



Acid Sulphate Soil Guidance

Acid Sulphate Soil Planning Policy Basic Guide

**Prepared for Whangarei District
Council by Opus International
Consultants**



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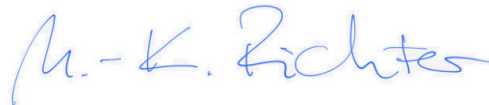
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1 Scope and Objectives

Following the identification of Acid Sulphate Soils in the local district Whangarei District Council with the assistance of Opus International Consultants have released the *Planning Policy for Acid Sulphate Soils* to manage the risk posed by these soils in the future.

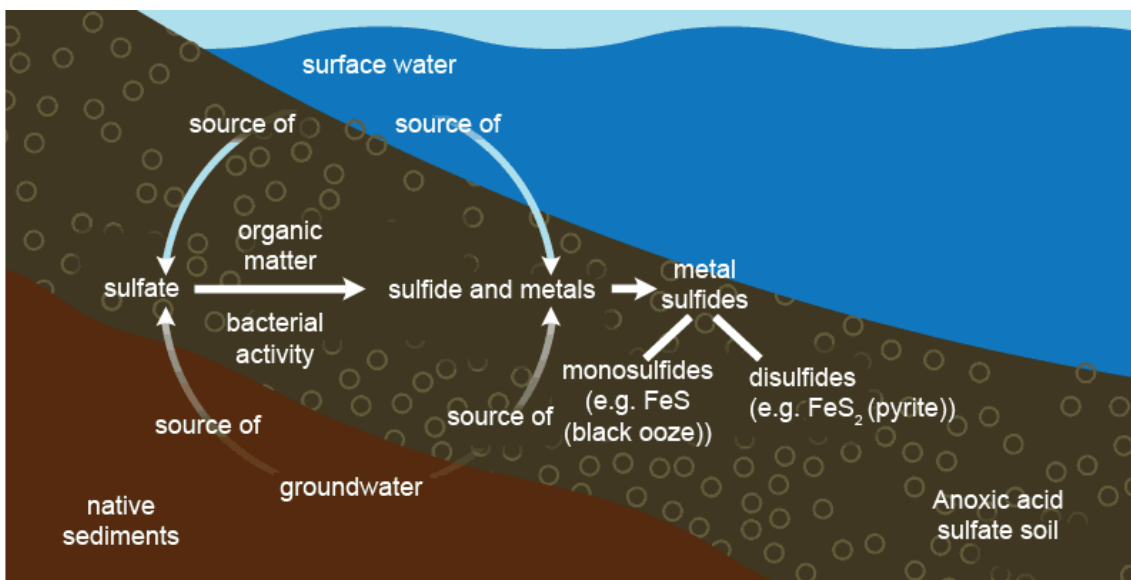
The objective of this document is to provide basic guidance to assist in interpreting the *Planning Policy for Acid Sulphate Soils*. This document aims to provide a general overview of acid sulphate soils and cover some common concerns land owners may have regarding what, if any, are the implications of owning or using land where these soils may be present.

For further information please contact the Waste and Drainage Department at Whangarei District Council.

2 Background

Acid Sulphate soils are naturally occurring, having been deposited when the sea level was around 5 metres higher than it is at present, 5 to 10 thousand years ago. While the land was under the sea, salts in the seawater mixed with this land. Now that the sea level has dropped this land which was under the sea and mixed with salty sea water is now available for use.

In some situations the salts, (most commonly sulphates) that were mixed with the land got trapped there, and, even though the land is now above sea level, the soil can still contain high amounts of sulphate compounds. Over time bacteria convert these sulphates into sulphides (Ahern et al. 1998). Sulphides can be quite odorous, hence it is common to smell rotten egg gas (which is a sulphide compound) in low lying muddy mangrove areas.



