Atlas of Australian Acid Sulfate Soils: Recent developments and future priorities

Rob Fitzpatrick[A,B], Steve Marvanek[A], Bernie Powell[C] and Gerard Grealish[A,B]

[A] CSIRO Land and Water, Urrbrae, South Australia, Australia, 5064. rob.fitzpatrick@csiro.au
[B] Earth and Environmental Sciences, The University of Adelaide, South Australia, Australia
[C] Department of Environment and Resource Management, Indooroopilly, Queensland Australia 4068.powellb@derm.qld.gov.au

Abstract
The Atlas of Australian Acid Sulfate Soils (AAASS) is a web-based hazard assessment tool with a nationally consistent legend, which provides information about the distribution and properties of acid sulfate soils (ASS) across Australia. This tool is available on ASRIS (Australian Soil Resource Information System: www.asris.gov.au) and every polygon or mapping unit is attributed with information pertaining to: (i) 4 classes of "probability of occurrence", (ii) 4 levels of confidence relating to the quality of data source, and (iii) 10 additional descriptors such as desiccation cracks. In Australia, ASS occupy an estimated 215,000 km^2 of which 58,000 km^2 is coastal ASS and 157,000 km^2 is inland ASS (Fitzpatrick *et al*. 2008a). In the coastal zone, 41,000 km^2 are exposed at some point during the tidal cycle, with the remaining 17,000 km^2 being permanently subaqueous. More than 126 km^2 of coastal ASS with sulfuric material have been mapped, however this is a significant underestimate, which will be modified with future work. Being web-based the Atlas is a constantly evolving national map of available ASS information, which also includes priority case studies at a range of localities across Australia. With ongoing recent field investigations and acquisition of more detailed local spatial data sets, especially in the Lower Lakes region in South Australia, resolution and accuracy of the inland ASS component are being continually improved from its current, first cut "broad brush" depiction.

Future priorities are to constantly integrate ASS data from any new regional ASS investigations to enhance, update and refine the AAASS and new case studies.

Key Words
Acid Sulfate Soils, mapping, soil classification, pH, wetlands, ASRIS.

Introduction
The Atlas of Australian ASS project was developed under the auspices of the National Committee for Acid Sulfate Soils (NatCASS) and completed by CSIRO Land and Water with assistance from staff in all states throughout Australia. The ASS mapping was inferred from a mix of state and territory ASS mapping and surrogate datasets. The ASS Atlas was put together in two parts using two different methodologies and classification paths. First, the Atlas of "Coastal" ASS was compiled using existing state ASS mapping (e.g. DIPNR 1997; QDEX 2008) and other datasets that mapped landscape indicators of ASS environments, e.g. coastal vegetation mapping. At a later stage, the interior of the Australian continent was back-filled with "Inland" ASS mapping, inferred from broader and coarser scale national soil and hydrography mapping. The results of these two exercises were combined to form the current Australian ASS Atlas (Fitzpatrick *et al.* 2008a), which is available on ASRIS (Australian Soil Resource Information System: www.asris.gov.au). ASRIS receives nearly 2000 visits per month with over half being new visitors. Copies or extracts of the AAASS are regularly sought by several government agencies, engineering firms and environmental consultants. But also farmers and land managers with internet access can readily see what the indicative ASS assessment is for their area of interest. The objective of this paper is to summarise recent developments and describe planned improvements.

Results and Discussion
The seamless, systematic and uniform Atlas of Australian Acid Sulfate Soils (AAASS), represents the most extensive depiction of ASS across the nation, to date and is the product of contributions from all states in Australia. The ASS map is largely modelled from small scale surrogate data but combines explicit ASS survey mapping where it exists.

The "Coastal" ASS component
Existing Coastal Acid Sulfate Soil mapping from states was re-interpreted to conform to the Atlas of Australian ASS legend classification (Fitzpatrick *et al.* 2008a). Classification of state mapping polygons to the Atlas legend was as follows: in the case of South Australia, New South Wales, Queensland and Western

Australia the original state ASS classifications were directly translated to the Atlas legend classification. These translations were undertaken by the creators of the state data and other experts within the respective states. Due to the more broad classifications of the original Victoria and Tasmania ASS mapping, polygons for these two states were initially translated to a broad Atlas legend grouping (e.g. Tidal, Non-tidal) by the data custodians then subsequently differentiated further through intersecting with other layers. These included the 3 second Shuttle Radar Topography Mission (SRTM), digital elevation mode (DEM) and North Coast Mangrove mapping geographic information system (GIS) datasets. The former being used to differentiate within the Non-Tidal zones (i.e. classes Ae-j and Be-j) and the latter was used to differentiate the Tidal zones (i.e. Ab-d, Bb-d). Mapping of the Tidal-Zone classes was augmented for all states except South Australia and New South Wales with 1:100K Coastal Waterways Geomorphic Habitat Mapping by Geoscience Australia. This dataset was used to infer additional areas of subaqueous soils in subtidal wetlands (class Aa & Ba) and Intertidal Flats (class Ab & Bb).

