Planning Scheme Policy 1 Acid Sulfate Soils

1.1 Purpose of the Policy

The purpose of this Planning Scheme Policy is to provide a guide to Council's requirements for acid sulfate soil investigations and management plans. The policy provides important information relating to identification, laboratory analysis, treatment and monitoring of acid sulfate soils based on the State Planning Policy 2/02 – Planning and Managing Development involving Acid Sulfate Soils. The latest version of the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland* (referred to in this policy as the *Queensland Sampling Guidelines*) should be consulted for more detailed information on acid sulfate soil investigation. The *Queensland Sampling Guidelines* form part of the *Queensland Acid Sulfate Soil Technical Manual* currently under development. The manual will also include chapters on management and treatment options for acid sulfate soils, guidance on environmental management plans, examples of industry best practice, laboratory analysis, 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 acid sulfate soils.

PART A – Self Assessable

For excavations less than $100m^3$, it is a legal requirement that persons adhere to the general environmental duty, that is to ensure all reasonable and practicable measures are taken to prevent or minimise environmental harm. The following information is provided to give guidance to self-assessable acid sulfate soil disturbances.

Treatment of Acid Sulfate Soils less than $100m^3$

Acceptable solution 2.1 for self assessable acid sulfate soil disturbances suggests a base rate of 25 kg lime/m^3 in order to safely treat disturbed soils.

Solutions 2.2 and 2.3 give acceptable solutions to avoid acid and contaminant release during stockpiling and treatment of excavated soils.

A treatment pad is an effective way of preventing the release of acid water and contaminants from stockpiled acid sulfate soils. Treatment pads should comprise of an impermeable compacted clay layer 0.3 – 0.5 metre deep and covered with a guard layer of agricultural lime (at a rate of 5kg lime/m^3). To prevent the release of acid waters and contaminants from stockpiled soils via runoff, treatment pads should be bunded, or trenches and catchpits installed around the treatment pad to contain stormwater runoff. Catch pits and trenches also need to be limed at a rate of 5 kg of agricultural lime /m^3, and must be fully covered once treatment operations are finalised.

Excavation pits, trenches and drainage lines

Exposed sediment and soils in excavation pits, trenches and drainage lines have the potential to oxidise and promote the release of iron, aluminium and other contaminants to the environment. These contaminants have the potential to cause environmental harm (eg. Iron assists growth of *Lyngbya*). Acceptable solution 2.3 also gives an solution for neutralising excavation pits, trenches or drainage lines that are to be permanently exposed. By spreading lime over exposed surfaces acidity can be neutralised and the solubility of these contaminants is reduced, thus preventing their release to the environment.

Covering exposed surfaces can also prevent further acidification. Acceptable solution 2.4 suggests that exposed sediment or soil is covered by appropriate vegetation or infrastructure. By quickly covering these exposed sediments or soils with turf, vegetation, non-acid fill or appropriate infrastructure further generation of acid sulfate from these soils can be avoided.

Groundwater and pit water

As with acid soils, acid groundwater and pit water also needs to be neutralised to prevent the release of contaminants to the environment and to mitigate environmental harm. The neutralisation of acidified waters is very important in reducing the solubility of metals (particularly iron and aluminium) preventing its transport to other waters, thus mitigating environmental harm and *Lyngbya* blooms. Solution 2.5 suggests that acidified groundwater and pit water should also be treated to neutralise acidity and prevent the release of contaminants to other waters.

The ideal pH that groundwater and pit water should be neutralised to depends on the nature of the existing groundwater or the characteristics of receiving waters. As a rule the pH of treated waters should have a pH between 6.5 and 8.5. However, some environments are naturally acidic (around 5.5) and care should be taken to prevent the release of treated waters with a pH above or below 5.5 to these waterways. Comparatively marine and estuarine waters are naturally higher in pH (around pH 8.2) and care should be taken to prevent the release of treated waters to these waterways with a pH less than 8 (though no higher than 8.5). **Advice should be sought from Council and/or the Environmental Protection Agency before releasing any treated waters to waterways.**

Agricultural lime CaCO3 is the safest and cheapest neutralising agent for neutralising waters. 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. More soluble neutralising agents are usually more effective at treating water and may want to be used where large volumes of water are being treated. Sodium bicarbonate NaHCO3 is quick to act and not subject to pH overshoot. Other cheaper fairly soluble neutralising agents such as hydrated lime $Ca(OH)_2$ 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.

