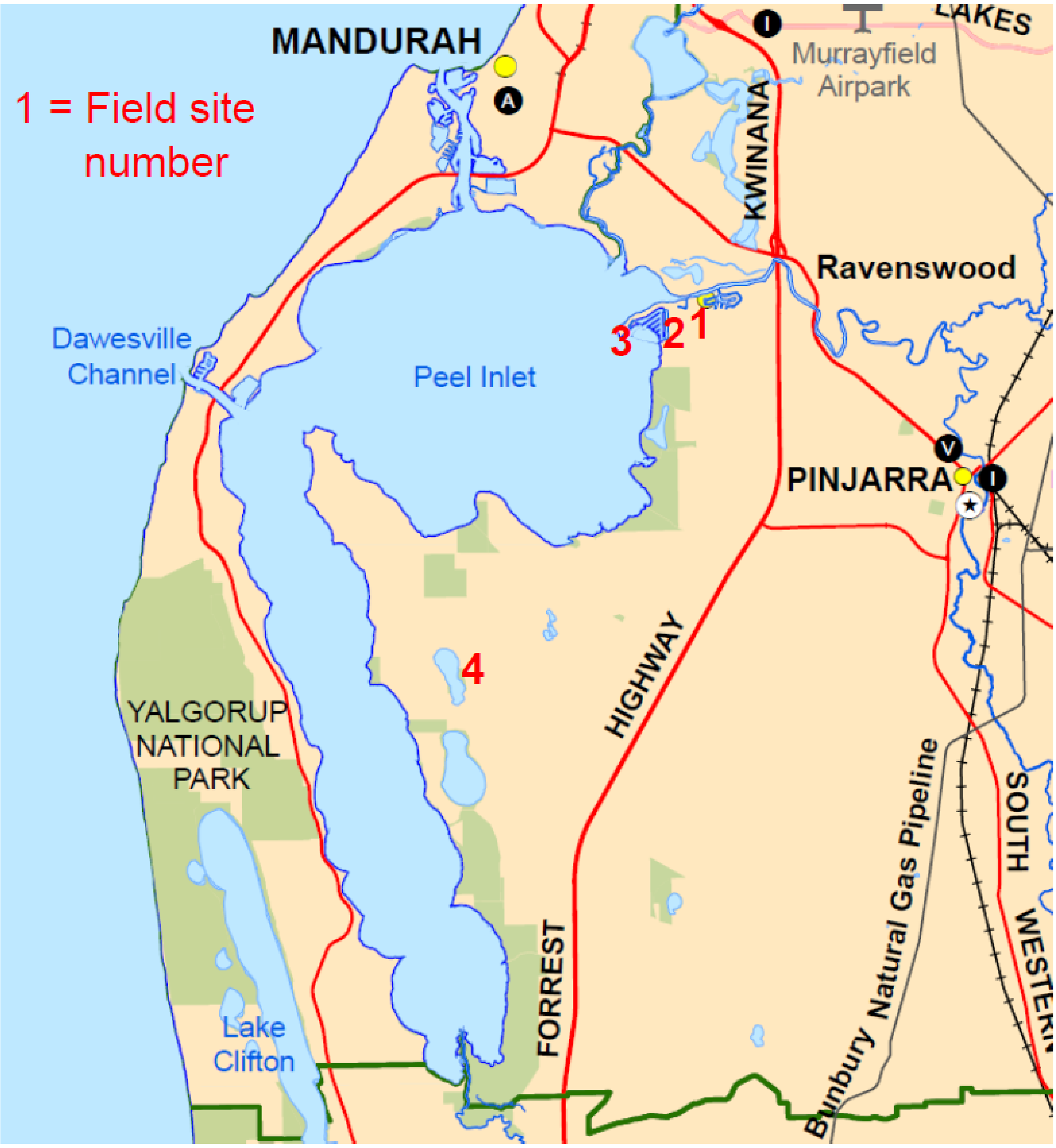
ACID SULFATE SOILS IN THE PEEL REGION

Notes to Accompany a Field Tour of Key Issues in the Region, October 2015



Acid sulfate soils near the Peel Estuary

Drilling and soil sampling in the Peel Region has identified an area of about 5000 hectares that is underlain by acid sulfate soils at a depth of less than 3 metres (i.e. a depth where disturbance by urban development is likely). These soils often contain the equivalent of 90 tonnes of stored acidity per hectare.

