148/ Neutralising Value for hydrated lime).
- If neutralising substantial quantities of ASS leachate, full laboratory analysis of the water will be necessary to adequately estimate the amount of neutralising material required.
- Neutralising agents such as hydrated lime Ca(OH)₂, quick lime CaO, and magnesium oxide MgO neutralise 2 mol of acidity (H⁺), while sodium bicarbonate NaHCO₃ and sodium hydroxide NaOH neutralise only 1 mol of acidity.

10.16 Issues to consider may include:

- the quality and purity of the neutralising agent being used;
- the effectiveness of the application technique;
- the existence of additional sources of acid leaching into the water body further acidifying the water; and
- the neutralising agent has become lumpy and sinks to the bottom of the waterbody, rendering it ineffective.

- 10.17** Neutralisation may be faster if higher rates are used, but this is not recommended, as it is expensive and resource wasteful. Moreover, overdosing may result, though this is less likely to be a concern with agricultural lime.
- 10.18** To increase the efficiency, the neutralising agent 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); or
 - using mobile water treatment equipment such as the 'Neutra-mill' and 'Aqua Fix' to dispense neutralising agents to large water bodies.
- 10.19** In some circumstances a neutralising agent in its solid form can be used, for example by:
- placing it in a porous bag of jute or hessian and tying the bag to drums so that it floats in the water. The material will then gradually disperse. This technique should only be considered where there is significant water movement; or
 - passing water across a bed or through a buffer of coarsely ground limestone CaCO_3 or other granulated neutralising agent. However, this is unlikely to be effective in the long-term as coarse particles of the neutralising agent may become coated with insoluble iron or other compounds, washed away or dissolved.
- 10.20** When the pH of ASS leachate has been below 4.5, it usually contains soluble iron and aluminium salts. When the pH is raised above 4.5, the iron precipitates as a red-brown stain/scum/solid, which can coat plants, monitoring equipment, the base or walls of dams, drains, pipes, piezometers and creeks. In addition, the soluble aluminium is a good flocculent and may cause other minerals to precipitate or for suspended clay particles to flocculate. Where the water contains considerable soluble iron, large quantities of acid can be generated as the pH is raised and iron hydroxides are precipitated. It is important to let any sludge settle before using treated water (otherwise it will block pipes and pumps) or before discharging treated water (to avoid adverse aesthetic and ecological effects). Chemicals can be used to reduce the settlement time if it does not settle quickly enough for the staging of the works, however care should be taken in choosing flocculating agents as these can also alter pH or cause other management problems.
- 10.21** The large-scale dosing of waters to alter the chemical characteristics, such as may be the case in the mining industry, is a specialised and highly technical task that requires considerable expertise and experience. Professional guidance should be obtained in these situations.
- 10.22** The pH of the water should be checked daily during the first two weeks following application or until the pH has stabilised and then on a regular basis according to the ASS management plan. The pH should be checked at least daily if there is any discharge from the site and preferably more frequently depending on the environmental sensitivity of the receiving environment. Automatic testing is strongly advocated.

APPENDIX 1: DEVISING DETAILED MEASURES FOR DEVELOPMENT ASSESSMENT

A1.1 The following material is not intended to be incorporated directly into a planning scheme, but should be used to help devise appropriate detailed measures for achieving the development outcomes of SPP 2/02 and integrating those measures with other provisions of the planning scheme. The material refers to scheme measures in terms of ‘overlays’ and associated ‘assessment criteria’ and is consistent with the approach and terminology suggested for planning schemes in the *IPA Plan Making Guideline 1/02* published by DLGP.

A1.2 Depending on the circumstances in a particular local government area and the organisation of the scheme provisions, there are different ways to incorporate the provisions for ASS issues in a planning scheme. For example:

- both the triggers for assessment and the assessment criteria may be dealt with **separately** through assessment tables and associated assessment criteria; **or**
- both the triggers for assessment and the assessment criteria may be integrated within one or more zone tables and their associated assessment criteria; **or**
- the **triggers for assessment may be integrated** with the assessment tables for one or more zones, but the **assessment criteria are located separately**.

Overlays

A1.3 The following areas should be mapped on an overlay(s), as appropriate for the local government area. The overlay(s) should be based upon the best available information.

Available Information	Area 1	Area 2
If the 5 metre contour is available	All land at or below the 5 metre contour	All land above the 5 metre contour but below the 20 metre contour

Or

Available Information	Overlay
If the 10 or 20 metre contour is the lowest available	All land below the 20 metre contour
If the 20 metre contour is not available use the lowest available contour, eg. the 50 metre contour	All land below the lowest available contour, eg. the 50 metre contour

Assessment triggers and assessment criteria

A1.4 It is suggested that development is made assessable under the planning scheme **if identified** by column 1 in the following table. Suggestions for one or more overall **outcomes sought** for each type of development are stated in column 2, as well as specific outcomes and solutions in some cases.