Protecting infrastructure

Acid sulfate soils can rapidly degrade infrastructure including concrete. The use of acid tolerant concrete or alternative products is recommended for construction in areas where acid sulfate soils are present.

PART B – Code Assessable

1.2 Information Requirements

The following information is to be provided to assist in the assessment of developments that may impact on acid sulfate soils.

Based on the acid sulfate soils overlay, it is assumed all land, soil and sediment below 5.0 metres AHD may contain acid sulfate soils, unless site-specific information is available confirming the contrary. In order to achieve either of the solutions of the code, a detailed acid sulfate soil investigation, undertaken by a qualified soil scientist, is required to determine:

(a) whether acid sulfate soils are present in the area to be disturbed by the works; and

(b) if present, the location, depth and maximum existing and potential acidity of acid sulfate soils relevant to the proposed disturbance.

If acid sulfate soils are proposed to be disturbed, a comprehensive acid sulfate soil management plan is required in accordance with this policy.

Council will require information to be submitted with the application to determine the applicability of the acid sulfate soils code, including the lowest point in metres AHD of the proposed excavation, together with the maximum volume of excavation below 5.0 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 5.0 metres AHD (for Area 1 only). Where insufficient information is supplied with the application, Council will seek further information as part of an information request to enable the assessment of the application.

Although potential impacts associated with disturbing acid sulfate soils can be managed, it is preferable to avoid or minimize the risk of disturbance. Development should avoid, as far as practicable, disturbance of acid sulfate soils and the development layout should be designed to this effect.

1. Identification and Investigation of Acid Sulfate Soils

(a) Desktop assessment and site investigation

Step 1 is necessary for all investigations and involves a desktop assessment and a site visit to identify indicators of acid sulfate soils, followed by soil sampling. 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:

(i) nature of the disturbance (excavation, filling or groundwater extraction);

(ii) specific location or locations of disturbance;

(iii) total area of the site (in m^2 or hectares) to be disturbed;

(iv) volume of material to be disturbed; and

(v) maximum depth of disturbance with reference to metres AHD (including any underground service pipes such as sewerage or stormwater).

At an early stage in the acid sulfate soil 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 further in this policy.

The desktop assessment should check the location of the proposed development against suitable acid sulfate soil maps (e.g. NRME *Special Acid Sulfate Soils Maps*) or other broad scale information if available. The most recent version and most detailed acid sulfate soil map should be used (e.g. 1:25 000 scale is preferred to 1:100 000 scale). If acid sulfate soil maps are not available the applicant should undertake an investigation to determine whether there is a known acid sulfate soil problem in the area (e.g. recorded in adjacent sites) and check if the site meets the geomorphic or site description criteria outlined below. Note that broad scale information cannot be used alone at the property scale to confirm absence of acid sulfate soils or define the amount of existing or potential acidity for a disturbance.

The following geomorphic or site description criteria should be used to determine if ASS are likely to be present:

(i) land with elevation less than 5.0 metres AHD;

(ii) soil and sediment of recent geological age (Holocene);

(iii) marine or estuarine sediments and tidal lakes;

(iv) low-lying coastal wetlands or back swamp areas, waterlogged or scalded areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes;

(v) coastal alluvial valleys;

(vi) areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging conditions such as mangroves, saltcouch, swamp-tolerant reeds, rushes, grasses (e.g. *Phragmites australi*s), paperbarks *(Melaleuca sp*p.) and swamp oak *(Casuarina sp*p.); and

(vii) 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.

Whilst it is uncommon, it is possible for Acid Sulfate Soils to occur above 5.0 metres AHD. Developments above 5.0 metres AHD should be aware of indications that Acid Sulfate Soils are present including:

- Iron stained (orange coloured) ground or surface water.
- The presence of pyrite (yellow mottles).
- Sulfur (rotten egg) odour.
- Low pH of soil or surface and groundwater (pH<5.5).

(b) Soil Sampling

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. Soil sampling involves auguring or drilling boreholes, describing the soil profile, undertaking field tests and collecting and storing soil samples. Table 1 lists soil and water indicators that can be used (as a result of either site investigations or field soil tests) to identify if acid sulfate soils are present. As many of the indicators for actual and potential acid sulfate soils 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 acid sulfate soil that also contains some un-oxidised iron sulfides or potential acidity. 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.