The "Inland" ASS component
Provisional inland ASS classifications were derived from National and Tasmanian state soil classification coverages combined with 1:250K series 3 Hydrography and Multi-resolution Valley Bottom Floor Index (MrVBF; Gallant and Dowling 2003). A matrix was devised to translate combinations of Soil Order (Isbell 1996) and landscape "wetness" to the Atlas legend. The basis for constructing the inland ASS Atlas component is very coarse because it is underpinned by the Atlas of Australian Soils (1:2M scale) with "wetness" inferred from 1:250K topographic hydrography (Appendix 2 in Fitzpatrick *et al.* 2008a). A principle feature of the ASS Atlas is that every polygon is attributed with information pertaining to quality of its source, confidence in the ASS legend classification code and scale of mapping (Fitzpatrick *et al.* 2008a). Hence, every polygon or mapping unit is attributed with information pertaining to: (i) classes of "probability of occurrence", (ii) levels of confidence relating to the quality of data source, and (iii) additional descriptors such as: desiccation cracks, hypersaline or gypseous horizons; fill, organic, sandy or clayey materials.

Nation wide estimates of the areas of various types of Acid Sulfate Soils
The Atlas has enabled estimates of the area of ASS extent to be calculated across Australia. With the area scaling factors applied, there is estimated to be 154,269 km^2 of high probability ASS areas and 65,771 km^2 of low probability ASS areas. In Australia, ASS occupies an estimated 215,000 km^2 of which 58,000 km^2 is coastal ASS and 157,000 km^2 is inland ASS (Fitzpatrick *et al*. 2008a). In the coastal zone, 41,000 km^2 are exposed at some point during the tidal cycle, with the remaining 17,000 km^2 being permanently subaqueous. More than 126 km^2 of coastal ASS with sulfuric material have been mapped.

Application of ASS Atlas legend to the mapping of ASS in Lower Lakes
With ongoing field investigations and acquisition of more detailed local spatial data sets, the resolution and accuracy of the inland ASS component is being continually improved from its current, first cut "broad brush" depiction. For example, the current extreme drought in South-eastern Australia has had a major impact on the availability of water resources in the Murray Darling Basin (MDB). Nowhere can this be more clearly seen than in the lower reaches of the River Murray, especially below Lock 1 (Blanchetown) in Lakes Alexandrina and Albert (Figure 1) where water levels are at an unprecedented low (below sea level). The low water levels have caused a number of impacts related to inland acid sulfate soils (ASS) to be realised for the first time (Fitzpatrick *et al*. 2008b, 2009a,b). The Australian Soil Classification (ASC; Isbell 1996) has proved tremendously useful for soil classification and advancing understanding of soils across Australia. However, because the ASC and other internationally recognised classification systems such as Soil Taxonomy (Soil Survey Staff 2003) are generalised schemes, there is still the need for additional and complementary systems specifically tailored to particular environmental problems (e.g. ASS), land uses or regions (Fitzpatrick *et al.* 2003). These general classification systems do not yet incorporate the following new terminologies: subaqueous soils (Fitzpatrick *et al*. 2008a), monosulfidic, hypersulfidic and hyposulfidic materials (Sullivan *et al*. 2009). Therefore, the simplified Soil Identification Key was specifically developed and designed for inland acid sulfate soils, initially for ASS in the River Murray and Lower Lakes systems to identify and classify the various types and subtypes of acid sulfate soils and non-acid sulfate soils (Fitzpatrick *et al.* 2008a,b; 2009a,b; Grealish *et al*. 2010). The Soil Identification Key was used as the basis in Lower Lakes soil map legend showing ASS classes that allowed integration and incorporation of the following additional information: (i) soil characteristics with depth, (ii) water depth, (iii) soil water saturation through the use of bathymetry, (iv) occurrence of monosulfidic material, (v) soil texture, (vi) location of calcrete and granite rock outcrops (Grealish *et al*. 2010). This map consolidates many sources of

information and provides a generalised overview of ASS variation that occurred when the survey was conducted in August 2009. Each map unit or polygon in Figure 1 bears a colour and stippling pattern, which shows its map unit that relates to the AAASS legend (Fitzpatrick *et al*. 2008a). The ASS map shown in Figure 1 identifies the following areas classified as: (i) Hypersulfidic deep water clays, which comprise 438 ha; (ii) Hypersulfidic subaqueous soils (sands & clays), which comprise 66,781 ha (covering 80% of 89,145 ha.).