ACID SULFATE SOILS

A. Where the 5 metre contour is available

Type of development made assessable	Outcomes sought to be achieved (and, if applicable, a solution)	Comment
<p>For land depicted within area 1:</p> <p>(a) works involving:</p> <ul style="list-style-type: none"> excavating or otherwise removing 100 m³ or more of soil or sediment; or filling of land with 500 m³ or more of material with an average depth of 0.5 m or greater; or <p>(b) material changes of use involving works (as described in (a) above) that are an intrinsic component of the use.</p>	<p>Overall outcome: The generation or release of acid and metal contaminants from ASS does not have significant adverse effects on the natural and built environment and human health.</p> <p>Specific outcome: Works avoid disturbing ASS or are managed to avoid or minimise the release of acid and metal contaminants.</p> <p>Solution 1: The disturbance of ASS is avoided by:</p> <ul style="list-style-type: none"> not excavating or otherwise removing soil or sediment identified as containing ASS; not permanently or temporarily extracting groundwater that results in the aeration of previously saturated ASS; not undertaking filling that results in: <ul style="list-style-type: none"> actual ASS being moved below the watertable; and previously saturated ASS being aerated. <p>or</p> <p>Solution 2: The disturbance of ASS avoids the release of acid and metal contaminants by:</p> <ul style="list-style-type: none"> neutralising existing acidity and preventing the generation of acid and metal contaminants; and preventing the release of surface or groundwater flows containing acid and metal contaminants into the environment. 	<p>It is assumed that all areas to which the SPP applies may contain ASS. Achieving either of the solutions requires the applicant to provide a detailed ASS investigation to determine:</p> <ul style="list-style-type: none"> whether ASS are present in the area to be disturbed by the works; and if present, the location, depth and maximum existing and potential acidity of ASS relevant to the proposed disturbance. <p>If ASS are to be disturbed by the proposed works, the applicant must also provide a comprehensive ASS management strategy outlining how the proposed development will achieve Solutions 1 or 2.</p> <p>Assessment criteria for ASS may be included in a separate ASS code or a code addressing other matters (e.g. a code for a zone that incorporates the ASS outcome and solution in relation to the area or type of development).</p> <p>See Note 1 at end of Appendix for advice regarding</p>
<p>For land depicted within area 2:</p> <p>(a) works involving excavating or otherwise removing 100 m³ or more of soil or sediment at or below 5 metres AHD; or</p> <p>(b) material changes of use involving works (as described in (a) above) that are an intrinsic component of the use.</p>	<p>Solution 1: The disturbance of ASS is avoided by:</p> <ul style="list-style-type: none"> not excavating or otherwise removing soil or sediment identified as containing ASS; and not permanently or temporarily extracting groundwater that results in the aeration of previously saturated ASS. <p>or</p> <p>Solution 2: The disturbance of ASS avoids the release of acid and metal contaminants by:</p> <ul style="list-style-type: none"> neutralising existing acidity and preventing the generation of acid and metal contaminants; and preventing the release of surface or groundwater flows containing acid and metal contaminants into the environment. 	<p>Development occurring in area 2 is exempt if the development does not excavate or otherwise remove 100 m³ or more of soil or sediment below 5 metres AHD. Achieving this development status requires the proponent to determine accurately the natural ground levels of the area(s) to be disturbed and the lowest level (metres AHD) of the soil and sediment to be excavated or otherwise removed.</p> <p>Also see comments on previous page.</p> <p>See Note 1 below for advice regarding assessment triggers.</p>

ACID SULFATE SOILS (continued)