Unlike many regions on the eastern seaboard where sulfidic soil materials typically have a gel-like clayey texture, most of the pyrite in the Peel Region is in silt- to sand-sized materials which generally have a reduced inorganic sulfur content of 0.5-1%. These materials are highly reactive and will start oxidising within hours to days of being exposed to oxygen. Consequently, great care must be taken when draining, dewatering or excavating these soils to prevent acid generation.

The main occurrences of acid sulfate soils in the Peel Region are:

- ***Serpentine River*** - Concentrations of sulfides in channel sediments of the Serpentine extend as far as Lake Amarillo. Sulfide minerals occur just below the shallow water table beneath dunes along much of the Serpentine River, and in a large area of low lying dunes at the mouth of the river. Dewatering for construction purposes and excessive groundwater abstraction in this area pose the greatest ASS disturbance risk;

- ***Murray River –*** sulfides are mostly restricted to the lower floodplain terraces near the river associated with sand and clay lenses. Short-term construction activities on the alluvial flats pose the greatest risk of disturbing sulfides, and there are only limited opportunities to treat acidic discharges before they are able to discharge to the river;

- ***South Yunderup –*** sulfide minerals have a patchy distribution in clayey to sandy sediments that comprise the Murray River delta. These soils are oxidising due to disturbance by urban development and drainage, and this will need to be carefully managed to prevent problems being exacerbated by ongoing development in the area. Management of existing acidity will be difficult because of the patchy distribution of sulfide minerals and because of widespread infrastructure and the proximity of waterways;

- ***Austin Bay (East Peel)*** - shallow, but patchy sulfides are associated with sands, silts and clays of a former lower river delta. Isolated areas of shallow soils with a high potential acidity occur. Soils near existing drainage channels are oxidising, and drains are discharging large amounts of acidity and metals into the environment. There is an urgent need to rehabilitate drains in this area to prevent this happening.

- ***Lakes Mealup and McLarty*** - sulfides generally associated with sands at the water-table. Disturbed acid sulphate soils were not found in this area (i.e. where substantial actual acidity occurs in soil profiles). However groundwater near Lake Mealup is acidic due to overdrainage. Drainage in the area needs careful management to raise the elevation of the water table in the area. Proposed development in the area will need careful management to prevent the disturbance of acid sulfate soils, particularly in the area between the estuary and the lakes.

- ***Western side of the Peel Estuary and the Harvey River mouth*** - most soils less than 5 m AHD contain sulfide minerals, however the potential acidity varies widely. Pockets of concentrated potential acidity associated with silts can lie adjacent to more marginal sandy materials. Development activities that cause disturbance of soils (particularly excavation and dewatering soils near the estuary) will require careful management in this area, particularly development with large excavations (e.g. canal estates).

- ***Lakes Clifton and Preston*** - Shallow clay and silt sediments beneath and adjacent to these lakes contain large amounts of sulfide minerals. The effect of disturbing these materials is not known, as they generally also contain large amounts of carbonate minerals which may have the potential to neutralise all of the acidity provided that the ***rates*** of sulfide oxidation and carbonate neutralisation reactions are comparable. Groundwater abstraction for agriculture coupled with continuing low rainfall are likely to be the largest disturbance risk factors in this area.

In addition to these soils, substantial amounts of sulfidic dredge spoil have been deposited in foreshore areas around the Peel-Harvey estuary and along the Murray and Serpentine Rivers (Figure 1). These materials are oxidising and are releasing metals and acidity into waterways in the area and may be the cause of incidences of “Red Spot” disease that have been reported by recreational fishers in the region (Figure 2).

Figure 3 shows the mapped distribution of acid sulfate soils around the northern part of the Peel Estuary.