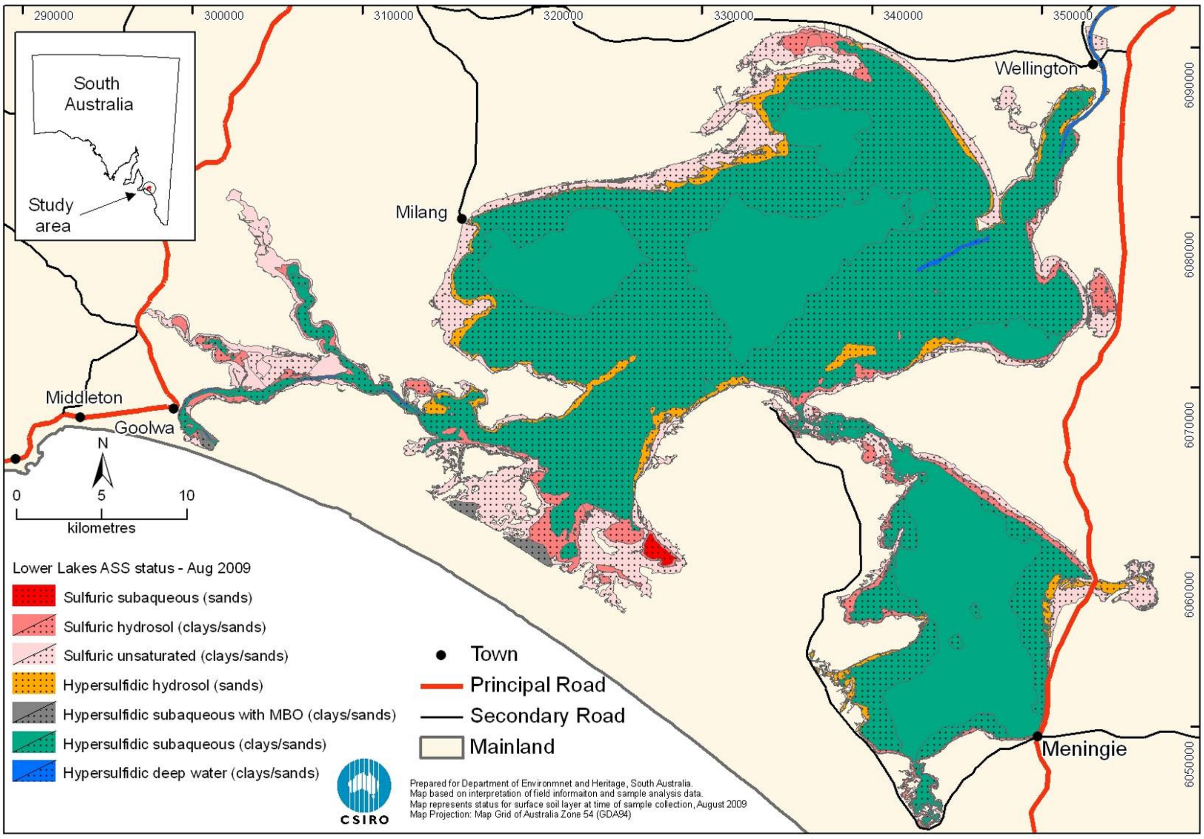

Figure 1. Acid Sulfate Soil map of Lake Alexandrina and Lake Albert (from Grealish *et al.* 2010).

The ASS map shown in Figure 1 identifies the following areas classified as: (i) Hypersulfidic deep water clays, which comprise 438 ha; (ii) Hypersulfidic subaqueous soils (sands & clays), which comprise 66,781 ha (covering 80% of 89,145 ha.). (iii) Hypersulfidic hydrosol sands and clays, which comprise 3,303 ha; (iv) Sulfuric subaqueous soils (sand and clays), which comprise 250 ha and (v) Sulfuric soils and Sulfuric hydrosols, which comprise 18,685 ha (covering 20% of 89,145 ha). The ASS map also provides a baseline for predicting by identification of 'hotspot' areas where potential problems will occur, requiring future management scenarios such as: (i) continual lowering of water levels, (ii) minimise oxidation by guiding installation of containment or rewetting infrastructures (irrigation, regulators, pumping) and (iii) neutralisation of sulfuric material with limestone (e.g. examples summarised in Fitzpatrick *et al*. 2009b).