*Source: Department of Primary Industries NSW

Figure 1: Acid Sulphate Soil Generation

If left undisturbed sulphides remain in the soil without causing any major issues. If the soils are disturbed, such as through drainage which lowers the groundwater level or earthworks which aerate the soil, the sulphides can react with oxygen. When the sulphides react with oxygen this can release sulphuric acid which can cause the groundwater to become acidic (Ahern et al. 1998). Acidic groundwater can have a number of implications.

When groundwater becomes more acidic, minerals in the soil can become more soluble, which can cause them to leach out of the soil and be discharged into the environment. An example of this is iron. Iron “rust” stains on surfaces are commonly associated with acidic groundwater. Other metals can also become more soluble and the resulting increase in metal concentration can be toxic to ecosystems (Ahern et al. 1998). Therefore, excavation and drainage of acid sulphate soils need to consider the potential impacts on the environment.

Another implication is acidic groundwater can corrode buried infrastructure such as concrete, steel and other sensitive materials. Consideration needs to be given to what material is used if it is to be installed in ground containing acid sulphate soils.

Generally the impacts resulting from acid sulphate soil disturbance reduce over time. Freshly disturbed soils are likely to generate the greatest increase in acidity, with the acid release tapering off over a 50 year period. Over this time the sulphide concentration in the soil is exhausted, and acid is slowly flushed from the groundwater table by continuous rainfall flows.

The following section has been prepared to answer questions relating to acid sulphate soils.

3 Specific issues related to Acid Sulphate Soils

3.1 Where do Acid Sulphate Soils normally occur?

Acid sulphate soils are a common occurrence in many parts of the world. In a more local context, they are known to occur all over the Australian coastline and have been regulated in Australia for many years. Their effects are usually more severe in warmer climates, such as northern and eastern Australia, but they are known to exist in cooler climates such as Tasmania.

In New Zealand an investigation for acid sulphate soils was undertaken by a soil scientist in the 1980's. The investigation identified that acid sulphate soils are present in Northland (Dent. 1980). However there has not been any management or regulation of these soils since that time. This may be because there has been little recorded evidence of them having significant impact on infrastructure until recently.

3.2 If Acid sulphate Soils have been around for 5,000 years why is it now becoming an issue in Whangarei?

In 2014 Whangarei District Council started having problems with buried pipe work in a recent development in Ruakaka as concrete within the storm water system began to suffer chemical corrosion. Investigations into the cause of corrosion identified the presence of acid sulphate soils. The extensive earthworks and lowering of the water table that occurred during development, and continual draining of the site through subsoil drains, caused, and continue to cause sulphides in the soils to react with oxygen and the release of sulphuric acid. The acid then corroded the concrete pipes (Opus. 2014).

There may be a number of reasons why acid damage has not been commonly noted to date in other locations:

- a. Not all mapped areas are as sandy and permeable as Ruakaka. Soils with low permeability have minimal ability to buffer acidity
- b. Most stormwater pipes are installed to standard that does not allow infiltration of groundwater. The development in Ruakaka actively encourages infiltration of groundwater into the stormwater system via subsoil drains.
- c. Damage to non-leaky pipes is possibly only restricted to the outer surface of pipes. The outer surfaces of pipes are rarely inspected because they are buried under the earth.

Given the presence of acid sulphate soils in Ruakaka, there has been assessment into the potential for these soils to exist elsewhere in the district. From this investigation the Acid Sulphate Planning Policy and Risk Map was produced.