B. Land identified on ASS overlay where 5 metre contour information is not available

Type of development made assessable	Outcomes sought to be achieved (and, if applicable, a solution)	Comment
<p>(a) works involving:</p> <ul style="list-style-type: none"> excavating or otherwise removing 100 m³ or more of soil or sediment at or below 5 metres AHD; or filling of land at or below the 5 metre contour with 500 m³ or more of material with an average depth of 0.5 m or greater; or <p>(b) material changes of use involving works (as described in (a) above) that are an intrinsic component of the use.</p>	<p>Overall outcome: The generation or release of acid and metal contaminants from ASS does not have significant adverse effects on the natural and built environment and human health.</p> <p>Specific outcome: Works avoid disturbing ASS or are managed to avoid or minimise the release of acid and metal contaminants.</p> <p>Solution 1: The disturbance of ASS is avoided by:</p> <ul style="list-style-type: none"> not excavating or otherwise removing soil or sediment identified as containing ASS; not permanently or temporarily extracting groundwater that results in the aeration of previously saturated ASS; not undertaking filling that results in: <ul style="list-style-type: none"> actual ASS being moved below the watertable; and previously saturated ASS being aerated. <p style="text-align: center;">or</p> <p>Solution 2: The disturbance of ASS avoids the release of acid and metal contaminants by:</p> <ul style="list-style-type: none"> neutralising existing acidity and preventing the generation of acid and metal contaminants; and preventing the release of surface or groundwater flows containing acid and metal contaminants into the environment. 	<p>It is assumed that all areas to which the SPP applies may contain ASS. Achieving either of the solutions requires the applicant to provide a detailed ASS investigation to determine:</p> <ul style="list-style-type: none"> whether ASS are present in the area to be disturbed by the works; and if present, the location, depth and maximum existing and potential acidity of ASS relevant to the proposed disturbance. <p>If ASS are to be disturbed by the proposed works, the applicant must also provide a comprehensive ASS management strategy outlining how the proposed development will achieve Solutions 1 or 2.</p> <p>Assessment criteria for ASS may be included in a separate ASS code or a code addressing other matters (e.g. a code for a zone that incorporates the ASS outcome and solution in relation to the area or type of development).</p> <p>See Note 1 at end of Appendix for advice regarding assessment triggers.</p>

NOTE 1: The triggers for assessment under the planning scheme may be incorporated in either zone or overlay assessment tables, as appropriate for the scheme, and the outcomes incorporated in zone or overlay assessment criteria, also as appropriate.

APPENDIX 2: SOIL AND WATER FIELD INDICATORS

A2.1 The site investigation will involve the applicant undertaking a visual field investigation of soil and water characteristics. Some helpful soils and water field indicators suggesting the presence of ASS are set out below. Some of the indicators will only be available when the borehole is augered.

Soil type	Indicators
actual acid sulfate soil (AASS)	<p>Soil characteristics</p> <ul style="list-style-type: none"> field $pH_F \leq 4$ (when field $pH_F > 4$ but < 5 may indicate some existing acidity and other indicators should be used to confirm presence or absence); presence of corroded shell; any jarositic horizons or substantial iron oxide mottling in surface encrustations or in any material dredged or excavated and left exposed; and <p>NB: <i>Jarosite is a characteristic pale yellow mineral deposit that can precipitate as pore fillings and coatings on fissures. In the situation of a fluctuating watertable, jarosite may be found along cracks and root channels in the soil. However, jarosite is not always found in actual ASS.</i></p> <ul style="list-style-type: none"> sulfurous smell e.g. hydrogen sulfide or 'rotten egg' gas. <p>Water characteristics</p> <ul style="list-style-type: none"> water of $pH < 5.5$ (and particularly below 4.5) in adjacent streams, drains, groundwater or ponding on the surface (this is not a definitive indicator as organic acids may contribute to low pH in some environments such as melaleuca swamps); unusually clear or milky blue-green drain water flowing from or within the area (aluminium released by ASS acts as a flocculating agent); and extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits. <p>Landscape and other characteristics</p> <ul style="list-style-type: none"> dead, dying, stunted vegetation*; scalded or bare low-lying areas*; corrosion of concrete and/or steel structures*. <p><i>* May also be due to excessive salinity or to salinity in combination with AASS.</i></p>
potential acid sulfate soil (PASS)	<p>Soil characteristics</p> <ul style="list-style-type: none"> waterlogged soils – unripe muds (soft, buttery, blue grey or dark greenish grey), silty sands or sands (mid to dark grey) or bottom sediments (dark grey to black e.g. monosulfides) possibly exposed at sides and bottoms of drains or cuttings, or in boreholes; soil $pH_F > 4$ and commonly neutral (see also Appendix 3 for details on soil field pH tests); soil $pH_{FOX} < 3$, with a large unit change from pH_F to pH_{FOX}, together with a strong reaction to peroxide; reaction to peroxide using semi-microscopic screening techniques; presence of shell; and a sulfurous smell e.g. hydrogen sulfide or 'rotten egg' gas. <p>Water characteristics</p> <ul style="list-style-type: none"> water pH usually neutral but may be acid.

NB: Caution should be taken when inspecting highly altered landscapes in the field (e.g. where inert fill has been placed over ASS material). Soil, water and landscape indicators may be masked by past landscape and drainage modifications and this should be taken into consideration when defining borehole locations.

APPENDIX 3: INTERPRETING SOIL FIELD pH TESTS

- A3.1** It is important to note that whilst a useful exploratory tool, soil field pH tests are indicative only and cannot be used as a substitute for laboratory analysis to determine the presence of ASS. Laboratory analysis is needed to quantify the amount of existing plus potential acidity. This Appendix provides information on how to interpret the results from soil field pH tests. For further information on how to conduct and interpret these tests, consult the latest version of the *Queensland Sampling Guidelines*.
- A3.2** Field pH tests should be conducted on the soil profile at regular intervals (0.25 metres) using a field pH meter calibrated according to the manufacturer's instructions. All results (pH_F and pH_{FOX} values, peroxide reaction) should be tabulated and reported.
- A3.3** Other semi-field tests such as examination under a microscope for pyrite and its reaction with peroxide on the slide may be useful tools to identify pyrite presence, but they require experience and training.

