



Investigation into the potential risk of acid sulfate soils on proposed development in the City of Greater Geelong

Report to the City of Greater Geelong

Jim Cox, Peter Dahlhaus, Phil Davies and Troy Clarkson

CSIRO Land and Water Client Report
Draft June 2005

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Cover Photograph:

Description: The view across Corio Bay, Geelong, Victoria

Photographer: Phil Davies

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Investigation into the potential risk of acid sulfate soils on proposed development in the City of Greater Geelong

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Executive Summary

Based on previous work, including a very good review by the Centre for Land Protection Research of Victorian Department of Primary Industries, a total of 11,745 ha of acid sulfate soils were reported within the Greater Geelong City shire, ranking it as the second greatest for extent of acid sulfate soils of all shires in Victoria.

This study was commenced to identify the potential for acid sulfate soils to have an impact on future development in the City of Greater Geelong and to determine if a major study of acid sulfate soils was warranted. Thus a desktop study was commenced to develop a series of overlays of the spatial distribution of specific parameters that the literature said were needed for potential acid sulfate soil development (e.g. low lying areas). From this an overlay was developed which predicted possible acid sulfate soil distribution within the City of Greater Geelong. This information was overlain by the planning zones. Twelve sites were then chosen for investigation where it was thought that acid sulfate soils may have an impact on future development in the City of Greater Geelong.

Soil samples to analyse for acid sulfate soils within the laboratory were only collected at three of the sites. The others were discounted as either there was no visible evidence of acid sulfate soils or acid sulfate sites within the area were confined to areas that were obvious wetland and zoned "Public Conservation and Resource". The only exception to this were sites at Avalon (AV02) and Point Henry (PH02). Prior to any development, these areas must be sampled for potential acid sulfate soils as their disturbance could lead to the development of sulfuric acid.

The laboratory analyses showed only one soil layer at one of the sites that was sampled had at most a "marginal" acid sulfate soil potential.

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Introduction

1.1 Background

1.1.1 General

Rampant *et al.*, 2003 have mapped the potential extent of ASS distribution along the Victorian coastline at 1:100,000 (Figure 1). Corangamite Catchment Management Authority (CCMA) reportedly has the second highest areal distribution of acid sulfate soils (ASS) of all CMAs in Victoria, with an estimated total extent of 13,845 ha (Rampant *et al.*, 2003). Of this total, 11,745 ha are reported as being found within the Greater Geelong City shire, ranking it as the second greatest for extent of ASS of all shires in Victoria. This study was commenced to investigate the potential risk of ASS on proposed development in the City of Greater Geelong.

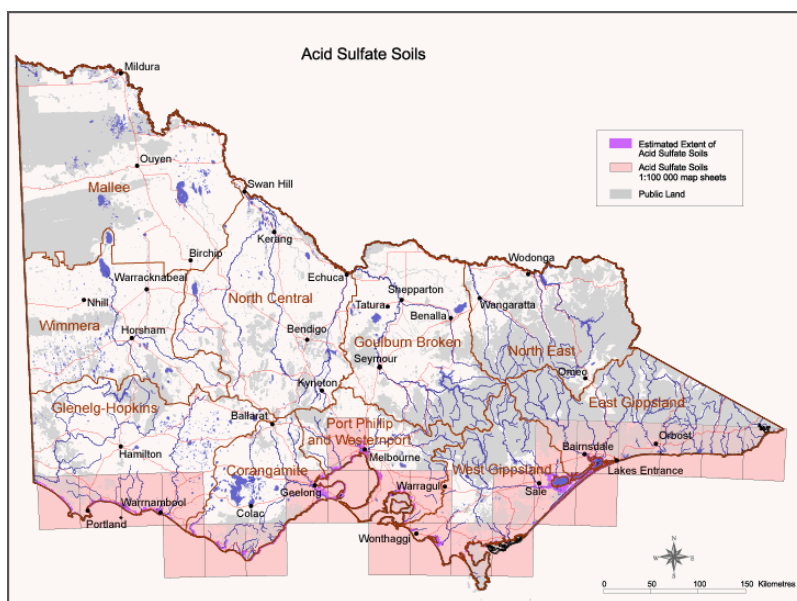


Figure 1. Distribution of coastal acid sulfate soils [Rampant *et al.* 2003].