3.3 Why is my property mapped?

The Acid Sulphate Soil Mapping is based on the following:

- a. All land with surface elevation ≤ 20 m OTPD; AND

- b. That land ≤ 20 m OTPD which consists of sedimentary deposits under the following groups in the Whangarei 1:25000 Geological Map 2009 – GNS Science (these are alluvial sediments deposited in recent times):
- » Karioitahi Group;
 - » Awhitu Group; and
 - » Tauranga Group

These criteria capture all land expected to contain the following characteristics

- Soil or sediment of recent geological age (Holocene)
- Marine or estuarine sediments and tidal lakes
- Low lying coastal wetlands and back swamp areas, waterlogged or scalded areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes
- Coastal alluvial valleys
- Areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging conditions
- Areas identified in geological descriptions or in maps as:
 - » Bearing sulphide minerals
 - » Peat or coal deposits

3.4 What is the relevance of these areas?

These areas may contain elevated levels of sulphides in the soil profile at a depth of less than 5 metres One Tree Point Datum (OTPD). For instance:

- When visiting a mangrove mudflat area at 0-1m OTPD, a rotten egg gas odour can often be smelt. This is indicative of sulphides in the soil.
- If the ground surface of a property was ~ 20 m OTPD and a hole was excavated to <5 m OTPD (i.e. 15 m deep), the soil below 5m may contain elevated levels of sulphides.

3.5 What is the relevance of sulphides?

Sulphides are primarily only a problem when they are disturbed and exposed to oxygen. The most common sulphide is iron sulphide (pyrite). When exposed to oxygen, pyrite will react and release sulphuric acid. This sulphuric acid dissolves into groundwater and surface water and can dissolve concrete and attack steel structures.

Concrete is particularly vulnerable to acidic water because it is made of alkaline material (calcium carbonate). Acid and alkaline materials are highly reactive with each other.

Concrete is also attacked by sulphuric acid in a secondary way. Once sulphuric acid has reacted with calcium carbonate in the concrete – it will form calcium sulphate (gypsum). The formation of gypsum inside concrete can lead to expansion cracking.

Release of acid can also be harmful to the environment. Acid may be harmful on its own, however it also dissolves metals from the soil and may cause elevated levels of these metals to accumulate in downstream waterways. One metal which often dissolves quite easily is iron. Large amounts of iron staining can be an indicator of acidic soils.

3.6 Are sulphides the only concern in these areas?

The mapped areas may also contain deposits of peat. Peat is also a concern for a number of reasons:

- Peat naturally contains sulphides
- Peat naturally contains high levels of humic matter which upon oxidation releases humic acid
- Peat naturally contains metals. These also release acidity upon oxidation.

The *Planning Policy for Acid Sulphate Soils* is intended to manage acid released from Acid Sulphate Soils and from peat.

4 New Development

A risk based planning approach has been implemented for new developments. This approach is originally adopted from *Queensland State Planning Policy 2/02 – Planning and Managing Development Involving Acid Sulphate Soils*.

4.1 Low Risk Activities

Low risk activities are those that occur in a mapped area but do not require disturbance of soil or change in the groundwater table below 5m OTPD. These activities are unlikely to be affected by the presence of Acid Sulphate soils and can proceed without any further action. These activities are denoted in **green** in **Figure 2** and **Figure 3**.

4.2 Moderate Risk Activities

Moderate risk activities are those that occur in a mapped area but require less than 100m³ of disturbance or a change to the groundwater table below 5m OTPD. In these cases concrete and steel structures need to be designed to meet certain chemical durability criteria for low pH and sulphates.