Field pH test (pH_F) i.e. pH of soil and water paste

- A3.4** The pH_F test measures the existing acidity of a 'soil:water' paste, and is therefore used to help identify if AASS are present. If the measured pH of the soil paste is $pH_F \leq 4$, oxidation of sulfides has probably occurred in the past, indicating the presence of AASS. Highly organic soils or heavily fertilised soils may also return a $pH_F \leq 4$. A $pH_F > 4$ but ≤ 5 indicates an acid soil, but the cause of the acidity will need to be further investigated by laboratory analysis. The pH_F test does not detect any unoxidised sulfides (i.e. PASS). For this reason, this test must be used in conjunction with the pH_{FOX} test.

Field pH peroxide test (pH_{FOX}) i.e. pH of soil and peroxide mix and reaction with peroxide

- A3.5** The pH_{FOX} test is used to indicate the presence of iron sulfides or PASS. This test involves adding 30% hydrogen peroxide (pH adjusted to 4.5–5.5) to a sample of soil. If sulfides are present a reaction will occur. The reaction can be influenced by the amount of sulfides present in the sample, the presence of organic matter or the presence of manganese. Once the reaction has occurred, the pH is measured.

A3.6 A combination of three factors is considered in arriving at a ‘positive field sulfide identification’:

- (i) **A reaction with hydrogen peroxide.** The strength of the reaction with peroxide is a useful indicator but cannot be used alone. Organic matter, coffee rock and other soil constituents such as manganese oxides can also cause a reaction. Care should be exercised in interpreting a reaction on surface soils and high organic matter soils such as peats and coffee rock, and some mangrove/estuarine muds and marine clays. This reaction should be rated, e.g. L = Low reaction, M = Medium reaction, H = High reaction, X = Extreme reaction.
- (ii) **The actual value of pH_{FOX} .** If the $\text{pH}_{\text{FOX}} < 3$, and a significant reaction occurred, then it strongly indicates a PASS. The more the pH_{FOX} drops below 3 the more positive the presence of sulfides.
- (iii) **A much lower pH_{FOX} than field pH_{F} .** The lower the final pH_{FOX} value and the greater the difference between the pH_{FOX} compared to the pH_{F} (ΔpH), the more indicative the presence of PASS. This difference may not be as great if starting with an already very acid pH_{F} (close to 4), but if the starting pH is neutral or alkaline then a larger change (ΔpH) should be expected. Where fine shell, coral or carbonate is present the change in pH (ΔpH) may not be as large due to buffering. The ‘fizz test’ (effervescence with 1 M HCl) should be used to test for carbonates and shell.

A3.7 A fuller explanation of field tests is given in Hey *et al.* (2000).

NB: Field techniques are useful exploratory tools, but are indicative only and definitely not quantitative. They are not a replacement for quantitative laboratory analyses. The field peroxide test has been found to be least useful on low analyses sands, particularly dredged sands approaching the action limit (0.03% S). It is also difficult to interpret field tests on highly organic or peat soils and coffee rock.

APPENDIX 4: ENVIRONMENTAL MANAGEMENT PLANS

- A4.1** The intention of an EM Plan is to provide ‘life of development’ control strategies in accordance with agreed performance criteria. An EM Plan needs to specify all potential environmental impacts, performance criteria, and mitigation strategies together with relevant monitoring, reporting and, if an undesirable impact or unforeseen level of impact occurs, the appropriate corrective action.
- A4.2** An EM Plan contains clear commitments, framed in a way that enables later assessment of the extent to which the commitment has been met. The commitments must be auditable.
- A4.3** An EM Plan is structured to address the key elements of environmental management on-site and in proximity to the site for the life of the development. Performance criteria for all elements are determined in the process of formulating an acceptable EM Plan.
- A4.4** Specifically an EM Plan must provide:
- evidence of practical and achievable plans for the management of the project to ensure that environmental requirements are complied with, by producing an integrated planning framework for comprehensive monitoring and control of construction and operational impacts. Specific commitments on strategies and design standards to be employed should also be given;
 - local, State and Commonwealth authorities and the proponent with a framework to confirm compliance with policies and conditions; and
 - the community with evidence of the management of the project in an environmentally acceptable manner.