Table 1: Soil and Water Field Indicators suggesting the presence of acid sulfate soils

Soil Type	Indicators
Actual acid sulfate soil (AASS)	**Soil characteristics** • field pHF ≤4 (when field pHF >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 **NB:** *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.* • sulfurous smell e.g. hydrogen sulfide or ‘rotten egg’ gas. **Water characteristics** • 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 wetlands); • 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. **Landscape and other characteristics** • dead, dying, stunted vegetation*; • scalded or bare low-lying areas*; and • corrosion of concrete and/or steel structures*. * This may also be due to excessive salinity or to salinity in combination with AASS.

Potential acid sulfate soil (PASS)	**Soil characteristics** • 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 pHF >4 and commonly neutral; • soil pHFOX <3, with a large unit change from pHF to pHFOX, 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. **Water characteristics** • water pH usually neutral but may be acid.

> ***Note:*** *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.*

The number of boreholes required is dependant on the volume of acid sulfate soil disturbance or for disturbances greater than 1000m^3, the area (m^2 or hectares) to be disturbed.

Table 2: Minimum Number of boreholes to be drilled, described, field tested and sampled for non-linear disturbances.

Volume of Disturbance (m^3)	Minimum Number of Boreholes
100-250	2
251-1000	3
>1000	4 or more See Queensland Sampling Guidelines

Refer to the Queensland Sampling Guidelines for borehole requirements for linear disturbances. Soil samples must be taken from boreholes to at least 2.0 metres depth, or at least 1.0 metre below the maximum depth of disturbance (whichever is greater). 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. Refer to the Queensland Sampling Guidelines for further information on how to conduct and interpret field tests.

The information gathered from this step will be required to assist in selecting appropriate samples for laboratory analysis. The information that will need to be collected and documented as part of the soil sampling procedure includes:

(i) the full grid reference of each borehole;

(ii) the exact location of each borehole shown on an appropriately scaled map;

(iii) an exact description of the vertical dimensions of the borehole relative to surface AHD;

(iv) a brief description of the equipment and/or methods used to retrieve the samples;

(v) a field description for each soil profile including soil texture 16 , colour, mottling and other diagnostic features (e.g. jarosite, shell);

(vi) results from field soil tests (field pH (pHF), pH after oxidation with hydrogen peroxide (pHFOX) and reaction with peroxide) at 0.25 metre vertical intervals to the base of the soil profile; and

(vii) collect samples at a maximum of 0.5 metre intervals down the soil profile e.g. 0–0.5 metres, 0.51–1.0 metres, 1.01–1.5 metres, 1.51–2.0 metres etc, ensuring each horizon is sampled.

Borehole depth must be to a minimum of 1.0 metre below the anticipated excavation depth. 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. 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.

All samples should be retained in storage (frozen or specially dried) until the field investigation report and any related acid sulfate soil management strategy has been assessed for the development. Further laboratory analysis may be required by Council to clarify results, or provide a more accurate understanding of the soil for management purposes. Further information on how to conduct sampling is contained in the latest version of the *Queensland Sampling Guidelines.* Occupational health and safety issues relating 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, should be considered by the responsible persons undertaking the investigation.

Field tests are essential for indicating whether acid sulfate soils are likely to be present or absent. In certain circumstances, results from field soil testing and other information gathered from Step 1 may provide strong evidence that acid sulfate soils are absent from the areas to be disturbed. In situations involving non-linear disturbance up to 1000m^3 that do not include activities that may alter groundwater, the applicant may submit this evidence to support non-completion of Step 2. Evidence includes compelling geomorphic and geologic information (e.g. soils developed on basalt) supported by field pH tests on the soil providing strong evidence that acid sulfate soils are absent from the areas to be disturbed.

(c) Sample Selection and Laboratory Analysis

Step 2, the laboratory analysis, together with the volume of disturbance, will be used to rate the level of treatment required for the disturbance. Borehole intensities, sampling intensities and guidance for staged sampling for disturbances greater than 1000m^3 or linear disturbances are detailed in the most recent edition of the *Queensland Sampling Guidelines*. These requirements have been incorporated 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 1000m^3, a reduced number of boreholes (and therefore of sampling and laboratory analysis) is required. If initial laboratory results based on the reduced sampling rates indicate that high 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.