Figure 2 Black Bream with “red spot” disease from the Serpentine River

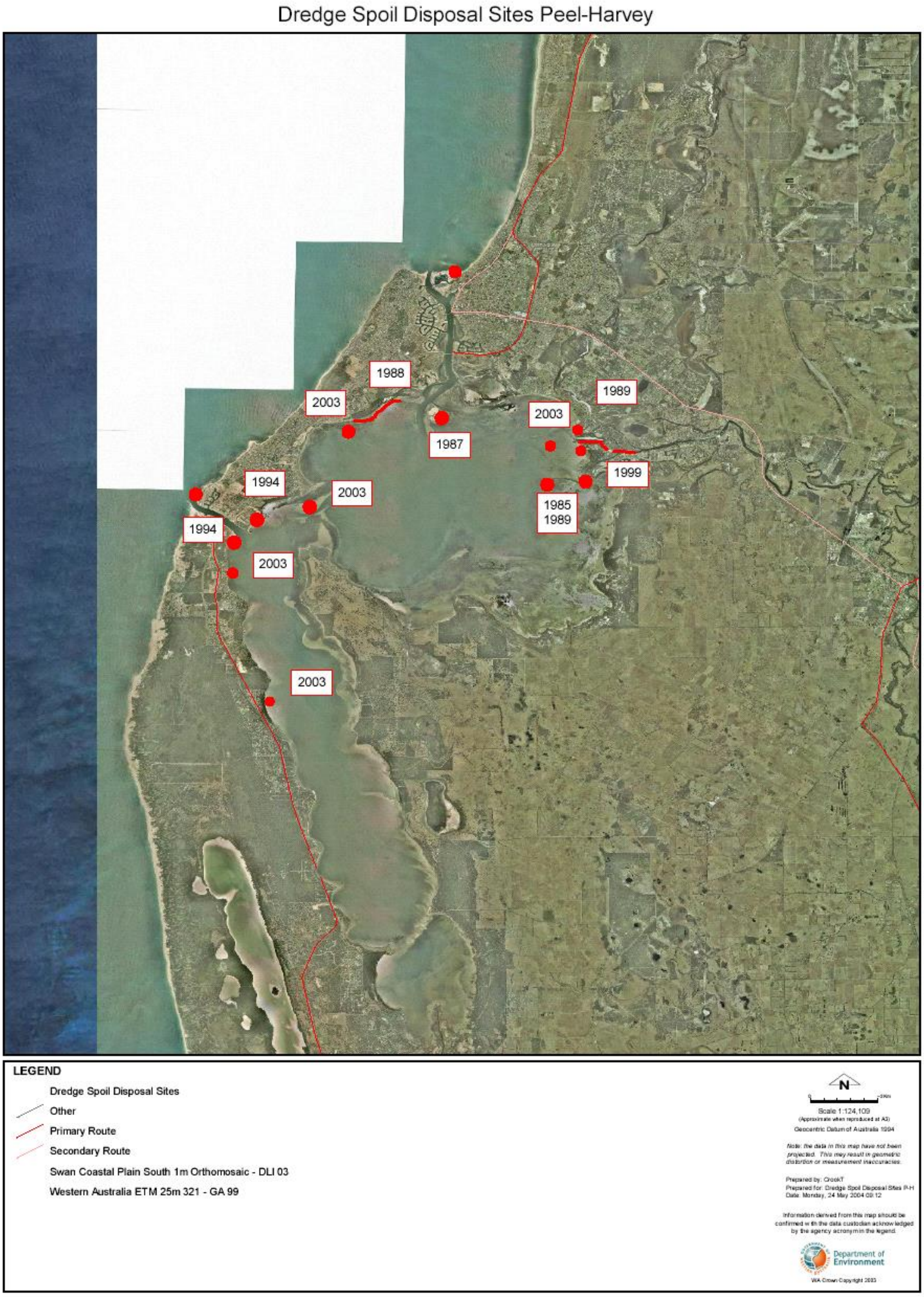


Figure 1. Historical dredge spoil disposal areas in the Peel Region

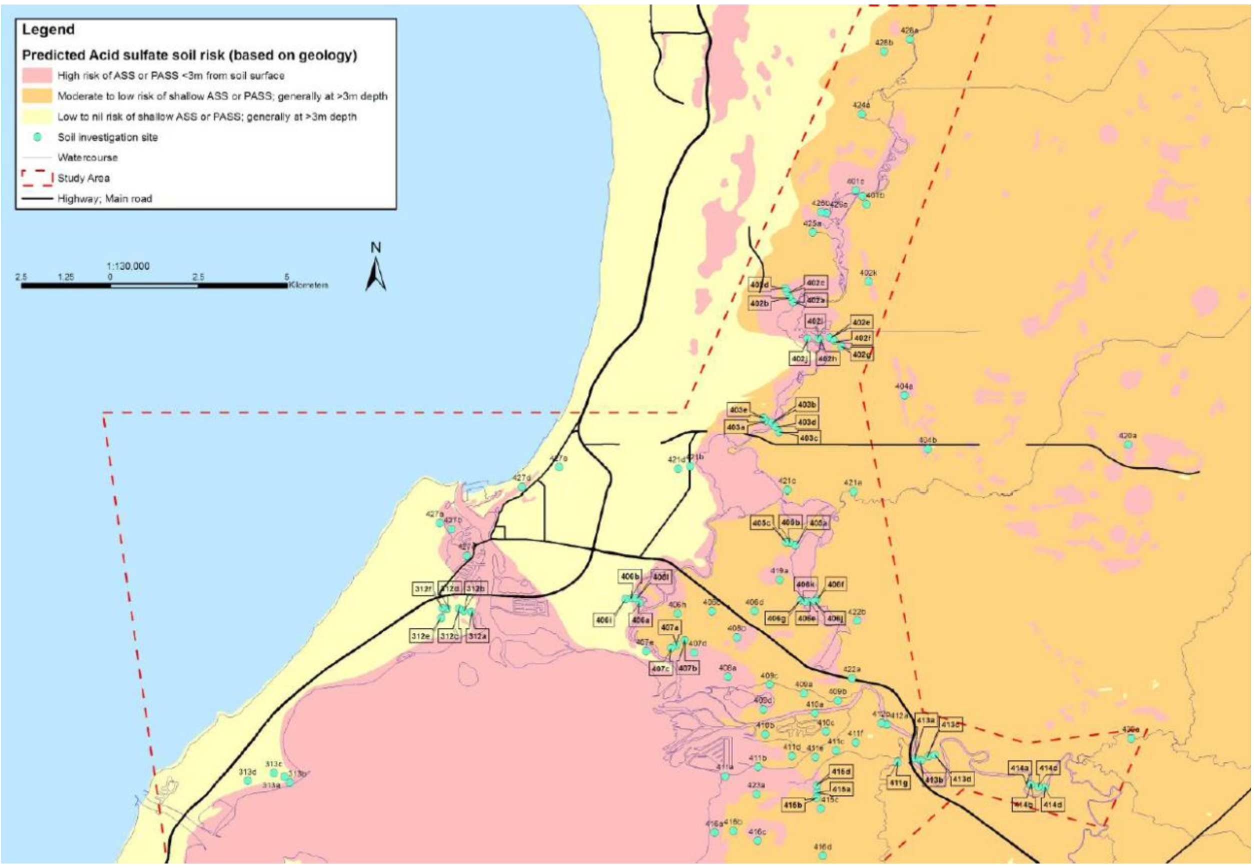


Figure 3. Distribution of acid sulfate soil materials beneath the northern part of the Peel-Harvey estuary

Field sites

Stop 1: Drainage management issues, Blue Gum Way, South Yunderup

Pyrite in silty estuarine sediments in this semi-rural area is oxidising due to excessively deep drainage. Soil materials within and adjacent to drains is highly acidic and contains a substantial amount of acidity stored as iron-aluminium sulfate mineral such as jarosite (present as yellow mottles in the soil profile).

In summer rainfall events and at the onset of winter, discharge from the drains and overland flow in this area has a pH of about 2.5, and there is extensive scalding and loss of vegetation due to the high acidity. It is likely that episodic discharges of acidic water continue throughout the winter, and there is probably sufficient acidity stored within the soil profile to maintain acidic discharges for many decades. The acidic drainage flows beneath South Yunderup Road, where it is corroding concrete culverts, and then flows into a main drain that discharges to the Peel Estuary. Overland flow adjacent to this drain is also generally acidic and typically contains high concentrations of dissolved aluminium and iron that are highly toxic to plants, creating bare “scalded” areas.