Format of an EM Plan

- A4.5** The following is a suggested format designed to ensure adequate detail has been provided to demonstrate that the proposed mitigation of potential impacts will result in appropriate management strategies.
- A4.6** Essential components are:
- establishment of agreed performance criteria and objectives in relation to environmental and social impacts;
 - detailed prevention, minimisation and mitigation strategies (including design standards) for controlling environmental impacts at specific sites;
 - details of the proposed monitoring of the effectiveness of remedial measures against the agreed performance criteria in consultation with relevant regulatory agencies and the community. The frequency of monitoring for each parameter and proposed location of monitoring sites should be shown to allow consideration of monitoring in risk assessment;
 - details of implementation responsibilities for environmental management (names of responsible positions or persons);
 - timing (milestones) of environmental management initiatives;
 - reporting requirements and auditing responsibilities for meeting environmental performance objectives and demonstrating ‘quality assurance’; and
 - corrective actions to rectify any deviation from performance standards.

Review of EM Plan

- A4.7** An EM Plan is reviewed and periodically updated to reflect knowledge gained during the course of operations and to reflect new knowledge and changed community standards (values). Changes to the management plan should be developed and implemented in consultation with relevant authorities.

Specific requirements for acid sulfate soils

- A4.8** The ASS component of the EM Plan should be prepared, and implementation commenced, prior to soil drainage or disturbance and should include the following:
- a two (2) dimensional map of the occurrence of ASS to 1 metre below the depth of disturbance. The map should identify separate areas of both AASS and PASS according to the upper depth of occurrence e.g. 0–0.5 m, 0.5–1 m, 1–1.5 m, etc.;
 - at complex sites, a number of cross-sectional diagrams or a three dimensional diagram of the site, showing various ASS layers (with corresponding soil analysis indicated) should be presented. This will assist greatly in understanding the site and form the basis for ASS management;
 - details of potential on-site and off-site effects of the disturbance of the soil and/or the groundwater levels;
 - prevention strategies for the oxidation of iron sulfides (e.g. avoiding the disturbance of ASS by redesigning layout of the excavations);
 - treatment strategies for ASS (including strategic reburial of PASS, neutralisation of AASS and PASS by thorough mixing of fine agricultural lime at 1.5 to 2 times the theoretical acid production potential, or hydraulic separation and treatment of the extracted material);
 - strategies for management of the watertable height on and off the site both during and post-construction;
 - monitoring strategies (manual, automated, and laboratory procedures) detailing requirements for surface water and groundwater monitoring for pH, electrical conductivity, dissolved oxygen, chloride, sulfate, total iron, dissolved iron, filtered aluminium, bicarbonate, calcium and monitoring biological indicators where required;
 - monitoring schedules for soil, including field pH (pH_F), field peroxide pH (pH_{FOX}) and laboratory procedures;
 - details of verification testing of soils;
 - details of the handling and storage of neutralising agents;
 - containment strategies (including bunding, lime dosing, use of silt curtains) to ensure that all contaminated stormwater, acid and leachate associated with the oxidation of ASS is prevented from entering the receiving environment both in the short and long-term (where pH, dissolved oxygen, dissolved iron, total iron and dissolved aluminium comply with limits documented in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000a));
 - performance criteria to be used to assess the effectiveness of the ASS management and monitoring measures; and
 - description of contingency procedures to be implemented on and off the site if the management procedures prove to be unsuccessful, acid is generated, leachate problems occur, and/or if performance criteria are breached, including designated personnel responsible for the contingency plans.

APPENDIX 5: TEXTURE-BASED ACID SULFATE SOIL ‘ACTION CRITERIA’

- A5.1** The *Action Criteria* are based on the sum of existing plus potential acidity. This is usually calculated as equivalent sulfur (e.g. s-TAA + S_{CR} in %S units) or equivalent acidity (e.g. TAA + a-S_{CR} in mol H⁺/tonne)²⁵. The highest laboratory result(s) is always used to assess against the action criteria. For further information consult the latest version of *Queensland Sampling Guidelines*.
- A5.2** As clay content tends to influence a soil’s natural pH buffering capacity, the action criteria are grouped by three broad texture categories – coarse, medium and fine. The criteria are used to define when ASS disturbed at a site will need to be treated and managed.
- A5.3** For projects that disturb ≥1000 tonnes of ASS with ≥0.03 %S or ≥18 mol H⁺/tonne equivalent acidity, a detailed management plan and development consent will be required.

Table 6: Texture-based acid sulfate soils ‘action criteria’

Type of Material		Action Criteria if 1–1000 tonnes of material is disturbed		Action Criteria if more than 1000 tonnes of material is disturbed	
		Existing + Potential Acidity		Existing + Potential Acidity	
Texture range McDonald <i>et al.</i> (1990)	Approx. clay content (%)	Equivalent sulfur (%S) (oven-dry basis)	Equivalent acidity (mol H ⁺ /tonne) (oven-dry basis)	Equivalent sulfur (%S) (oven-dry basis)	Equivalent acidity (mol H ⁺ /tonne) (oven-dry basis)
Coarse Texture Sands to loamy sands	≤5	0.03	18	0.03	18
Medium Texture Sandy loams to light clays	5–40	0.06	36	0.03	18
Fine Texture Medium to heavy clays and silty clays	≥40	0.1	62	0.03	18

- A5.4** Refer to the latest version of the *Queensland Sampling Guidelines* for updates on this table.