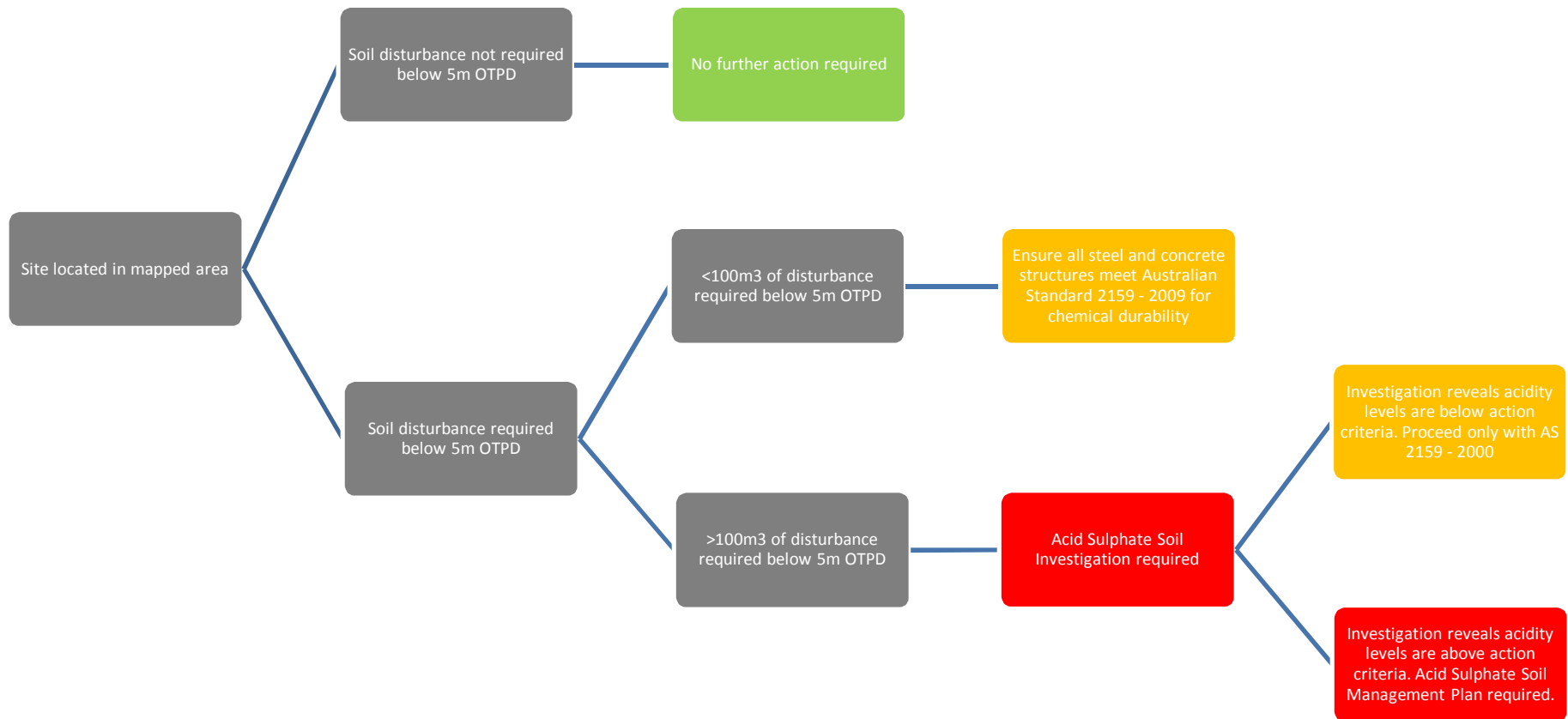
A suggested approach for chemical durability design is provided by *Australian Standard 2159 – 2009* (further information is provided in **Appendix A**). These activities are denoted in **amber** in **Figure 2** and **Figure 3**.

4.3 High Risk Activities

High risk activities are those that occur in a mapped area and require >100m³ of disturbance below 5m OTPD or change to the groundwater table below 5m OTPD. A formal acid sulphate soil investigation is required for these activities. These activities are denoted by **red** in **Figure 2** and **Figure 3**.

