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ACID SULFATE SOILS ASSESSMENT AND MANAGEMENT IN NEW SOUTH WALES

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ABSTRACT

Acid Sulfate Soils (ASS) are both a land and water management issue which can have profound economic and environmental impacts. New South Wales has recognised this and is adopting coordinated and collaborative strategies to redress the problem. ASS are widespread in estuarine floodplains of coastal NSW and when disturbed produce large volumes of sulfuric acid which can degrade lowland environments, contaminate groundwater and surface water and seriously impact adjacent estuarine ecosystems. The serious damage attributable to the release of acid from these soils has resulted in increasing community concern over the issue. An integrated strategy, which includes a number of unique components, has been adopted in NSW to address these concerns, including:

- **Coordination** through the formation of an Acid Sulfate Soils Management Advisory Committee (ASSMAC) consisting of state agency, environment and industry representatives to provide advice to government and coordinate the implementation of policy, together with an expert sub-committee to provide technical advice. ASSMAC has produced a technical manual and prepared funding submissions to government.

- **Identification** of the scope of the problem through: 1) 1:25,000 scale ASS Risk Maps of 620,000 ha of coastal land using innovative geomorphic criteria related to the environment of formation of pyrite; 2) documenting the worst 50,000 ha as 'hot spots' or priority areas for management and remediation based on the depth of ASS, existing environmental impacts, susceptibility of receiving waters and land drainage density, and; 3) mapping of the drain networks and associated drain control structures.

- **Prevention** of further disturbance of ASS principally by developing consistent local environmental planning controls over new developments. The ASS Risk Maps form the basis of new ASS Planning Maps.

- **Remediation** of existing problem areas through significant industry initiatives particularly by the sugar cane industry and active participation by the oyster and fishing industries and through rehabilitation funding by government in 'hot spots' and for community projects.

- **Education** of the community and rural industries in best management practice involving: 1) two national conferences; 2) appointment of information and advisory staff and three technical support teams by State agencies; 3) seminars, field days and a regular newsletter and; 4) publication of a technical manual covering planning, assessment, laboratory methods, management plans, rehabilitation and industry best management practice.

- **Research** into knowledge gaps to improve best management practice whereby university researchers collaborate closely with agencies, landholders and industry groups.

KEYWORDS: Acid sulfate soil, coastal floodplains, acid water, rehabilitation, government strategy

INTRODUCTION

Acid Sulfate Soils (ASS) are both a land and water management issue which can have profound economic and environmental impacts. I contend that they are as significant an issue both from an environmental and economic perspective as salinity in the Murray - Darling Basin. The resulting acid water is known to kill fish and oysters (Sammut *et al.* 1996), corrode engineering structures and reduce agricultural productivity (Mullen and Kaur 1999). It also limits biodiversity by degrading valuable estuarine and wetland habitat (Sammut *et al.* 1996) and is reported to be a major greenhouse gas emission source (Hicks *et al.* 1999).

THE PROBLEM OF ACID SULFATE SOILS

Acid sulfate soils are sediments deposited under estuarine conditions (ie. close to sea level), and which contain the sulfidic mineral pyrite. ASS are found underlying many coastal floodplains, in coastal wetlands, and as bottom sediments in coastal estuaries.

As long as ASS are not disturbed or drained, these materials are relatively harmless and are termed potential ASS. However, if the sediments are exposed to air, the pyrite is oxidised and sulfuric acid is generated. When the rate of acid production exceeds the neutralising capacity of the soil, actual ASS are formed. As a result, soil pH may fall to below 4.

Iron and aluminium may become soluble in toxic quantities, with their precipitates affecting water quality and coating stream banks and benthos. Massive kills of aquatic life can occur due to low pH, aluminium toxicity, and deoxygenation of water resulting from the secondary oxidation of Fe^{2+}. Although mobile organisms are sometimes able to avoid poor quality water and molluscs, such as oysters, are able to close their shells for a period, many aquatic organisms are killed by the poor quality water. In addition to the acute effects of ASS, increased attention is now being placed on the chronic effects on aquatic systems. These are common and widespread, and include diseases as well as reduced hatching, survival and growth rates across a wide range of aquatic species. (Sammut *et al*. 1996).

The frequency and magnitude of water quality problems associated with ASS are generally due to the drainage of agricultural land (Walker 1963). Large volumes of acid may be stored in soil or groundwaters and are displaced from backswamps into drains and coastal streams by rainfall. Floodgated drains may also act as acid reservoirs, which can release acid gradually or in large flushes.

