Technical Note

Acid Sulfate Soils

TN 22

Introduction

The purpose of this technical note is to provide a simple and practical guide covering the following:

- The formation, occurrence and effects of acid sulfate soils
- How to identify and manage acid sulfate soils during road construction activities

Formation of Acid Sulfate Soils

Acid sulfate soils (ASS) are naturally occurring soils containing elevated levels of metal sulfide minerals (principally the iron sulfide mineral pyrite). ASS are formed when soil containing iron and organic matter becomes waterlogged with sulfate rich water (principally sea water). Under these waterlogged, anaerobic (oxygen free) conditions, bacterial decomposition of the organic matter in the presence of iron and sulfates results in the formation of metal sulfide minerals. If ASS are exposed to air the metal sulfide minerals oxidise and sulfuric acid is ultimately produced when the soil's capacity to neutralise the acidity is exceeded. If ASS remain under waterlogged, anaerobic conditions, oxidation of metal sulfide minerals cannot occur and they remain inert.

ASS are divided into two main categories:

Potential acid sulfate (sulfidic) soils contain metal sulfide minerals that have not been exposed to air and oxidised.

Actual acid sulfate (sulfuric) soils contain metal sulfide minerals that have been exposed to air and have oxidised, producing sulfuric acid in excess of the soil's capacity to neutralise the acidity.

Potential acid sulfate soils become actual acid sulfate soils when the water table is lowered, allowing air to enter the soil, or the soil is excavated and exposed to air, and oxidation of metal sulfide minerals occurs.

A third, rarer, category of ASS is monosulfidic black ooze (MBO). MBO is a black coloured material containing high levels of organic matter and iron monosulfide and is typically found in the bed of salt water or brackish lakes, swamps, drains and channels. MBO oxidises rapidly when disturbed.

Occurrence of ASS

ASS generally occur in low lying coastal areas, and especially in coastal wetlands, where the reduced level is less than 10 m Australian Height Datum (AHD). ASS can also occur in wetland systems extending many kilometres inland from the coast where the reduced level remains below 10 m AHD, such as the Gippsland Lakes system and in areas under coastal sand dunes with a reduced level greater than 10 m AHD. Less commonly, ASS also occur in inland wetland systems with a reduced level greater than 10 m AHD, such as the Kerang Lakes system.

Maps showing potential occurrences of ASS in Victoria are presented in the Victorian Coastal Acid Sulfate Soils Strategy (DSE 2009) and can be accessed from the Department of Sustainability and Environment website.

Effects of ASS

When ASS are exposed to air, oxidation of metal sulfide minerals occurs which produces sulfuric acid which in turn can mobilise heavy metals in the soil such as arsenic and aluminium. Disturbing ASS can have long term adverse impacts on both the natural environment and engineering works.

Sulfuric acid and heavy metals can be released in sufficient concentration to be toxic to fish, native animals, stock, and aquatic and terrestrial vegetation. The acidification of soils can also lead to reduction or loss of productivity of agricultural land.

Sulfuric acid will corrode iron, steel and aluminium components of engineering works. Sulfuric acid also attacks concrete, causing the concrete to expand, weaken and spall, subsequently exposing reinforcement to corrosion, as shown in Figure 1. The loss of heavy metals also breaks down soil structure in clays which may allow subsidence and erosion to occur.

Figure 1: Concrete bridge pier damaged by acidic runoff from ASS.

Identification of Acid Sulfate Soils

Many road construction activities may disturb ASS, including:

- Stripping of topsoil
- Excavation for table drains, subsurface drains, culverts and sediment retention basins
- Excavations for services
- Excavation for cuts and subsequent dewatering of the surrounding area
- Construction of embankments (which may induce heave and raise ASS above the water table)
- Construction of bridge foundations

The *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* (DSE 2010) sets out a four stage risk identification and assessment process aimed at avoiding adverse effects from disturbing ASS. VicRoads uses this process to ensure that the occurrence of ASS at the site of any proposed road construction activities is identified early in the planning process and the works are planned to minimise or avoid disturbance of acid sulfate soils.

Stage A: Preliminary Hazard Assessment

Stage A requires an initial desktop assessment to determine if there is any potential for ASS to occur at the site of any proposed road construction activities. If the initial desktop assessment finds that ASS has previously been identified at or near the site, or the site has been mapped as a potential occurrence of ASS a site inspection is required.