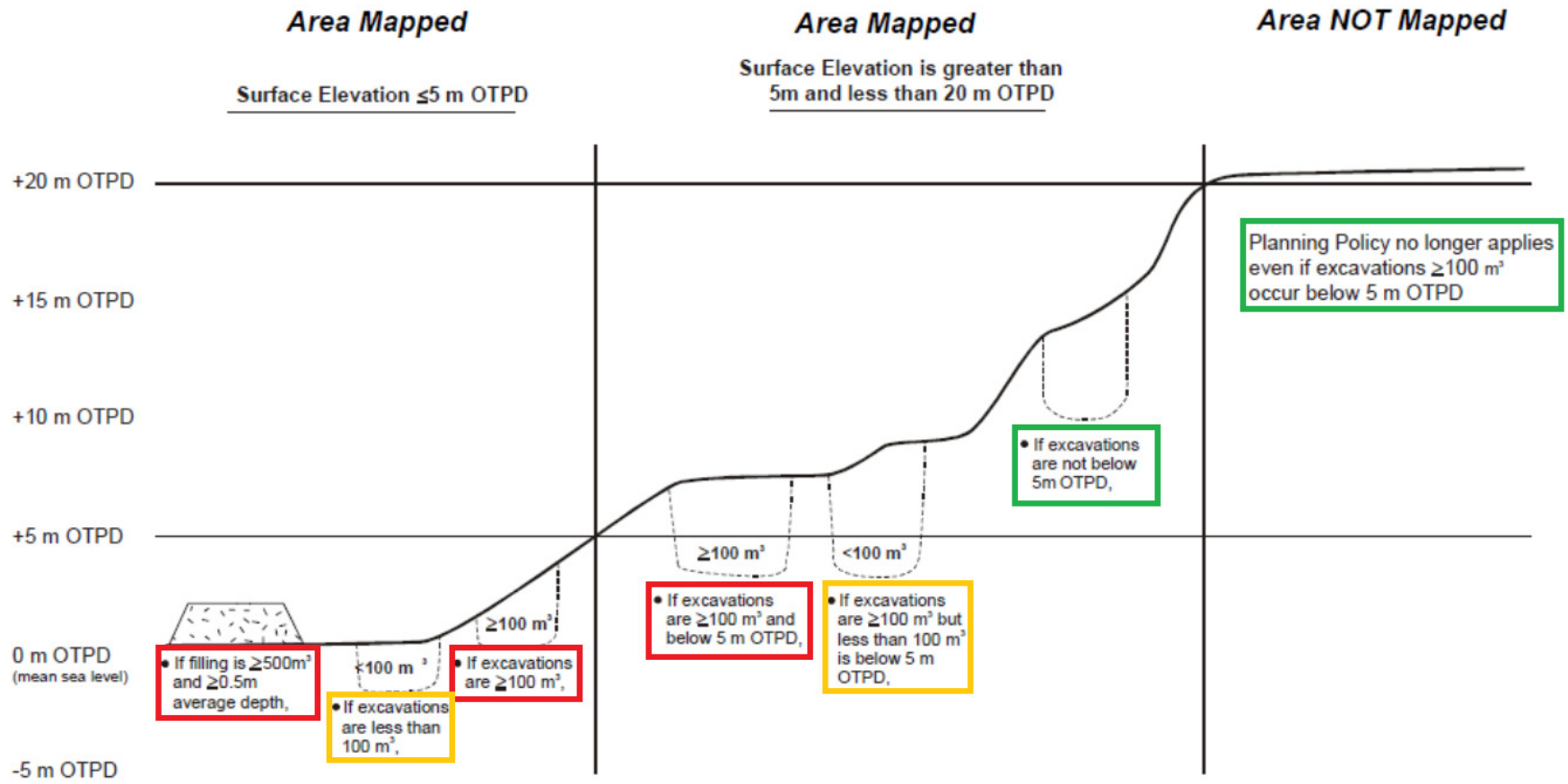
- If the investigation reveals that acidity levels do not breach action criteria then the development can proceed as a **moderate risk** activity
- If the investigation reveals that acidity levels breach action criteria then the activity must proceed as a **high risk activity**, and an acid sulphate soil management plan is required.

Further information on Acid Sulphate Soil Investigations and Management Plans is provided in **Section 6.0** and **Section 7.0**



*OTPD = One Tree Point Datum

Figure 2: Acid Sulphate Soil Assessment Flow Chart



*Source – Queensland State Planning Policy 2/02 – Planning and Managing Development Involving Acid Sulphate Soils

Figure 3: Acid Sulphate Soil Assessment Diagram

5 Existing Development

Development has occurred in these mapped areas below 5m OPTD in the past. Some of this development may be susceptible to damage and some of it is not.