²⁵ A combination of symbols/abbreviations is used to define whether an analytical result is a direct measurement of acid or sulfur content, or a derived measure (expressed in ‘equivalent units’ for convenience of calculation). For example, S_{CR} (%S) is a direct measure of reduced inorganic sulfur which theoretically should produce acid on oxidation. If S_{CR} (%S) is converted into equivalent acid units, this conversion is indicated by the prefix ‘a-’ resulting in a-S_{CR} (mol H⁺/tonne). Conversely, if TAA (mol H⁺/tonne), which is a direct measure of acidity, is converted into equivalent sulfur units, this conversion is indicated by the prefix ‘s-’ resulting in s-TAA (%S).

APPENDIX 6: REFERENCES

- A6.1** For a more comprehensive list of helpful references, please contact the Department of Natural Resources and Mines' Queensland Acid Sulfate Soils Investigation Team (QASSIT), phone: 07 3896 9819.
- Ahern CR, Ahern MR and Powell B (1998). *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*. Department of Natural Resources, Indooroopilly, Queensland, Australia. DNRQ980124
- Ahern CR, Hey KM, Watling KM and Eldershaw VJ (eds) (2000). *Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers*, Brisbane, 20–22 June, 2000. Department of Natural Resources, Indooroopilly, Queensland, Australia.
- Alexander DG (ed) (2000). *Hydrographic Procedure Water Quality Sampling, May 2000*. Department of Natural Resources, Brisbane, Queensland
- ANZECC and ARMCANZ (2000a). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.
- ANZECC and ARMCANZ (2000b). *Australian and New Zealand Guidelines for Water Quality Monitoring and Reporting*. National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.
- Dalrymple RW, Zaitlin BA and Boyd R (1992). Estuarine facies models: conceptual basis for stratigraphic implications. *Journal of Sedimentary Petrology* 62, 1130–1146.
- Environmental Protection Agency (1999). *Water Quality Sampling Manual*, 3rd edition, December 1999. Environmental Protection Agency, Brisbane, Queensland.
- Hey KM and Ahern CR (2000). Preliminary methods for recognition of acid sulfate soils: Desktop assessment and use of on-site indicators. In: *Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers*. Ahern CR, Hey KM, Watling KM and Eldershaw VJ (eds), Brisbane, 20–22 June, 2000. Department of Natural Resources, Indooroopilly, Queensland, Australia.
- Lapidus J (1990). *Collins Dictionary of Geology*. Collins Publishing, Melbourne, Victoria, Australia.
- McDonald R, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). *Australian Soil and Land Survey Field Handbook* (2nd edition), Inkata Press, Melbourne.
- McElnea AE, Ahern CR and Menzies NW (2002a). Improvement to peroxide oxidation methods for analysing sulfur in acid sulfate soils. *Australian Journal of Soil Research* 40(7).
- McElnea AE, Ahern CR and Menzies NW (2002b). The measurement of actual acidity in acid sulfate soils and the determination of sulfidic acidity in suspension after peroxide oxidation. *Australian Journal of Soil Research* 40(7).

Murray Darling Basin Groundwater Quality Sampling Guidelines, August 1997, Technical Report No. 3, Groundwater Working Group, Murray Darling Basin Commission.

Mulvey PJ (1993). Pollution prevention and management of sulfidic clays and sands. In: *Proceedings of the National Conference on Acid Sulfate on Acid Sulfate Soils*, Cooloongatta, June 1993. (Ed) R Bush, NSW Department of Agriculture. Wollongbar, NSW. pp 116-129.

APPENDIX 7: NR&M SPECIAL ACID SULFATE SOILS MAPS

- A7.1** The following outlines the quality and nature of information that is used in the preparation and presentation of NR&M *Special Acid Sulfate Soils Maps*.

Map reliability and scale

- A7.2** Map reliability is based on soil or sediment cores taken at intensities equivalent to approximately one per square centimetre of published map. For example, for a 1:100 000 scale map, the intensity is approximately one core per 100 hectares, whereas for a 1:25 000 scale map, approximately one core per 6 hectares is taken. The scale of a map is clearly marked on the map and accompanying information in the map key or in a supporting publication is provided on how the map may be used (eg. 1:100 000 map scales will define areas of low and high probability ASS, whilst 1:25 000 mapping will additionally define the depth to certain soil layers).

Sampling equipment

- A7.3** A range of manual and mechanical sampling equipment specially designed to cater for the recovery of intact cores from saturated sands, soft plastic muds, and other ASS material.