During a site inspection, the presence of the following indicators of ASS occurrence should be assessed:

- Mangroves, reeds, rushes and other swamp and/or salt tolerant vegetation
- Swamps and flood plains
- Waterlogged soil
- Scalded or bare ground, as shown in Figure 2
- Sulfurous (rotten egg) odour
- Grey, blue-grey or blue-green soils beneath topsoil exposed in cuts
- Jarosite (a pale yellow mineral) on exposed soils or on the outside of spoil heaps
- Unusually clear or milky blue-green drain discharge
- Iron staining on drain surfaces, creek banks or of groundwater discharge, as shown in Figures 3 and 4
- Excessive corrosion of steel structures
- Excessive deterioration of concrete structures, as shown in Figure 1

Figure 2: Scalded ground.

Figure 3: Iron staining of surface water ponding on ASS.

Figure 4: Iron staining of groundwater discharge.

If indicators of the presence of ASS are found during a site inspection, the likely occurrence of ASS can be determined using a simple field test consisting of measuring the pH of soil samples before and after oxidation. A detailed procedure for conducting field testing for ASS is contained in Appendix B of the *Best Practice Guidelines* (DSE 2010). This procedure consists of measuring the pH of the insitu soil, as shown in Figure 5, and then oxidising the soil with a hydrogen peroxide solution before measuring the pH of the oxidised soil. This procedure is used by VicRoads with one addition: that the soil mixed with hydrogen peroxide solution be allowed to oxidise for 24 hours before the pH of the oxidised soil is measured. This requires the samples of soil mixed with hydrogen peroxide solution to be prepared in sealable containers and temporarily stored before the pH of the oxidised soil is measured.

The oxidisation of soil with hydrogen peroxide solution is an exothermic reaction which can be inhibited by cold weather. Placing the sample container in hot water will help initiate a reaction when ambient temperatures are low, as shown in Figure 6.

Interpretation of the results of field testing is based on four measurements:

- The pH of the insitu soil
- The reaction rate of the soil and hydrogen peroxide solution
- The pH of the oxidised soil
- The difference between the pH of the insitu soil and oxidised soil

A pH of insitu soil or oxidised soil less than 5 indicates the presence of ASS. Reaction rates are designated a number between 0 and 4 corresponding with no or extreme reaction respectively, and a reaction rate of 2 or greater indicates the presence of ASS. A pH difference between insitu soil and oxidised soil greater than two indicates the presence of ASS.

The presence and size of shells, other carbonate minerals or organic matter in field testing samples should be noted as these can provide a buffering effect known as acid neutralizing capacity (ANC). For example, when a soil containing shell fragments (especially <0.5 mm in size) is oxidised, the pH may initially decrease as sulfuric acid is produced and then increase as the calcium carbonate in the shell fragments reacts with and neutralises the sulfuric acid.

If the Stage A preliminary hazard assessment does not eliminate the potential for ASS to occur at the site of any proposed road construction activities, Stage B of the risk identification and assessment process must be undertaken.

Figure 5: Measuring pH of insitu soil samples.

Figure 6: Using hot water to accelerate oxidisation of soil with hydrogen peroxide solution.

Stage B: Detailed Soil Site Assessment

Stage B of the risk identification and assessment process is a detailed soil site assessment to determine the net acidity of the soil at the site. Extensive investigation consisting of boreholes and/or test pits, soil sampling and laboratory testing of soil samples is required. The types and numbers of soil samples and laboratory tests to be undertaken during the Stage B assessment are described in the Best Practice Guidelines (DSE 2010). The net acidity is the actual acidity of the insitu soil plus the potential acidity of the oxidised soil, and is measured in units of %S (% sulfur). If the net acidity is less than 0.03%S, ASS are not present and the proposed road construction activities can proceed without restriction. If the net acidity is 0.03%S or greater, ASS are present and Stages C and D of the risk identification and assessment process must be undertaken.

Stage C and D: Surface and Groundwater Assessment and Hazard Assessment

Stage C of the risk identification and assessment process is a surface water and groundwater investigation to determine the effects on these systems if ASS is disturbed. Sampling and laboratory testing of water samples is required. The types of laboratory tests to be undertaken during the Stage C assessment are described in the Best Practice Guidelines (DSE 2010). Investigation of groundwater hydrology is particularly important as fluctuations in the water table as a result of the proposed road construction activities could expose ASS to oxygen and/or mobilise sulfuric acid in the ASS.