Acid sulfate soils have $\text{pH} < 3.5$ and contain iron sulfides (pyrite, FeS_2) or mono-sulfides (FeS). They are usually dark grey and soft; and can be clay or sand. When iron sulfides are exposed to air (drained or disturbed) they produce sulfuric acid. Acid sulfate soils can overlie PASS (potential ASS) which are iron sulfides contained in waterlogged sediments with a pH 6.5-7.5. The waterlogging prevents oxidation and production of sulfuric acid. Most ASS formed within the past 10,000 yrs after the last major sea level change (Graham and Larson, 2000).

Coastal ASS/PASS occurrences in Australia have largely been mapped (mangrove swamps, salt marshes, estuaries and tidal lakes) at a relatively broad scale (e.g. 1:100,000), although there have been some assessments made in Queensland and South Australia at finer scales (e.g. Merry *et al.*, 2003). Inland ASS and PASS have not been mapped. They usually occupy relatively small areas associated with (saline) groundwater discharge but may be large in total extent.

1.1.2 Impacts of ASS

The impacts of ASS can be numerous and include:

- Sulfuric acid mobilises Fe, Al, Mn and Cd, and lowers soil pH making some soils toxic to plant growth causing scalding (similar to salinity);
- Sulfuric acid corrodes concrete, iron and steel foundations and piping;
- Acid waters can cause rust coloured stains and slimes;
- Plastic corrugated drainage becomes blocked by iron oxides;
- Drainage waters can release sufficient sulfuric acid and Al to affect the aquatic food chain - can result in aquatic plant and fish death;
- Acid waters can mobilise heavy metals such as cadmium which can be adsorbed by fish and aquatic life;
- Poor quality stock water;
- Bitumen road failure;
- Irreversible soil shrinkage;
- Low bearing capacity of soils;
- Human health problems: algae, heavy metals in drinking water, dermatitis, eye inflammations; and
- Arsenic toxicity.

1.1.3 Foul smells caused by ASS

Wetlands rich in sulfidic materials produce noxious smells when drying. H₂S is given off as well as volatile organic S in some instances (Figure 2).

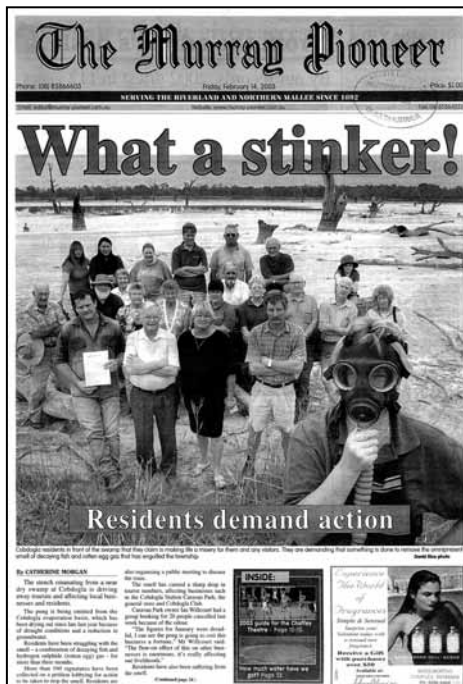


Figure 2. News clipping from the Murray Pioneer, 14 February 2004.

1.1.4 Deoxygenation caused by ASS

The re-suspension of sulfidic materials can rapidly consume water column oxygen and cause fish kills (e.g. Bush *et al.*, 2002; Sullivan *et al.*, 2002) (Figure 3). This may be an issue during managed wetting/drying cycles in wetlands.



