Acid Sulfate Soil Toposequences in Wetlands of the Lower River Murray

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Abstract

Water levels have fallen dramatically in wetlands along a 250 kilometre length of the lower River Murray between Blanchetown (Lock 1) and Wellington, South Australia, in many cases exposing acid sulfate soil materials. The objective of this study was to provide critical baseline information to support management decisions for the soils and wetlands to minimise impact of these inland region acid sulfate soils. This paper: 1) presents an overview of the acid sulfate soil characteristics, 2) demonstrates the utility of toposequence models to provide an understanding of soil variation, and 3) describes how the information is used to support planning of management options.

For 62 wetlands, a total of 198 sites were investigated. Acid base accounting data identified 534 out of 653 samples (82%) as having a positive net acidity. Classification of soil material based on pH and chromium reducible sulfur values identified acid sulfate soil material in 270 out of 638 samples (43%). Forty-seven of the sixty-two wetlands (71%) have an acid sulfate soil extent within the wetland that is of concern. Conceptual toposequence models were developed which identified a recurring pattern of soil variation and provided a useful means to communicate information to decision makers and managers.

Key Words

Acid sulfate soils, toposequences, wetlands, River Murray.

Introduction

Wetlands along a 250 kilometre length of the lower River Murray between Blanchetown (Lock 1) and Wellington, South Australia (Figure 1) provide essential ecosystem services that include maintaining water quality in the river channel, providing habitats for native fish, frogs and other fauna, and recreational areas as well as for town supply and agriculture. Unprecedented drought during the past decade has recently led to significantly lowered river weir-pool levels, previously from about +0.75m AHD, down to -0.5m AHD, causing disconnections between numerous wetlands and the river channel. Nearly all of the 77 wetlands in this region are now dry, exposing acid sulfate soil materials that were previously covered with water. There is concern that these soils will be a hazard to ecosystem function and river water quality through acidification, release of toxic metals and de-oxygenation of water and environmental degradation of landscapes due to: (i) acidic soil, (ii) air borne dust, (iii) transport of acidity and metals once water levels rise, and (iv) acidic pulses during and following rainfall events.

Previous work by CSIRO Land and Water and others in subaqueous soil (lakes and rivers) and wetland environments in this region have identified various occurrences of sulfidic, sulfuric and monosulfidic black ooze materials in acid sulfate soils (see recent review paper and key references in Fitzpatrick *et al.* 2009). Occurrences of these acid sulfate soil materials can have serious environmental consequences relating to soil and water acidification, de-oxygenation of water, emission of foul smelling gases (H_2S, organo-S compounds) and release of heavy and trace metals (Simpson *et al.* 2008). However, apart from the preliminary work of Fitzpatrick *et al.* (2008) there is very limited information on the distribution, characteristics and processes of acid sulfate soils in this region to assist in the detailed understanding of such complex landscapes to support management decisions for the soils and wetlands to minimise impact. Consequently, the objective of this study was to provide the following critical baseline information to underpin and support planning of management options to mitigate harm to essential ecosystem services: 1) an overview of the acid sulfate soil distribution characteristics, 2) toposequence models to provide an understanding of soil processes and 3) local and regional variability in 62 of the 77 wetlands between Blanchetown and Wellington (Figure 1).

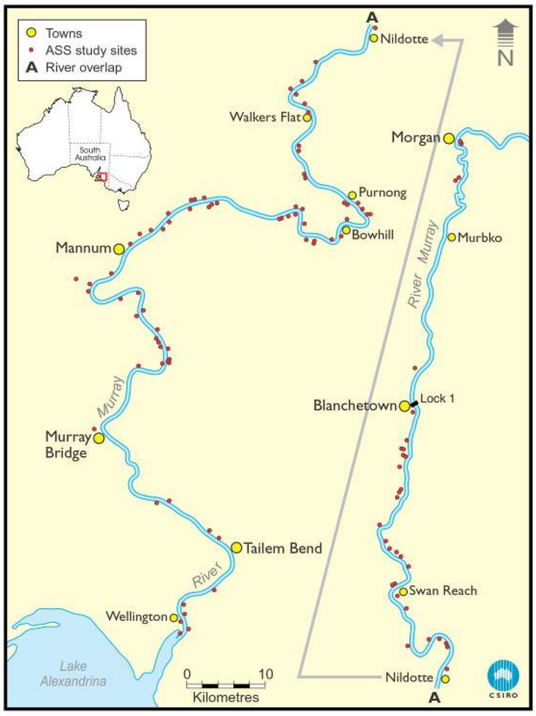

Figure 1. Wetland locations and sample sites along the lower River Murray from Blanchetown to Wellington.