Wherever this acidic water flows into accumulations of organic matter, jet black layers of iron monosulfide “black oozes” (MBOs) are formed on the soil surface and in the bottom of drains. These materials are created by sulfate reducing bacteria which reverse the pyrite oxidation reaction to form sulfide minerals and release alkalinity. However in summer these layers are oxidised, releasing acid that is mobilised at the onset of the next rainfall event.

Historically, acidic drainage water commonly overflowed from the main drain at this site and used to discharge into a large pond which is used by stock and pets as a source of drinking water. As this could have posed a risk to the health of animals due to heavy metal accumulation in the pond, a former land owner was advised, and he took measures to divert overland flow away from the pond.

Drainage management is a key issue in areas underlain by acid sulfate soils. Many of the acidity problems on coastal plains in New South Wales and Queensland have been caused by excessive drainage from drains that are over-deep. Consequently, a lot of resources have been spent on reducing both the drainage density and the depth of drains in these areas to reduce the export rate of acidity and metals. The ultimate goal is to create whole of catchment management strategies to progressively reduce acid production and export. Land and Water Australia and New South Wales government agencies have released a guideline document entitled "Restoring the Balance: Guidelines for Managing Floodgates and Drainage Systems on Coastal Floodplains" that explains how whole-of-catchment drainage management strategies can be implemented, and many of these principals are applicable in the Peel Region and elsewhere on the Swan Coastal Plain. The document is available at the following web site:

http://www.dpi.nsw.gov.au/agriculture/resources/soils/ass/general/balance

Stop 2: Urban development on acidifying dredge spoil, South Yunderup

Canal developments in the Yunderup area are among the oldest in Australia and commenced in the late 1970s.

A proposed new residential development in South Yunderup has been put on hold after the discovery that the construction fill is highly acidic and is generating acidic leachate that is discharging to a drain and is contaminating groundwater. The fill at the site consists of pyritic dredge spoil which now has soil pH values at the surface that are commonly less than 4. Natural soils beneath the dredge spoil are also sulfidic. Groundwater and drainage from the site has a pH of 2.5 to about 5 and a Total Acidity of about 400 mg/L as $CaCO_3$, and is therefore likely to be highly corrosive to concrete and steel infrastructure and highly toxic to aquatic organisms on discharge to waterways and estuaries. The widespread distribution of jarosite mottles (Fig. 4) indicates that there is a considerable amount of stored acidity in the dredge spoil. Investigations that were undertaken in 2012 by Southern Cross University have also confirmed that acidifying dredge spoil is widely distributed in South Yunderup.

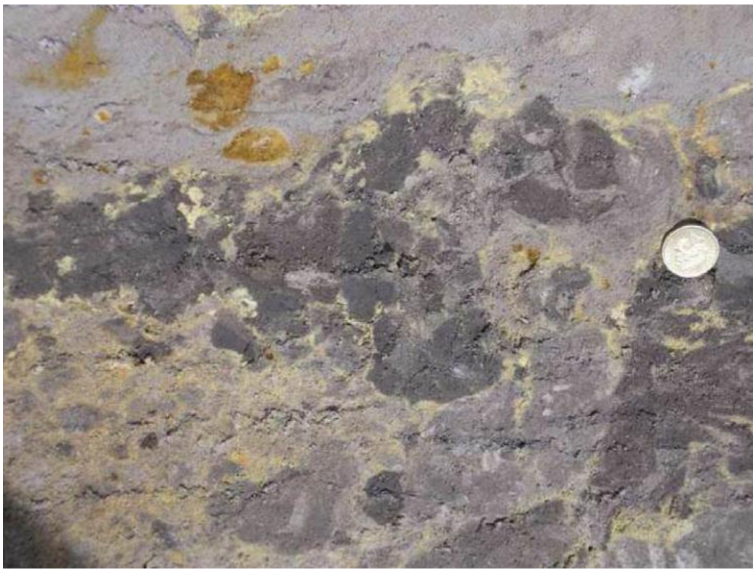


Figure 4. Shallow excavation into dredge spoil that has been deposited at Murray Waters Boulevard in South Yunderup showing mottles of jarosite (yellow colour), ferruginous mottles and remnant unoxidised sulfidic material (dark grey)(Photo: Leigh Sullivan).