For non linear disturbance up to 1000m^3

The sampling protocol outlined below, together with the following table, should be used as a guide to selecting samples for laboratory analysis where a non-linear disturbance up to 1000m^3 is proposed:

(i) Determine the number of boreholes required (detailed above);

(ii) Collect samples at the required interval and collate field information;

(iii) Using the field results from Step 1, select the *soil profile* most likely to contain acid sulfate soils;

(iv) From this soil profile, and using the field results as a guide, select one sample that is most likely to contain acid sulfate soil from *each metre interval*;

(v) Using the field results, select a single (one) sample most likely to contain ASS from *each* additional soil profile;

(vi) Submit the selected samples for laboratory analysis, and store the remaining samples frozen or specially dried for possible future use.

All other disturbances

For disturbances that are greater than 1000m^3, linear disturbances and activities involving alteration to groundwater, consult the *Queensland Sampling Guidelines* when selecting samples for laboratory analysis.

Table 3: Minimum number of samples to be initially selected for laboratory analysis (per total volume, not per borehole) for non-linear disturbances less than 1000m^3

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

Selected samples are required to be analysed in a laboratory for the existing and potential acidity of the soil. Potential acidity can be determined by Chromium Reducible Sulfur (SCR), Peroxide Oxidisable Sulfur (SPOS) and Total Oxidisable Sulfur (STOS). For samples with pHF <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.

Using laboratory results from Step 2
For all disturbances

If no single laboratory results exceed the texture-based acid sulfate soil *Action Criteria* in Table 4 (i.e. absence of ASS has been confirmed), then the applicant can submit the application with the supporting information.

If any one of the laboratory results exceed the texture-based acid sulfate soil *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 5. If the level of treatment is very high (VH) or extra high (XH) then additional laboratory analysis will usually be required to give a better quantification of the location, the maximum amount of existing plus potential acidity and volume of acid sulfate soil to be disturbed.

For non-linear disturbances up to 1000m^3

If the combination of the disturbance volume and the highest laboratory result applied to Table 5 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). 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.

Table 4: Texture-based acid sulfate soils action criteria (for updates on this table, refer to the Queensland Sampling Guidelines)

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 *et al.* (1990)	**Approx. clay content (%)**	**Equivalent sulfur (%S) (oven-dry basis)**	**Equivalent acidity (mol H^+/ tonne) (oven-dry basis)**	**Equivalent sulphur (%S) (oven-dry basis)**	**Equivalent acidity (mol H^+/tonne) (oven-dry basis)**
Course 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

The *Action Criteria* are based on the sum of existing plus potential acidity. This is usually calculated as equivalent sulfur (e.g. s-TAA + SCR in %S units) or equivalent acidity (e.g. TAA + a-SCR in mol H+/tonne). 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*. 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 acid sulfate soils disturbed at a site will need to be treated and managed.

Table 5: 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.

Disturbed ASS (tonnes) (≈m³) *	Soil Analysis# - Potential Acidity plus Existing Acidity (converted to equivalent S% units)													
	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
10000	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 (m^3) 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 100m^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.

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. Further analysis of the stored samples and/or more detailed justification will be required if the applicant wishes to neutralise different layers of the soil with different amounts of neutralizing 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 and the latest version of the *Queensland Sampling Guideline*s should be consulted.

In situations where acid sulfate soils are found at the construction stage of a development even though the investigation (undertaken in accordance with this policy indicated otherwise), the disturbed acid sulfate soils still require treatment and management to minimise adverse environmental impacts.

2. Investigation of Groundwater Prior to Disturbance

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. Groundwater treatment *in situ* is usually not feasible. A suitably qualified professional experienced in assessing and managing acid sulfate soils and groundwater issues should undertake all investigations.

Information gathered from an investigation of groundwater prior to disturbance should be used to demonstrate:

(i) the presence or absence of acidic groundwaters prior to works that may result in the release of such waters;

(ii) that the proposed development will not result in previously saturated acid sulfate soils being aerated through groundwater extraction or filling; and

(iii) that if previously-saturated acid sulfate soils 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.

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):

(i) 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;

(ii) 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;

(iii) identify adjoining on-site 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

(iv) identify any adjoining existing groundwater users, density of water extraction bores and uses of groundwater extraction.

Using the above information, the applicant should demonstrate that there will 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:

(i) the hydraulic characteristics of any aquifer (e.g. thickness, type, porosity, transmissibility);

(ii) groundwater gradient and flow direction;

(iii) soil permeability and attenuation/sorption characteristics (soils with high permeability increase the potential for infiltration to the groundwater); and

(iv) pumping tests.