Methods

Field assessment

Between August and October 2008, 198 soil profiles in 62 wetlands were studied, from which 687 soil layers were described and 653 soil samples were collected. The sample site location and number of sample sites placed within a wetland were determined by the type and size of the wetland. A number of factors were taken into consideration, and in general, 3 to 4 sites were located to represent a topographic transect within the wetland. Sampling locations were typically selected at the centre (low), edge (high), and intermediate points (mid) of each wetland. For wetlands that covered a larger surface area, extra transects were added to provide a better spatial distribution of sites.

Four to six layers were typically sampled per soil profile and generally the layers consisted of a surface (about 0 to 5 centimetres), subsurface (5 to 20 centimetres), subsoil (about 20 to 50 centimetres), deep subsoil (50 to 100 centimetres), occasionally subdivisions of the above intervals, and a deeper layer below if extracted. Samples were described according to standard methodology (McDonald *et al.* 1998; Schoeneberger *et al.* 2002). Layer depth ranges were recorded and for each layer the morphology and physical properties were described including: colour (matrix and mottles), texture, structure, consistency, and where present, features such as surface mineral efflorescences, plant material, and odour. Soil samples corresponding to the described layers were collected in sample jars for laboratory analysis and in chip-trays for archive storage and ageing experiments.

Laboratory analysis

Laboratory analyses included $\mathrm{pH}_{\mathrm{water}}$, $\mathrm{pH}_{\mathrm{peroxide}}$, $\mathrm{pH}_{\mathrm{incubation}}$, and acid base accounting parameters (S_{CR} (sulfide % S), $\mathrm{pH}_{\mathrm{KCl}}$, Titratable Actual Acidity (TAA), Acid Neutralising Capacity (ANC) and water-extractable SO_4 (1:5 soil:water suspension). Methods are described in Fitzpatrick *et al.* (2008).

Results

The 62 wetlands ranged in size from < 1 to 250 hectares, and while each wetland had unique characteristics, there were a number of similarities with regard to soil morphology and distribution. The soils were often sampled as dry or moist, as surface water was not present at the majority of sites (only 5 sites had surface water), and the water table was occasionally encountered within 1 metre of the soil surface. Soil textures within the wetlands were dominated by clays that had cracks forming columnar structure with a firm to hard consistency. In some areas, the cracks were partially in-filled with windblown material or crumbling of the surface peds (Figure 2). Sandy soils occurred more frequently on the higher wetland margins and typically had no structure with a loose consistency. Medium textured or loamy soils were minor in occurrence.

Key laboratory measurements are summarised and presented in Table 1. Net acidity was positive in 534 out of 653 samples (82% of samples). These positive net acidity results occurred at all wetlands sampled along the 250 km of River Murray and at different depths indicating the widespread occurrence of acid sulfate soil materials.

Classification of soil material based on pH_{water} and the pH change between pH_{water} and $pH_{incubation}$ (Sullivan *et al.* 2008) identified sulfuric soil material in 55 out of 638 samples (9%), hypersulfidic soil material in 32 samples (5%), hyposulfidic soil material in 183 samples (29%). Sulfuric soil materials tended to occur in sandy surface soil layers where oxidation had occurred, while hypersulfidic and hyposulfidic soil materials occurred in the clay surface and subsurface layers. The distribution of these classified soil materials is still under investigation, but initial findings indicate that they are more likely to occur in the mid to down-river wetlands and unlikely to be identified in the wetlands near the up-river Blanchetown end.

Resource and time constraints meant that a limited number of sites were available to understand soil distribution. Conceptual toposequence models were developed for the wetlands showing soil material distribution and processes occurring to aid the interpretation of landscape patterns. These models allowed us to identify any recurrent patterns of soil variation. An example is presented in Figure 2. Describing acid sulfate soils in this way also provided an effective means to communicate information to decision makers and managers.