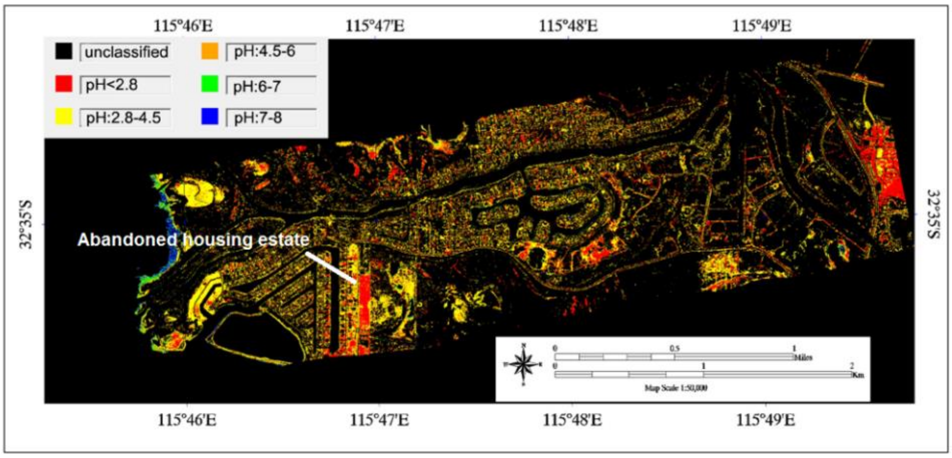


Fig. 5. Simulated pH of shallow soils in South Yunderup from hyperspectral imagery (from Shi, 2014)

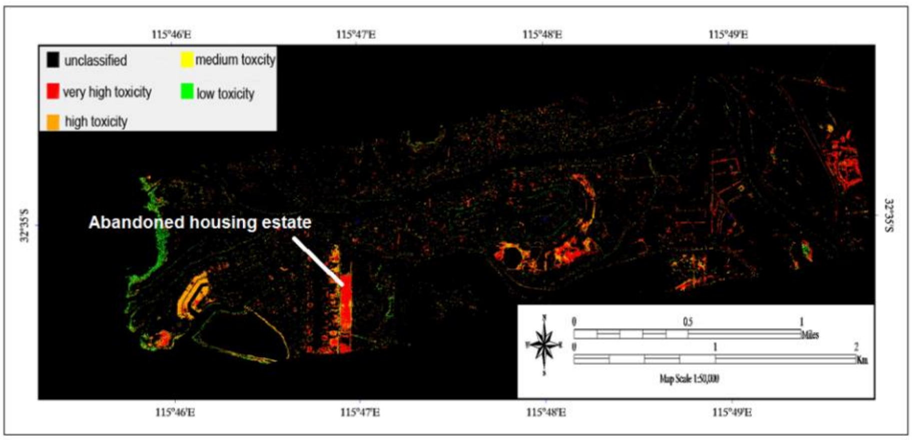


Fig. 6 Predicted aluminium toxicity in shallow soils from hyperspectral imagery (from Shi, 2014)

Hyperspectral imagery (Shi, 2014) suggests that the abandoned housing development at this site is likely to be a significant source of soluble aluminium and other metals in drainage that is discharged to the Peel estuary (Figs 5 and 6). Water sampling carried out in the Peel Estuary near Yunderup (Kilminster *et al*., 2011) has indicated that soluble aluminium concentrations are locally elevated in the estuary near South Yunderup, and that the sulphur isotope signature in estuarine water suggests that water quality has been locally affected by the oxidation of sulfide minerals. Water in canals in South Yunderup may also contain elevated levels of iron, nickel and arsenic at concentrations of environmental concern (Ljung *et al*., 2010).

Stop 3. Dredge spoil disposal area, Murray River mouth

Access to the South Yunderup canal estate is made via a 2 km long channel which has to be periodically dredged to enable vessels with deep hulls to enter the canals. Historically, spoil from dredging the channel was disposed of in ponds at the mouth of the Murray River. However, this material was later found to contain substantial amounts of sulfide minerals which were oxidising and releasing acidity and metals into drainage from the site that was discharging into the Peel-Harvey estuary (a Ramsar wetland).