The acidity released also produces extremely aggressive soil conditions for construction when using concrete and steel. Corrosion by acidity and salts can cause serious problems for pipelines, cables, pylons and roads. Significant costs to the community can be incurred through the maintenance of public structures such as bridges, pipelines and floodgates.

The serious damage attributable to the release of acid from these soils has resulted in increasing community concern over the issue. NSW has recognised this and is adopting coordinated and collaborative strategies to redress the problem. An integrated strategy, which includes a number of unique components, has been adopted in NSW to address these concerns. These strategies are outlined below.

COORDINATION OF GOVERNMENT RESPONSE

In 1994 the NSW government established the Acid Sulfate Soils Management Advisory Committee (ASSMAC) to coordinate a whole of government response to ASS issues. ASSMAC has representatives of state agencies, local government, universities, landholders, industry and the environment movement. It provides advice to government and coordinates the implementation of policy. It is supported by an expert sub-committee to provide technical advice.

ASSMAC has developed a strategic plan which aims to:

- identify the distribution of ASS in NSW;
- make the community aware of ASS drainage problems and educate key stakeholders about ASS management;
- prevent disturbance of ASS by: industry self regulation through adoption of codes of best drainage practice; introduction of development controls on ASS through local environmental plans (LEPs) and development control plans (DCPs); and farm drainage plans
- treat disturbed ASS to prevent acid outflows by: use of neutralising agents in new developments; and rehabilitation of previously disturbed ASS areas.
- research and develop land management practices which will reduce acid outflows.

ASSMAC has produced a comprehensive ASS technical manual (Stone *et al.* 1998) which provides advice on best practice in planning, assessment, and management of areas of ASS. The manual has a comprehensive section on laboratory methods and also addresses drain management, groundwater management, ASS management plans and industry best practice.

ASSMAC has been invited to prepare a submission to the state government outlining the rehabilitation strategies required and seeking appropriate funding.

IDENTIFICATION OF THE EXTENT OF THE PROBLEM

A critical element in the successful management of ASS is a precise understanding of the extent and distribution of the problem. In 1995 The NSW Department of Land and Water Conservation prepared a series of 129 ASS Risk Maps at 1:25,000 scale covering the whole NSW coastline (Naylor *et al.* 1995). The mapping employed a geomorphic approach whereby landscape elements were defined and mapped based on a model of ASS development which assumed a generic link between the distribution of ASS and Holocene estuarine sediments. This model proved to be successful and the resulting maps give a good indication of the risk of encountering ASS and the depth at which it can be found. The maps were coded for *high risk, low risk* or *no risk* and depths of *surface, 0 - 1 m, 1 - 2 m* and *2 - 4 m*. The total area mapped was 676 760 ha of which 403 349 ha was high risk and 213 719 ha low risk, 39 292 ha no known occurrence and 20 401 ha of disturbed terrain. Of this total, 143 739 ha was bottom sediments which amounted to 21.0% of the total area. An important assumption used in the mapping that the upper depth of ASS of was at less than 1 m AHD was found to be appropriate, as all actual ASS was found below this level and most potential ASS was found below 0.3 m AHD (Atkinson *et al*. 1996).

One of the recommended strategies of the *Draft National Strategy for the Management of Acid Sulfate Soils* is to identify high environmental impact sites for rehabilitation. Priority Management Areas (or 'hot spots') for management of ASS in NSW floodplains have been mapped by Tulau (1999a,b,c,d,e,), Tulau and Naylor (1999) and Davies and Mumby (1999). The mapping identifies areas and related issues of highest priority for remedial action, based on land and water impacts due to ASS. Priority Management Areas are areas where land management decisions in relation to ASS have contributed to, and can lead to further, severe soil acidification, poor water quality, reduction in agricultural productivity and capability, loss of estuarine habitat, and/or degraded vegetation and wildlife. In most Priority Management Areas, wetlands have undergone extensive engineered drainage and flood mitigation schemes. Priority Management Areas have strategic importance with respect to the management of estuarine and floodplain areas and ambient water quality, and require urgent changes to land management to improve environmental quality.

The Priority Management Areas cover a total of 54 500 ha. Three such areas have been identified in the Tweed, one near Byron Bay, five in the Richmond, four in the Clarence, five in the Macleay, six in the Hastings – Camden Haven, four in the Manning and one in the Shoalhaven catchment. Priority Management Areas range in size from the 4 500 ha Tuckean Swamp on the Richmond to the 300 ha Rossglen area on the Camden Haven River. A great deal of diversity also occurs between the areas relating to the nature of the drainage system, salinity of receiving waters, the elevation, and other characteristics.