Based on the understanding of soil material distribution identified by the conceptual toposequence models and evaluation of the soil material classification and net acidity data, 47 out of the 62 assessed wetlands (71%) were identified as having an acid sulfate soil condition and extent within the wetland that is of concern.

Table 1. Summary data for laboratory measurements of soil pH and net acidity for sampled layers

	pH_{water}	$pH_{peroxide}$	$pH_{incubation}$	Chromium Reducible Sulfur ($\%S_{CR}$)	Net Acidity (mol H^+ t^{-1})
Number	638	638	632	653	653
Mean	5.89	3.58	5.27	0.06	-5.03
Median	5.88	2.91	5.11	0.01	18.36
Minimum	2.43	1.20	1.68	0.00	-3128.82
Maximum	9.08	8.76	8.45	2.21	1402.39

Conclusions

This study has provided quantitative information identifying the widespread distribution of inland acid sulfate soil materials occurring in wetlands adjacent to the River Murray. A large, consistent and comprehensive data set of field, laboratory, photographic and map information has been collected and is currently under detailed evaluation and assessment. The data summarised in this paper provides an initial overview of key findings.

The data collected has already been used extensively by several Murray-Darling Basin agencies to:

- Determine impacts (both positive and negative) of the drought on wetlands.
- Identify those wetlands at high risk from acid sulfate soil hazards.
- Identify management options to reduce risks due to the current dry wetlands on the surrounding landscape.
- Guide selection of management options for when water reconnection occurs,
- Identify risks/outcomes associated with long-term disconnection as well as reconnection.
- Inform decisions regarding reconnection of wetlands upon return of normal river weirpool levels.
- Inform future potential hydrological management of wetlands and associated on-going monitoring needs.

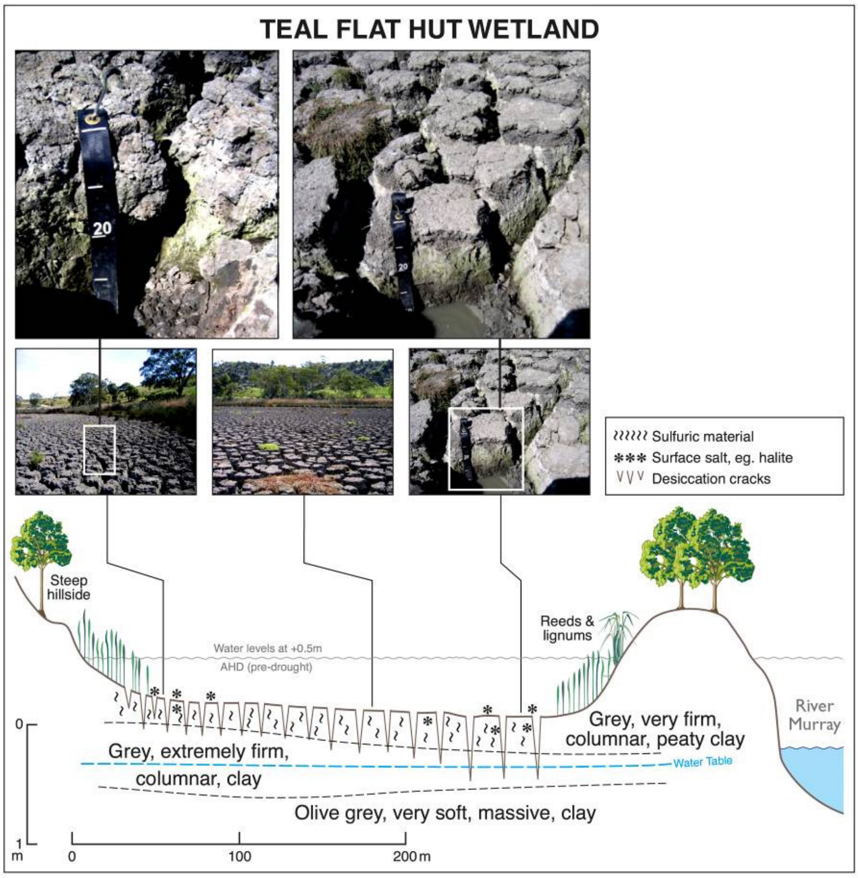

Figure 2. Conceptual toposequence cross-section of Teal Flat Hut wetland, showing the distribution of various acid sulfate soil materials (for 2008 conditions) and other key soil features together with photographs

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