Soil core integrity and depth

- A7.4** Core length is no less than 80% of the depth of the borehole from which the core was extracted, and a diameter of not less than 38 mm. The depth of cores is a minimum of 2 metres and is usually 5 metres, or to the depth of the non-marine sediment basement.

Site information

- A7.5** A site description is made at the location of each borehole. Field description of landform, vegetation and the morphology of cored material is based on methodology according to McDonald *et al.* (1990), and is carried out by a competent soil surveyor. The site location is recorded in standard Australian Map Grid coordinates to an accuracy of 3 metres.

Sampling, field testing and laboratory analysis

- A7.6** Sampling, field testing and laboratory analysis is carried out in accordance with the latest version of the *Queensland Sampling Guidelines*. Samples (approximately 0.5 kg) are collected at 0.5 m intervals down the soil profile, or within each soil or sedimentary layer. Samples are bagged, labelled and frozen in the field for future laboratory analysis. Field tests (pH_F and pH_{FOX}) are conducted at 0.25 m intervals down the soil profile in the field and results are tabulated. Upon arrival at the laboratory, samples are either frozen or oven-dried at 80°C for 48 hours for laboratory analysis.

Data retrieval

- A7.7** All site description data is stored in a retrievable electronic data format within a Geographic Information System (GIS). Laboratory data is subject to quality assurance.

Map unit information

- A7.8** A database is maintained in a GIS that includes data on individual map units, referred to as Unique Map Areas (UMA's). This includes the identity of the sites that occur in the UMA and a statement about the reliability of that UMA.

APPENDIX 8: GLOSSARY

Acid sulfate soils (ASS): soil or sediment containing highly acidic soil horizons or layers affected by the oxidation of iron sulfides (actual ASS) and/or soil or sediment containing iron sulfides or other sulfidic material that has not been exposed to air and oxidised (potential ASS).

NB: The term acid sulfate soil generally includes both actual and potential ASS. Actual and potential ASS are often found in the same soil profile, with actual ASS generally overlying potential acid sulfate soil horizons.

Actual acid sulfate soils (AASS): soil or sediment containing highly acidic soil horizons or layers affected by the oxidation of soil materials that are rich in iron sulfides, primarily pyrite. This oxidation produces hydrogen ions in excess of the sediment's capacity to neutralise the acidity, resulting in soils of pH 4 or less. These soils can usually be identified by the presence of jarosite.

Potential acid sulfate soils (PASS): soil or sediment containing iron sulfides or sulfidic material that have not been exposed to air and oxidised. The field pH of these soils in their undisturbed state is pH 4 or more, and may be neutral or slightly alkaline.

Agricultural lime: a neutralising agent commonly used to treat acidic soils; by composition, it is commonly 95–98% pure calcium carbonate (CaCO_3); it is insoluble in pure water, with a pH of ~8.3; application rates will depend on the purity and fineness of the product.

AHD (Australian Height Datum): the datum used for the determination of elevations in Australia. The determination used a national network of bench marks and tide gauges, and set mean sea level as zero elevation.

Anaerobic conditions: conditions whereby air (oxygen) is excluded, usually by waterlogging.

Aquifer: rock or sediment in a formation, group of formations or part of a formation that is capable of storing and transmitting water (or another fluid) in significant quantities to bores, wells or springs.

Beach ridge or Beach-ridge plain: a beach ridge is a very long, nearly straight, low ridge, built up by waves and usually modified by wind. A beach ridge is often a relict feature remote from the beach. They are usually separated by narrow swales [depressions] of varying width and depth depending on how closely the successive ridge crests have been formed (McDonald *et al.* 1990). A broad sequence of such ridges is called a beach-ridge plain.

Borehole: the actual hole created when an auger or push-tube is inserted into the soil body; the portion removed (the core) will demonstrate the soil profile.

Community infrastructure: infrastructure listed in Schedule 5 of the IPA.

Drain water: water contained in a drain, which flows into a drain, or flows immediately from a drain.

Estuary (Estuarine): numerous definitions have been given for estuaries. The standard definition for an estuary only describes the interaction between river and marine currents ‘...a widened mouth of a river valley where freshwater intermixes with seawater and where tidal effects occur’ (Lapidus 1990). Perhaps the most pertinent one in a coastal geological sense relates to one that incorporates all the influences contributing to the dynamics of the estuary.

Dalrymple *et al.* (1992) proposed such a definition ‘...the seaward portion of a drowned valley system which received sediment from both fluvial and marine sources and which contains facies influenced by tide, wave and fluvial processes. The estuary is considered to extend from the landward limit of tidal facies at its head to the seaward limit of coastal facies at its mouth.’ The definition is based on the premise that estuaries form as a result of sea-level rise.

Extracting groundwater: this includes drainage, pumping or otherwise removing groundwater.