Management processes need to be developed for each Priority Management Area which recognise this diversity, and which have clear environmental objectives. The development of strategic plans based on Priority Management Areas will enable Commonwealth, state and local government, industry and community groups to make informed decisions concerning the allocation of resources. Future resources should be targeted to the Priority Management Areas in order to fill identified gaps in knowledge, and to assist in the preparation and implementation of ASS management plans.

Mapping of the agricultural drain network on the NSW north coast has also been completed (Atkinson *et al.* 2000). A series of 61 drainage network maps at a scale of 1:25 000 provide the location and dimensions of all constructed drains and engineered waterways within the coastal floodplains on the NSW north coast. In addition a floodgate and structures assessment accompanies these maps, which locates and describes structures deemed to significantly inhibit tidal flow or fish passage.

This information will contribute to soil and hydrological investigations within the coastal floodplains. The project also provides benchmark statistics on drainage density allowing the strategic assessment and regulation of future drainage works and for scoping and costing of remediation projects.

PREVENTION OF FURTHER DISTURBANCE

The most significant single strategy to arrest the continuing exposure of new areas of ASS was the introduction of planning constraints in the form of amendments to Local Environmental Plans (LEPs) by coastal councils. The first of these was developed by Hastings Council (McKenzie 1996) and the adoption of LEPs based on the Hastings model by all NSW coastal councils has been encouraged by state agencies (Stone *et al.* 1998). The model LEP is based on ASS Planning Maps that have been developed from the ASS Risk Maps by the Department of Land and Water Conservation. The ASS Planning Maps establish five classes of land based on the probability of ASS occurrence and the type of works which might disturb them. They specifically consider the depth to which excavations may be carried out and the potential effect on the watertable of the works. All works that fall within the criteria, including those ancillary to agriculture, now require development consent. This has effectively brought within the planning consent process all excavation, drain construction and dam construction on ASS that was previously exempt because it was ancillary to agriculture.

The other effective piece of legislation that has constrained inappropriate works on ASS is the *Protection of the Environment Operations Act 1997 (POEO Act).* This act consolidates previous legislation relating to pollution of air, soil, noise and environmental offences. The act provides for Environment Protection Notices, including clean-up notices, prevention notices and prohibition notices. Clean-up notices are used to direct an occupier of premises where a pollution incident has occurred to take such clean-up action as is required in the notice. These are used for existing pollution events. Prevention notices can be issued where the appropriate regulatory authority (EPA or local council) reasonably suspects that an activity has been carried out in an environmentally unsatisfactory manner. These notices are usually used to require that an ASS management plan be prepared and implemented. Prohibition notices can be issued by the Minister for the Environment where the EPA has reported to the Minister that that the emission or discharge of pollutants is causing or is likely to cause harm to the environment. This allows for the cessation of polluting activities. Failure to comply with notices is an offence and no right of appeal is provided. The offence caries significant penalties (Brunton 1997).

There are numerous other acts under which government agencies can constrain inappropriate development of ASS. Although some of these have been tested in the courts, often the outcomes have been less than satisfactory as it has often been necessary to prove actions and impacts. The need to engage expert witnesses has also added to the expense of prosecutions. Some successful cases have resulted in fines being imposed, which has had a deterrent effect but has not resulted in satisfactory environmental outcomes. The NSW government is currently reviewing appropriate legislation to manage ASS and is developing a protocol to clarify the roles and responsibilities of various government agencies.

To date, the combination of powers available to local councils under their ASS LEPs and the *POEO Act 1997,* has provided the best combination of regulatory tools to constrain inappropriate development on ASS. Both are relatively simple to understand, easy to administer and inexpensive to enforce. Both can be used to require adequate treatment of ASS issues to prevent the incremental worsening of the problem.

REMEDIATION OF DEGRADED AREAS

After scoping the problem and adopting a legislative framework that would arrest the further oxidation of any new ASS, the next most critical issue to tackle is the remediation of existing areas of ASS on the coastal floodplains. This is by far the most intractable problem as there is a vast store of acid already in the system (White *et al*. 1997) which, if untreated, will release acid into the estuaries for 100 years or more.