The most susceptible assets to acid damage consist of underground infrastructure, which generally belongs to the local Council. Concrete storm water and sewage pipes are the most vulnerable because these are installed deep underground and are exposed to moving groundwater flow and infiltration.

Typically residential assets are less susceptible to acid damage. Most concrete floor slabs in the Whangarei District are installed on the surface without deep footings and minimal disturbance to the soil is required to lay the slab. Therefore the soil is generally not exposed to oxygen (reducing the ability to generate acid), and the slab is not exposed to moving groundwater flows. If deep footings have been installed and significant disturbance of the soil profile has previously occurred, it is possible that damage may become notable after a period of more than 5 years. The damage occurs mainly as a result of secondary attack mentioned in **section 3.5**. As calcium sulphate is produced in the soil it can swell leading to cracked slabs and walls. Deep footings with significant levels of disturbance and backfilling are not expected to be common in the Whangarei District. Where deep footings may have been used, they tend to consist of timber piles. Timber is not susceptible to corrosion by acid.

It is noted that this document provides a general overview only and further investigation may be required for individual properties.

6 Undertaking an Acid Sulphate Soil Investigation for High Risk Activities

An acid sulphate soil investigation is generally carried out concurrently with a geotechnical investigation. Only a person recognised as an expert in the field (scientist or engineer) must carry out such an investigation.

The following methodology is provided from the Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils in Queensland 1998 (Department of Natural Resources, Queensland).

6.1 Sampling

Sampling involves drilling a number of boreholes. The boreholes need to be drilled to a depth 0.5 m below the proposed depth of disturbance during development. A soil sample is obtained at each 0.5 m interval.

The number of boreholes depends on the type of development and area of development.

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

*More detailed transect sampling (50 m intervals) will usually be required along proposed excavations e.g. drainage lines, underground services etc

6.2 Analysis

A suitably qualified scientist or engineer will use a range of tests to determine the level of acid in the samples.

Preliminary screening can be conducted on the samples. This involves measuring the pH and the pH following oxidation with hydrogen peroxide. These tests are known as the pH and pH(ox). Their resulting levels and the differences between them are an indicator of the current and potential acidity of the sample. Usually the top 10% most acidic samples are then sent on for full laboratory analysis.

Full laboratory analysis consists of one of two methods:

- The Suspension Peroxide Combined Acidity and Sulphate (SPOCAS) method. This measures both the “acid trail” and the “sulphur trail”. In summary it can determine acidity from all sources (sulphides, organic acidity, and acidity released by oxidation of metals).
- The Chromium suite primarily only focuses on acidity generated by sulphides.

At this point in time the use of the SPOCAS method is preferred. This is because fine sands with minimal acid buffering capacity and organic matter such as peat are known to occur in Whangarei District. Accordingly it is best to know about acid from all sources.

6.3 Action Criteria

The laboratory results will indicate the quantity of acid that is currently present, and the quantity that can potentially be generated following complete oxidation. These results are then compared against Action Criteria. Generally the Action Criteria is set at a quantity of 18 mol H⁺ / tonne. More lenient action criteria can be adopted for soils with low permeability (loams and clays) as they have some acid buffering capacity.

- If the results are **above** the action criteria – then an acid sulphate soil management plan is required
 - » The management plan must be submitted as part of the Assessment of Environmental Effects in the Resource Consent application.
- If the results are **below** the action criteria – then there is no requirement for an acid sulphate soil management plan. However design of structures must still consider AS 2159 – 2009.

7 Producing an Acid Sulphate Soil Management Plan

Only a person recognised as an expert in the field (scientist or engineer) must produce an acid sulphate soil management plan. A management plan describes how:

1. Acidic soils can be avoided; and/or
2. How disturbance to acidic soils can be minimised; and/or
3. How disturbed acidic soils can be neutralised to prevent harm.