Stage D of the risk identification and assessment process consists of undertaking a hazard assessment and considering options for the management of ASS at the site of any proposed road construction activities. The hazard assessment is based on a matrix of the net acidity versus the tonnes of ASS to be disturbed at the site of any proposed road construction activities, and is used to rate the site as a low, medium or high hazard. When considering options for the management of disturbed ASS the following must be considered:

- The effect on any sensitive receptors identified in Stage C
- Whether the proposed works can be modified to avoid disturbing ASS
- Whether management can be effectively carried out

Stage D emphasises the need to avoid disturbing ASS or at least design the proposed road construction activities to minimise disturbance of ASS. Proposed road construction activities at high hazard sites where disturbance of ASS may affect sensitive receptors and management of the disturbed ASS may not be effective are unlikely to proceed, and redesign is strongly recommended.

Management Strategies

After Stage D of the risk identification and assessment process is completed for the site of any proposed road construction activities, if the site is a low or medium hazard and the considerations described above have been successfully addressed, an ASS management plan is prepared. The ASS management plan describes how the disturbance of ASS will be managed throughout the road construction activities and monitored after completion.

Management strategies for disturbed ASS are listed below in order of priority:

- Avoid disturbance
- Minimise disturbance
- Prevent oxidation
- Neutralise acidity
- Dispose offsite

Good planning and design in many cases will allow the proposed road construction activities to proceed without disturbing ASS. Where disturbance of ASS is unavoidable, minimising impacts through redesign of excavations and avoiding groundwater fluctuations should be undertaken. Excavations may be confined to areas of the site with <0.03 %S, driven piles may be used instead of bored piles or strip footings, and elements of the proposed road construction activities may be relocated to areas of the site with <0.03 %S or to other sites.

Oxidation of disturbed or exposed ASS can be prevented by minimising the period of exposure to the air using the following management strategies:

- Stage excavations to reduce the volume of disturbed or exposed ASS at any time
- Place clean fill over exposed ASS
- Rebury disturbed ASS below the water table
- Raise the water table artificially or flood the excavation

Disturbed or exposed ASS can be neutralised by the addition of an alkaline material, usually agricultural lime. The amount of alkaline material required is determined from the net acidity of the ASS measured during the Stage B detailed soil site assessment using the process described in the Best Practice Guidelines (DSE 2010). Neutralising agent must be thoroughly mixed with the ASS to achieve a soil pH of between 6.5 and 8.5. A validation testing regime must be established to verify that the neutralisation is effective. Where large quantities of ASS require neutralisation, a treatment pad consisting of a clay liner and bund must be constructed in accordance with the Best Practice Guidelines (DSE 2010).

Road maintenance activities that require localised excavation of small amounts of material in areas likely to contain ASS can be managed by adding bagged lime to excavated material onsite prior to backfilling.

At sites involving excavation below the water table, neutralisation of acidic groundwater discharge may also be required. Drains or shallow basins are typically used to collect acidic groundwater which is then treated with specialised equipment before being discharged as surface water or used to recharge the groundwater table. These treatments are very expensive and require thorough planning prior to implementation.

If ASS are to be disposed offsite, the Victorian Industrial Waste Management Policy (Waste Acid Sulfate Soils) (EPA 1999) requires an environmental management plan (EMP) to be prepared and submitted to the Victorian Environment Protection Authority (EPA) for approval. This option is expensive and considered a last resort management strategy.

References

1. Department of Sustainability and Environment (Victoria) 2009, *Victorian Coastal Acid Sulfate Soils Strategy*, Victorian State Government, East Melbourne.
2. Department of Sustainability and Environment (Victoria) 2010, *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils*, Victorian State Government, East Melbourne.
3. Environment Protection Authority (Victoria) 1999, *Acid Sulfate Soil and Rock*, Publication 655.1, EPA, Melbourne.
4. Environment Protection Authority (Victoria) 1999, *Industrial Waste Management Policy (Waste Acid Sulfate Soils)*, Victorian Government Printer, Melbourne.

Contact Officer

For further information or if works are planned in an area of known acid sulfate soil occurrence, please contact The Manager, Geotechnical Services:

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Technical Note - Revision Summary

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Date	Clause Number	Description of Revision	Authorised by
June 2006	Full document	Minor corrections made and references to new TN 94 added.	BAM - RSM
March 2013	Full document	Major corrections made and previous TN 94 (now withdrawn) incorporated.	PA – P&M