Future priorities of AAASS and ASS Database

Future priorities are to constantly integrate ASS data from new regional ASS investigations such as priority case studies currently being conducted in the MDB (e.g. Lower Lakes region shown in Figure 1) to enhance, update and refine the AAASS. Such key studies are being incorporated in the constantly evolving national ASS map of available ASS information and especially also include a range of new localities across Australia (e.g. Tasmania, part of the Queensland wet tropics, Northern Territory and Western Australia Wheat Belt).

Acknowledgements

David Jacquier (CSIRO), Leigh Sullivan (Southern Cross University), John Williams (DIPNR), Glenn Atkinson (DIPNR), Mitch Tulau (DIPNR), Greg Chapman (DIPNR), Jason Hill (Dept Natural Resources, Environment & Arts, NT) Brad Degens, Steve Appleyard and Steve Wong (Dept of Environment & Conservation, WA), Doug Fotheringham (DEH, SA), Doug Crawford (DPI) Austin Brown (DPI), Don Malcolm (QNRM), Rob Moreton and Ken Bird (Dept Primary Industry, Water and Environment, TAS).

References

DIPNR (Department of Infrastructure, Planning and Natural Resources) (1997). Acid Sulfate Soils Risk Mapping. 128 map sheets at a scale of 1:25 000. This project was co-funded by the Natural Resources Audit Council (NRAC), and revised in 1997. ANZLIC unique identifier: ANZNS0359000004.

Fitzpatrick RW, Grealish G, Shand P, Simpson SL, Merry RH, Raven MD (2009a) Acid Sulfate Soil Assessment in Finniss River, Currency Creek, Black Swamp and Goolwa Channel, South Australia. CSIRO Land and Water Science Report 26/09. CSIRO, Adelaide, 213 pp.

Fitzpatrick RW, Powell B, McKenzie NJ, Maschmedt DJ, Schoknecht N, Jacquier DW (2003) Demands on Soil Classification in Australia. In 'Soil Classification: A Global Desk Reference'. (Eds H Eswaran, T Rice, R Ahrens, BA Stewart) pp. 77–100. (CRC Press LLC Boco Raton. FL).

Fitzpatrick RW, Powell B, Marvanek S (2008a) Atlas of Australian Acid Sulfate Soils. In 'Inland Acid Sulfate Soil Systems Across Australia'. (Eds RW Fitzpatrick, P Shand) pp. 90–97. CRC LEME Open File Report No. 249. (Thematic Volume) (CRC LEME, Perth, Australia).

Fitzpatrick RW, Shand P, Merry RH (2009b) Acid Sulfate Soils. In 'Natural History of the Riverland and Murraylands'. (Ed JT Jennings). pp. 65-111 (Royal Society of SA Inc. Adelaide, South Australia).

Fitzpatrick RW, Shand P, Marvanek S, Merry RH, Thomas M, Simpson SL, Raven MD, McClure S (2008b) Acid sulfate soils in subaqueous, waterlogged and drained soil environments in Lake Albert, Lake Alexandrina and River Murray below Blanchetown (Lock 1): properties, distribution, genesis, risks and management. Prepared for Department of Environment and Heritage, SA. *CSIRO Land and Water Science Report 46/08.* CSIRO, Adelaide, 167. pp.

Grealish G, Fitzpatrick RW, Chappell A, Marvanek S (2010) Spatial variability of subaqueous and terrestrial Acid Sulfate Soils and their properties, for the Lower Lakes, South Australia. Project Report for Murray Futures Lower Lakes & Coorong Recovery Acid Sulfate Soils Program. Prepared for: Department of Environment and Heritage, South Australia and Department of the Environment, Water, Heritage and Arts. Client Report: CSIRO Sustainable Agriculture National Research Flagship 143 pp. http://www.clw.csiro.au/publications/science/2010.pdf

Gallant JC, Dowling TI (2003) A multiresolution index of valley bottom flatness for mapping depositional areas. *Water Resources Research* **39,** 1347.

Isbell RF (1996) The Australian soil classification system. CSIRO, Publishing, Melbourne.

Soil Survey Staff (2003) Keys to Soil Taxonomy. Ninth Edition. U.S. Dept. Agr. Nat. Res. Cons. Service, Washington D.C.

Sullivan LA, Fitzpatrick RW, Bush, RT Burton ED, Shand P, Ward NJ (2009) Modifications to the classification of acid sulfate soil materials. Southern Cross GeoScience Tech Report 309. pp. 11.

QDEX (Queensland Digital Exploration Reports System) (2008) Hardcopy ASS maps, GIS coverages, sample site descriptions and laboratory data may be purchased from (NRScDataCoordinator@derm.qld.gov.au)