In many cases option 3 will be the primary management method because disturbance cannot be avoided or minimised. In those cases appropriate neutralisation methods are expected. Neutralisation usually involves application of agricultural lime (calcium carbonate). Liming rates with appropriate safety factors, liming application methods, and monitoring will be required.

Currently the most appropriate guidelines for Acid Sulphate Soil Management Plans is the *Soil Management Guidelines in Queensland Acid Sulphate Soils Technical Manual (2002)* (Department of Natural Resources, Queensland).

8 References

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APPENDIX A

Australian Standard AS 2159 – 2009 Section 6 is relevant when designing concrete and steel structures to withstand corrosive environments. This standard refers to piles, however the knowledge can be transferred to other structures.

Most importantly – refer to Note 6 in Section 6.3 for Acid Sulphate Soils: The soil testing should include testing for both actual and potential acid sulphate aggressiveness.

- This simply means that not only should pH of the soil be tested, but also pH of the soil following oxidation with 30% concentrate hydrogen peroxide. This is usually referred to as the pH(ox).

CONCRETE

Exposure Classification – refer to Table 6.4.2 (C) of AS 2159 - 2009 to compare sulphate, pH, pH (ox) and chlorides against exposure thresholds

Table 1: Reproduction of Table 6.4.2 (C) of AS 2159 - 2009

Exposure conditions				Exposure classification	
Sulphates (expressed as SO ₄ *)		pH	Chlorides in groundwater	Soil conditions A	Soil conditions B
In soil ppm	In groundwater ppm				
<5000	<1000	>5.5	<6000	Mild	Non-aggressive
5000-10 000	1000-3000	4.5 – 5.5	6000-12 000	Moderate	Mild
10 000-20 000	3000-10 000	4-4.5	12 000 – 30 000	Severe	Moderate
>20 000	> 10 000	<4	>30 000	Very Severe	Severe

*Approximately 100 ppm SO₄ = 80 ppm SO₃

Soil conditions A – high permeability soils (e.g. sands and gravels) which are in groundwater

Soil conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater

Table 2: Reproduction of Table 6.4.3 of AS 2159 - 2009

Exposure Classification	Minimum concrete strength (<i>f_c</i>) MPa		Minimum cover to reinforcement			
	Precast and prestressed piles	Cast in place piles	50 year design life		100 year design life	
			Precast and prestressed piles	Cast in place piles	Precast and prestressed piles	Cast in place piles
Non-aggressive	50	25*	20	45	25	65
Mild	50	32	20	60	30	75
Moderate	50	40	25	65	40	85
Severe	50	50	40	70	50	100
Very Severe	>50 (preferably >60)	>50 (preferably >60)	40	75	50	120

*For reinforced piles, use $f_c = 32$ MPa minimum

STEEL

Table 3: Reproduction of Table 6.5.2 (C) of AS 2159 - 2009

pH	Exposure conditions			Exposure classification	
	Chlorides Cl		Resistivity ohm.cm	Soil condition A	Soil condition B
	In soil ppm	In groundwater ppm			
>5	<5000	<1000	>5000	Non-aggressive	Non-aggressive
4-5	5000-20 000	1000-10 000	2000-5000	Mild	Non-aggressive
3-4	20,000-50 000	10 000-20 000	1000-2000	Moderate	Mild
<3	>50 000	>20 000	<1000	Severe	Moderate

Soil conditions A – high permeability soils (e.g. sands and gravels) which are in groundwater

Soil conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater

Table 4: Reproduction of Table 6.5.3 of AS 2159 - 2009

Exposure Classification	Uniform corrosion allowance (mm/year)
Non-aggressive	<0.01
Mild	0.01-0.02
Moderate	0.02-0.04
Severe	0.04-0.1
Very severe	>0.1



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