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 ($Cl^-:SO_4^{2-}$) ratio should also be calculated.

Note: Analysis of groundwater or drain water for the soluble chloride: soluble sulfate ($Cl^-:SO_4^{2-}$) 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 19400 mg/L, the ratio of $Cl^-:SO_4^{2-}$ 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 acid sulfate soil in the landscape. A $Cl^-:SO_4^{2-}$ 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 $Cl^-:SO_4^{2-}$ ratio results. The $Cl^-:SO_4^{2-}$ 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.

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. 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.

If groundwater investigations indicate that existing groundwaters are acceptable by the ANZECC guidelines water quality criteria:

(i) 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

(ii) weekly monitoring for pH is still required if an on-site water storage (greater than 100m^3 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 this policy to mitigate the potential for environmental damage should the structure fail.

3. Investigation Related to Filling Activities

Filling involves the placement of soil, sediment and/or other material to raise the elevation of the land surface. It includes '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* acid sulfate soils need to be considered prior to filling.

Soil or sediment above the texture-based acid sulfate soils *Action Criteria* (see Table 4) is not suitable for use as fill if not adequately treated. Filling activities may disturb *in situ* acid sulfate soils by:

(i) bringing actual acid sulfate soils into contact with the groundwater (and thus potentially mobilising and transporting existing acidity out of the actual acid sulfate soils into the groundwater); and/or

(ii) displacing or extruding previously saturated potential acid sulfate soils above the watertable and aerating these soils or sediments.

To determine the potential for *in situ* acid sulfate soils to be disturbed by filling, the applicant will need to:

(i) define the nature (both physical and chemical properties) of the underlying soil and sediment;

(ii) determine the magnitude and direction of forces that will be exerted on the underlying soil and sediment by the fill material; and

(iii) predict any changes to watertable/groundwater levels that may occur and the interactions of groundwater with underlying soil and sediment.

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* acid sulfate soils are likely to be disturbed by the proposed filling. The information should include (but is not limited to):

(i) mass or volume, basal area and thickness of fill;

(ii) proximity of filling activities to open excavation faces, cavities or watercourses and drains;

(iii) depth to any potential acid sulfate soil and/or actual acid sulfate soil layer(s);

(iv) thickness of any potential acid sulfate soil layer and/or actual acid sulfate soil layer(s);

(v) soil physical and chemical characteristics including texture, moisture content and existing plus potential acidity of underlying soil and sediment;

(vi) underlying strata (eg. consolidated bedrock, coffee rock); and/or

(vii) groundwater dynamics.

If, based on the above information, it is considered likely that disturbance to *in situ* acid sulfate soils 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. A geotechnical assessment by a suitably qualified geotechnical engineer or engineering geologist may be required to adequately define the risks associated with filling.

4. Treatment And Management Of Disturbed Acid Sulfate Soils

The preferred management approach to deal with acid sulfate soils is to avoid disturbance wherever possible. Acid sulfate soils that have been or will be disturbed require treatment and management to prevent acid generation and neutralise existing acidity. 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 acid sulfate soils and outlines the levels of management and reporting that might be expected for these given levels of treatment.

A range of strategies and options are available to manage acid sulfate soil disturbances. Further technical guidance should be sought before considering the use of these options. The most common strategies include:

(i) Avoidance;

(ii) Minimisation of disturbance;

(iii) Neutralisation;

(iv) Strategic reburial (or reinterment); and

(v) Hydraulic separation techniques.

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*.

With all levels of treatment and management, the information provided with the application should include details of the preliminary investigations and the acid sulfate soil investigation report including disturbance dimensions, volume calculations, field soil test results and laboratory analysis results.

Determining the 'level of treatment'

Table 5 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.

Table 5 can also be used to define the amount of fine agricultural lime (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 acid sulfate soils. 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 5 will need to be adjusted accordingly.

The tonnes of lime required for treating the total mass of acid sulfate soil can be read off Table 5 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 (SCR), Peroxide Oxidisable Sulfur (SPOS) and Total Oxidisable Sulfur (STOS). 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 *Queensland Acid Sulfate Soil Technical Manua*l) contains further information on approved laboratory methods.

The treatment levels determined from Table 5 are outlined below.