The first stage of the process of remediating areas of ASS affected land and water is to identify the specific problem to be addressed and to frame appropriate objectives consistent with national, state and local policies. Remediation objectives usually include improving water quality and/or rehabilitating ASS scalds. Other objectives, such as increasing agricultural productivity or restoring wetlands may or may not be consistent with these objectives. It is important that remediation proposals meet generally acceptable environmental goals, recognise the need for effective site-specific solutions, include effective monitoring of remediation measures, and promote community awareness of appropriate remediation techniques (Williams and Porter 1999).

Remediation strategies should seek to optimise the expenditure of resources by attempting to meet multiple objectives. Objectives should be decided by, or in close consultation with, land owners, land managers, local government, industry and state agencies. Once the broad objectives for the management and remediation of an ASS area has been decided on, the strategy options for achieving those objectives must be assessed.

There are only a limited number of strategies available for dealing with acid in the environment. These are containment, neutralisation, dilution, and transformation (Atkinson and Tulau 1999). Dilution involves adding water to raise the pH; or allowing acid to escape into the environment at an acceptable rate. To be effective there must be sufficient water available for dilution or the means to control the slow leakage of acid. It is therefore an appropriate strategy in larger rivers. Neutralisation strategies involve the reaction of the acid with a neutralising agent, usually either lime ($CaCO_3$) or the bicarbonate in seawater. Neutralisation with lime is a high cost option which has strategic applications only. Seawater neutralisation is possible in lower estuaries where waters contain a sufficient percentage of bicarbonate but not in upper estuaries. Containment requires that acid is not allowed to escape into the environment. Acid is contained within the soil profile, in natural backswamp depressions, artificial surface ponds or in drains. This leads to higher watertables behind the containing structures, creating intermittent to permanent wetlands and may have significant land management implications. A final means of dealing with acid is to attempt to transform it by reduction into other stable compounds. This is worthy of considerable research but so far has not been demonstrated in field situations. Of these four strategies, often containment is the only viable option available.

The most appropriate combination of these strategies will be applied within the ASS Management Priority Areas (Tulau 1999f). The Priority Management Areas represent 54,500 ha or 20% of the total amount of ASS affected land. This worst 20% of the land probably contributes 80% of the acid and therefore is targeted as the first priority for remediation planning and funding

Prior to the development of comprehensive rehabilitation and management plans for the Priority Management Areas, rehabilitation is being addressed through industry best practice guidelines, extension advice to landholders and group projects. Tulau (1999f) has reviewed the policy environment within which this remediation must take place and has discussed the various community organisational structures and the land management change agreements that can be used to facilitate ASS remediation. To date the NSW Government has provided $2.1M over 3 years for ASS project funding principally to support demonstration rehabilitation projects and community education. Well planned and integrated rehabilitation projects in the Priority Management Areas will cost considerably more. Effective large scale remediation will be a major social issue requiring mechanisms to be put in place to facilitate the necessary changes in landuse and the structural adjustments that might be required. These matters are the subject of current deliberations.

EDUCATION OF STAKEHOLDERS

Education of the community and rural industries in best management practice has been a major thrust of ASSMAC's strategy. It has been acknowledged that the origins of the ASS problem date back many years and involves both government supported works and government agency supported land management practices. This being the case it was not appropriate to embark on a regulatory response once the problem was recognised. Rather it should be to educate the community to change practices to achieve better environmental outcomes. Both incentives and penalties can form part of that education strategy particularly in the more extreme cases. However much can be achieved by raising the awareness of the community through education.

ASSMAC has sponsored two general national conferences on ASS in 1993 and 1996 and a recent technical workshop on remediation and assessment of broadacre ASS. It has appointed information and advisory staff and three technical support teams through the state agencies. These staff conduct seminars and field days and provide on site technical remediation advice. The information officer produces a widely distributed newsletter called ASSAY and maintains a web site at *http://www.agric.nsw.gov.au/Arm/acidss/index.html* for disseminating information. The ASS manual (Stone *et al.* 1998) covering planning, assessment, laboratory methods, management plans, rehabilitation and industry best management practice is also a major education resource.

RESEARCH INTO KNOWLEDGE GAPS

ASSMAC is encouraging research on a range of ASS issues to improve best management practice. Current areas of research priority are watertable management, ponded pastures, floodgate management, seawater neutralisation, bioremediation and farm forestry. University researchers collaborate closely with agencies, landholders and industry groups. Active centres of ASS research in NSW are CSIRO, the schools of Geography at UNSW, Environmental Engineering at Wollongong University, CRES at Australian National University, and the Centre for Research on ASS at Southern Cross University.

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