Flocculation: the process whereby small particles clump together into particles of greater mass; commonly seen as iron flocs in streams.

Framboidal (pyrite): microscopic pyrite crystals aggregated in clusters resembling the shape of a raspberry. Common in ASS.

Groundwater: subsurface water in the zone of saturation, including water below the watertable and water occupying cavities, pores and openings in underlying soil and rock.

Holocene: a period of time from about 10 000 years ago to the present, an epoch of the Quaternary period.

Integrated Development Assessment System (IDAS): IDAS is a framework that establishes a common statutory system for making, assessing and deciding development applications.

IPA planning scheme: an IPA planning scheme is a scheme prepared under the *Integrated Planning Act 1997*.

Jarosite: an acidic pale yellow iron sulfate mineral: $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$. Jarosite is a by-product of the acid sulfate soil oxidation process, formed at pH less than 3.7; commonly found precipitated along root channels and other soil surfaces exposed to air.

Leachate: the soil constituent that is washed out from a mixture of soil solids.

Mobilise: situation where the naturally occurring metals in soil or sediment are changed from an insoluble to a soluble state.

Neutralising: the process whereby acid produced (by the oxidation of iron sulfides) is counteracted by the addition of an ameliorant such as lime (CaCO_3); there are formulae for calculating the amount of ameliorant needed.

Oxidised: process of chemical change involving the addition of oxygen following exposure to air.

pH: a measure of the acidity of alkalinity of a soil or water body on a logarithmic scale of 0 to 14; a pH <7 is acid, pH 7 is neutral, and pH >7 is alkaline. Note that one unit change in pH is a ten-fold change in acidity.

- Piezometer:** a pipe of small diameter installed in a borehole that is used to measure the height (elevation) of the watertable (piezometric or potentiometric surface). The term can also refer to the instrumentation installed in the pipe. Nested piezometers are a group of piezometers established at different depths to measure the height of the watertable throughout an aquifer.
- Pyrite:** pale-bronze or brass-yellow, isometric mineral: FeS_2 ; the most widespread and abundant of the sulfide minerals.
- Quaternary:** a geological time period extending from 1.8 million years ago to present time; incorporates both the Pleistocene and Holocene epochs.
- Recharge area:** the portion of the landscape in which rainwater enters the soil body moving down the profile to the groundwater.
- Scalded areas:** areas which are bare of vegetation due to extremely adverse growing conditions, such as being too acid.
- Soil and sediment:** the natural accumulation of unconsolidated mineral particles (derived from weathered rocks) and organic matter that covers much of the earth's surface. The chemical and physical composition varies greatly between soil and sediment types. Clays, silts, sands, gravels, peats, muds and indurated sands (e.g. 'coffee rock') are all examples of soil and sediment.
- Soil permeability:** a measure of the ease with which water can enter or move through a soil body.
- Soil profile:** this is an accurate representation of spatial proportions of the different vertical layers in a soil body; each layer has individual chemical and physical properties that govern its behaviour.
- Special acid sulfate soils map:** mapping prepared and presented in accordance with the Department of Natural Resources and Mines requirements for map reliability and scale, sampling equipment, soil core integrity and depth, site information, sampling, field testing and laboratory analysis. These maps are scale specific, and should only be used in keeping with information defining their proper use. See Appendix 7 in SPP Guideline 2/02 for additional information.
- Transitional planning scheme:** A planning scheme prepared under the former *Local Government (Planning & Environment) Act*, although that scheme might be amended under the *Integrated Planning Act 1997*.
- Watertable:** portion of the ground saturated with water; often used specifically to refer to the upper limit of the saturated ground.

Published by:

Natural Resource Sciences
Department of Natural Resources and Mines
Block C, 80 Meiers Road
Indooroopilly Queensland 4068
Telephone: (07) 3896 9819
Facsimile: (07) 3896 9782

Planning Services
Department of Local Government and Planning
PO Box 31
Brisbane Albert Street Queensland 4002
Telephone: (07) 3235 4566
Facsimile: (07) 3235 4563

Copies of the State Planning Policy 2/02: *Planning and Managing Development Involving Acid Sulfate Soils* and its supporting Guideline are available by contacting the above or on the Department of Natural Resources and Mine's website at www.nrm.qld.gov.au as well as the Department of Local Government and Planning's website at www.dlgp.qld.gov.au.

© Copyright 2002 the State of Queensland (Department of Local Government and Planning and the Department of Natural Resources and Mines.)

Reproduction is permitted for not-for-profit purposes and as permitted by the Copyright Act 1968, with appropriate acknowledgement. Otherwise reproduction is prohibited unless formal permission is obtained from the Queensland Government.

Reprinted with corrections March 2003

QNRM03152

August 2002

NOTES

ISBN 0 7242 9671 9