Recent investigations (Shi *et al.*, 2015) has indicated that sediments in the dredge spoil disposal area have a total sulfur content of about 1-4% and values of total potential acidity (TPA) that typically exceed 1000 moles H^+/tonne. Laboratory incubation tests that were undertaken on fresh, monosulfidic dredge spoil (Shi *et al.*, 2015) under a variety of wetting and drying regimes for a period of about 100 days indicated that the mineral assemblage in these materials changed substantially with “ripening” over this time period. Minerals produced in the spoil after oxidation included jarosite, goethite, hematite and gypsum. Leachate from the dredge spoil after 94 days of oxidation contained more than 8 mg/L of dissolved aluminium and more than 1 mg/L of uranium.

Research by Southern Cross University and the University of Western Australia has found that iron monosulfide minerals and pyrite are actively forming in silty sediments that accumulate in the dredged channel (see *e.g*. Morgan *et al*., 2011; Kraal *et al*., 2013a), and the Shire of Murray has found that the frequency of dredging needed to keep the access channel open is increasing. This has created a major management problem for the Shire which is having difficulties in supporting the increasing costs of the dredging operations. For example, the Shire of Murray had to pay about $200K in 1999, but this increased to more than $500K in 2006 to ensure environmental hazards associated with sulfide oxidation would be managed.

In recent dredging operations, the Shire of Murray has tried to mitigate problems associated with sulfide oxidation by disposing dredged spoil in offshore areas within the Peel estuary. However, it is unlikely that this will be sustainable on an ongoing basis because the estuary is very shallow. Research has also indicated that retaining sulfidic sediments in the estuary provides an ongoing source of nutrients for the overlying water column (see e.g. Kraal *et al.*, 2013b), especially when these sediments are disturbed by dredging (Morgan *et al*., 2012), by intense storms, or even by boating traffic.

Managing the dredging and disposal of sulfidic sediments within the Peel-Harvey Estuary is a major issue for local government authorities in the region which do not have the financial resources or the level of expertise required to deal with these materials. Long-term solutions are required to enable dredging to be undertaken in a cost-effective manner while minimising the potential for significant environmental impacts taking place when sulfidic sediments are disturbed and disposed of.

References

Kilminster, K., Norton, S. and Miller, F., 2011. *Assessing the Impacts of Acid Sulfate Soils on Water Quality in South-Western Australian Catchments and Estuaries*. Department of Water, Water Science Technical Series, Report No 19. Report is available from web site http://www.water.wa.gov.au/PublicationStore/88353.pdf

Kraal, P., Burton, E.D., Bush, R.T., 2013a. Iron monosulfide accumulation and pyrite formation in eutrophic estuarine sediments. *Geochimica et Cosmochimica Acta*, **122**, 75-88.

Kraal, P., Burton, E.D., Rose, A.L., Cheetham, M.D., Bush, R.T. and Sullivan, L.A., 2013. Decoupling between water column oxygenation and benthic phosphate dynamics in a shallow eutrophic estuary. *Environmental Science and Technology*, **47**, 3114-3121.

Ljung, K., Maley, F. and Cook, A., 2010. Canal estate development in an acid sulfate soil – Implications for human metal exposure. *Landscape and Urban Planning*, **97(2)**, 123-131.

Morgan, B., Burton, E.D. and Rate, A.W., 2011. Iron monosulfide enrichment and the presence of organosulfur in eutrophic estuarine sediments. *Chemical Geology*, **2012**, 119-130.

Morgan, B., Rate, A.W. and Burton, E.D., 2012. Water chemistry and nutrient release during the resuspension if FeS-rich sediments in a eutrophic estuarine system. *Science of the Total Environment*, **432**, 47-56.

Shi, X., 2014. *Hyperspectral Sensing of Acid Sulphate Soils and their Environmental Impacts in South Yunderup, Western Australia*. Curtin University Ph.D. Thesis available from web site http://espace.library.curtin.edu.au/R/?func=dbin-jump-full&object_id=198086&local_base=GEN01-ERA02.

Shi, X, Oldmeadow, D. and Aspandiar, M., 2015. Observations on mineral transformations and potential environmental consequences during the oxidation of iron sulphide rich minerals in incubation experiments. *European Journal of Soil Science*, **66**, 393-405.