Low level of treatment (Category L)

For disturbances of acid sulfate soils requiring treatment at a rate of less than 0.1 tonnes of aglime as per Table 5, the management should ensure:

(i) manage site runoff and infiltration; and

(ii) 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)

For disturbances of acid sulfate soils requiring treatment at a rate of between 0.1 and 1 tonne of aglime as per Table 5, the management should ensure:

(i) 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);

(ii) manage site runoff through bunding and prevent or treat infiltration passing through acid sulfate soils to groundwater during earthworks; and

(iii) ensure that the lime is thoroughly mixed with the soil.

High level of treatment (Category H)

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

(i) more detailed plans of disturbance and detailed acid sulfate soils investigation report;

(ii) 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);

(iii) ensure that the lime has been thoroughly mixed with the soil;

(iv) provide bunding of the site using non-acid sulfate soils material to collect all site runoff during earthworks;

(v) 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

(vi) prevent infiltration passing through acid sulfate soils to groundwater or apply extra layer of aglime to intercept any infiltration from acid sulfate soils.

Very high level of treatment (Category VH)

For disturbances of acid sulfate soils requiring treatment at a rate of between 5 and 25 tonnes of aglime as per Table 5, (and no alteration of the permanent watertable levels are involved) then the proposed management should include (but not be limited to):

(i) more detailed plans of disturbance and acid sulfate soils investigation report (using a higher laboratory analysis intensity if minimal laboratory analysis was undertaken as outlined in this policy);

(ii) 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);

(iii) verification that the acid sulfate soils have been appropriately treated and that lime has been thoroughly mixed with the soil;

(iv) provide substantial bunding of the site using non-acid sulfate soils material to collect all site runoff during earthworks;

(v) 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);

(vi) prevent infiltration passing through acid sulfate soils to groundwater or apply extra layer of lime to intercept any infiltration from acid sulfate soils; and

(vii) provide a simple but adequate environmental management plan based on the requirements outlined in this policy.

Extra high level of treatment (Category XH)

NB: If Council considers 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 (i.e. an environmental management plan may be required).

For disturbances of acid sulfate soils requiring treatment at a rate of greater than 25 tonnes of agricultural lime as per Table 5 or alteration of the watertable or for disturbances affecting the groundwater, an environmental management plan must be provided. Details for an environmental management plan are contained in this policy.

This plan should provide for ongoing management and monitoring of the effects of the disturbance of acid sulfate soils 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.

General Management Practices

In order to prevent the release of acid water and contaminants from stockpiled acid sulfate soils a treatment pad will need to be constructed. Treatment pads should comprise of an impermeable compacted clay layer 0.3 – 0.5 metres deep underneath a guard layer of agricultural lime (minimum 5 kg lime/m^3). To prevent the release of acid waters and contaminants from stockpiled soils via runoff, treatment pads should be bunded, or catch pits and trenches installed around the treatment pad (catch pits and trenches also need to be limed at 5 kg agricultural lime/m^3) to contain stormwater runoff. Catch pits and trenches must be covered post treatment operations.

Exposed sediment and soils in excavation pits and trenches have the potential to oxidise and promote the release of iron, aluminium and other contaminants to the environment. These contaminants have the potential to cause environmental harm (eg. iron assists the growth of Lyngbya). By spreading lime over exposed surfaces of excavation pits and trenches, acidity can be neutralised and the solubility of these contaminants is reduced, thus preventing their release to the environment. By quickly covering these exposed treated sediments or soils with turf, vegetation, non-acid fill or appropriate infrastructure the generation of acid sulfate from these soils in the future can be avoided.

Acid sulfate soils can rapidly degrade infrastructure including concrete. The use of acid tolerant concrete or alternative products is recommended for construction in areas where acid sulfate soils are present.

The management of acid sulfate soils associated with excavations greater than 100m^3 is a legal requirement of the Caboolture Shire Council Planning Scheme, supported by the State Planning Policy 2/02 "Planning and Managing Development involving Acid Sulfate Soils". For these developments as well as excavations less than 100m^3, it is a legal requirement that persons adhere to the general environmental duty, that is to ensure all reasonable and practicable measures are taken to prevent or minimise environmental harm. Appropriate investigation and treatment measures are necessary steps. Verification testing is also an important component in project management to ensure that acid sulfate soils are adequately managed.

Verification testing

Verification tests of treated Acid Sulfate Soils (ASS) or Potential Acid Sulfate Soils (PASS) are required before spoils reburial or use of fill, either in the same development operation or separate operations, is permitted. The purpose of verification testing is to ensure that spoils have been adequately treated and to ensure that the potential for acid leachate from treated spoils is eliminated. Details of verification testing should be included in acid sulfate soil management plans and the results of testing should be submitted to Council as a compliance certificate or similar form.

Verification tests should be performed on each separately treated spoil with a minimum number of tests equal to the total number of boreholes used for Acid Sulfate Soil Investigations. Adequate treatment should be verified by (as a minimum) comparing % TIC (Total Inorganic Carbon) with % Sulfur (Chromium reducible Sulfur), and a pH value. Treatment is adequate when the %TIC is 1.5 times greater than the %S.

5. **Treatment And Management of Surface And Drainage Waters From Disturbed Acid Sulfate Soils**

Surface and groundwater flows (including to any associated water storages) coming from areas containing acid sulfate soils should be treated and managed to prevent the leaching of acid and metal contaminants into the environment. 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.

Applicants should seek qualified professional assistance, as the chemistry of water quality can be a complex environmental issue. Note the requirement for monitoring and treatment of surface and drainage waters increases with the higher levels of treatment. 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

Water quality criteria should be determined using local water quality reference values defined for specific local waterway types, or, should these not be available, 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).

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 acid sulfate soils includes, but is not limited to:

(i) pH;

(ii) Electrical Conductivity;

(iii) Dissolved Oxygen;

(iv) Aluminium (Al);

(v) Total and Dissolved Iron (Fe); and

(vi) Total Organic Carbon.

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).

Research has demonstrated that the chemistry of aluminium in natural waters is complex and the solubility of aluminium species is pH dependant. 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. 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.

The discharge of water (surface or groundwater) to surface waters, particularly to marine and freshwater waterways, should not contain Iron and Total Organic Carbon concentrations should not exceed 10 mg/L. The pH of discharge water should be above 5.5 and should be within the range specified for aquatic ecosystem protection by local water quality reference values or, should these not be available, the ANZECC Water Quality Guidelines.

Neutralising acid leachate and drainage water

The neutralisation of acid leachate and drainage water is not permitted to take place within a natural waterway. Acid leachate and drainage water should be treated in appropriately constructed treatment ponds that prevent the transport of untreated acid leachate or drainage water to surface water or groundwater.

The rate of application of treatment products for treating acid water should be carefully calculated to avoid the possibility of ‘overshooting’. The optimum water pH level is dependant upon the ecosystem type, and is usually between 6.5 and 8.5 (refer to local water quality reference values or, should these not be available, ANZECC Water Quality Guidelines). Overshooting can occur quite easily if more soluble or caustic neutralising agents such as hydrated lime $Ca(OH)_2$ (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.

Agricultural lime CaCO3 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. More soluble neutralising agents are usually more effective at treating water. Sodium bicarbonate NaHCO3 is quick to act and not subject to pH overshoot. Other cheaper fairly soluble neutralising agents such as hydrated lime $Ca(OH)_2$ 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.

Acidic groundwater and pit water in excavation pits and trenches are likely to contain high concentrations of soluble aluminium, iron and other metals. These waters need to be neutralised to prevent further acid generation and to prevent the release of contaminants to the environment. The ideal pH depends on the nature of the existing groundwater or the characteristics of receiving waters. Some environments are naturally acidic (around 5.5) and care should be taken to prevent the release of treated waters to these waterways. Comparatively marine and estuarine waters are naturally higher in pH (around pH 8.5) and care should be taken to prevent the release of treated waters to these waterways with a pH less than 8. Advice should be sought from Council and/or EPA before releasing any treated waters to waterways. The pH of waters should be monitored regularly after thorough mixing when neutralising with lime. Sufficient time (minimum 24 hours) also needs to be given to waters treated with hydrated lime to reach equilibrium. The titratable acidity of the water is useful for determining specific liming requirements of water and may be useful when considering the treatment of large volumes of acid water (over 10 mega-litres of water). Agricultural lime should be used as the default neutralising agent if there is uncertainty or lack of confidence with regard to the choice of neutralising agent for neutralising acid waters as the potential for environmental harm associated with over shooting is significant when using hydrated lime.

Calculating the quantity of neutralising agent

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 $1 m^3$ of acid water is equivalent to 1 kilolitre (1000 litres) and $1000 m^3$ is equivalent to 1 megalitre (ML). 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 6 shows the minimum quantities of pure aglime, hydrated lime and sodium bicarbonate needed to treat dams or drains of 1 ML ($1000 m^3$) 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.

Table 6: 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 6:

1. $1m^3$ = 1000 litre = 1 kilolitre = 0.001 Megalitre
2. 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.
3. 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.
4. 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.
5. 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.
6. 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).
7. 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.
8. 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 $NaHCO_3$ and sodium hydroxide NaOH neutralise only 1 mol of acidity.

As acid sulfate soils 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. Issues to consider may include:

(i) the quality and purity of the neutralising agent being used;

(ii) the effectiveness of the application technique;

(iii) the existence of additional sources of acid leaching into the water body further acidifying the water; and

(iv) the neutralising agent has become lumpy and sinks to the bottom of the waterbody, rendering it ineffective.

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:

(i) spraying the slurry over the water with a dispersion pump;

(ii) pumping the slurry into the waterbody with air sparging (compressed air delivered through pipes) to improve mixing once added to water;

(iii) pouring the slurry out behind a small motorboat and letting the motor mix it in;

(iv) incorporating the slurry into the dredge line (when pumping dredge material); or

(v) using mobile water treatment equipment such as the 'Neutra-mill' and 'Aqua Fix' to dispense neutralising agents to large water bodies.

In some circumstances a neutralising agent in its solid form can be used, for example by:

(i) 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

(ii) passing water across a bed or through a buffer of coarsely ground limestone CaCO3 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.

When the pH of acid sulfate soils 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.

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 acid sulfate soils 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.

6. **Environmental Management Plans**

The intention of an Environmental Management Plan is to provide 'life of development' control strategies in accordance with agreed performance criteria. An Environmental Management 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. An Environmental Management 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. An Environmental Management 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 Environmental Management Plan.

Specifically an Environmental Management Plan must provide:

(i) 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;

(ii) local, State and Commonwealth authorities and the proponent with a framework to confirm compliance with policies and conditions; and

(iii) the community with evidence of the management of the project in an environmentally acceptable manner.

Format of an Environmental Management Plan

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.

Essential components are:

(i) establishment of agreed performance criteria and objectives in relation to environmental and social impacts;

(ii) detailed prevention, minimisation and mitigation strategies (including design standards) for controlling environmental impacts at specific sites;

(iii) 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;

(iv) details of implementation responsibilities for environmental management (names of responsible positions or persons);

(v) timing (milestones) of environmental management initiatives;

(vi) reporting requirements and auditing responsibilities for meeting environmental performance objectives and demonstrating 'quality assurance'; and

(vii) corrective actions to rectify any deviation from performance standards.

Review of Environmental Management Plan

An Environmental Management 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

The acid sulfate soils component of the Environmental Management Plan should be prepared, and implementation commenced, prior to soil drainage or disturbance and should include the following:

(i) a two (2) dimensional map of the occurrence of acid sulfate soils to 1.0 metre below the depth of disturbance. The map should identify separate areas of both actual acid sulfate soils and potential acid sulfate soils according to the upper depth of occurrence e.g. 0–0.5 metres, 0.5–1 metres, 1–1.5 metres, etc.;

(ii) at complex sites, a number of cross-sectional diagrams or a three dimensional diagram of the site, showing various acid sulfate soils layers (with corresponding soil analysis indicated) should be presented. This will assist greatly in understanding the site and form the basis for acid sulfate soils management;

(iii) details of potential on-site and off-site effects of the disturbance of the soil and/or the groundwater levels;

(iv) prevention strategies for the oxidation of iron sulfides (e.g. avoiding the disturbance of acid sulfate soils by redesigning layout of the excavations);

(v) treatment strategies for acid sulfate soils (including strategic reburial of potential acid sulfate soils, neutralisation of actual acid sulfate soils and potential acid sulfate soils 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);

(vi) strategies for management of the watertable height on and off the site both during and post-construction;

(vii) 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;

(viii) monitoring schedules for soil, including field pH (pHF), field peroxide pH (pHFOX) and laboratory procedures;

(ix) details of verification testing of soils;

(x) details of the handling and storage of neutralising agents;

(xi) containment strategies (including bunding, lime dosing, use of silt curtains) to ensure that all contaminated stormwater, acid and leachate associated with the oxidation of acid sulfate soils 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);

(xii) performance criteria to be used to assess the effectiveness of the acid sulfate soil management and monitoring measures; and

(xiii) 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.