Figure 3. Sulfidic sediment plume from Little Duck Lagoon to Salt Creek [Mardi van der Wielen, RMCWMB].

1.1.5 Acidification caused by ASS

The oxidation of sulfidic materials generates sulfuric acid. If acid production is greater than the acid neutralising capacity (ANC), ecosystem acidification can occur (Figure 4). Acidification results in elevated dissolved metal concentration and fish kills (e.g. Sammut *et al.*, 1996).



Figure 4. Bottle Bend Lagoon acidified to pH < 3 during a drawdown in 2002 [P D'Santos NSW Murray Wetlands working group].

1.1.6 Occurrence of coastal acid sulfate soils

Coastal ASS can be found where elevation is below 5 m. ASS layers are common at or less than 1.5 m above high tide level but may be buried by many metres of alluvial material when located in major river systems. Differing coastal geomorphological histories result in ASS layers being found at even greater heights above high tide level. River and estuarine floodplains, swamps and tidal flats; and incised river channels often many kilometres inland up to 5 m above mean high tide level are potential areas for finding ASS.

1.1.7 Occurrence of inland acid sulfate soils

Inland ASS can be found under the following conditions:

- Non tidal;
- Swamps, marshes;
- Saline, sulfate rich groundwaters;
- Pyrite (Fe and S rich) geology;
- Dryland salinity;
- Erosion; and
- Mine spoils.

1.1.8 Processes

The requirements for PASS are:

- Sulfate in water (> 10 mg/L; seawater or saline groundwater);
- Sediments containing iron oxides and organic matter; and
- Waterlogging (saturation).

The requirements for ASS are:

- Exposure of PASS to air - oxidise to produce sulfuric acid. PASS are associated with soil structure decline and scalded surfaces.

1.1.9 Environments

The environments in which ASS can be found:

- Natural – PASS covered by water and vegetated. Small amounts of acid released from the soil are neutralised by tidal flows, flood waters etc; and
- Modified (drained/modified for agricultural production) – Water levels drop and expose PASS. Acid is generated and can be released into streams and/or groundwater.

1.2 Aims of the report

1.2.1 General

This was a pilot study to improve knowledge of ASS in the City of Greater Geelong and indicate whether there is a potential risk of ASS being disturbed as a result of development.

More specifically:

- Mainly a desktop study but with field sampling at a number of sites identified as highest probability of ASS from the desktop study;
- Analyse the appropriate landscape parameters and the municipal development overlays to determine possible high risk PASS areas within the City of Greater Geelong;
- Identify at least two (and up to five) possible PASS sites that may have high ASS risk;
- Sample the sites and test the soils to determine the soil properties and ASS risk;
- Report on the study, with particular emphasis on any risks identified and the potential impact on assets at both the municipal and catchment scales; and
- Liaison with State Government agencies to ensure the outcomes are in-line with previous and current statewide studies.

1.2.2 Expected output

A brief report outlining the results, potential impact and potential management of ASS.

1.2.3 Project outcomes

- A pilot study to improve knowledge of acid sulfate soils in south-west Victoria and indicating whether there is a potential risk of ASS being disturbed as a result of development;
- A report which will help determine the need to develop acid sulfate soil management overlays for all municipalities in the CCMA region;
- Information to improve the awareness of acid sulfate soils within local government and to help them evaluate the need to develop tools (eg. management overlays) to reduce the risk of disturbing these soils if developed.

2 Methods

2.1 Desktop investigation

Prior to site visits, sampling and laboratory testing, a desktop assessment for preliminary appraisal of ASS risk was undertaken. This involved the collation and analysis of spatial data sets within a geographic information system (GIS) framework. Based on guidelines set by QDNR (Graham and Larsen, 1999) and local knowledge, it was determined that the following data sets were valuable to a desktop analysis:

- Elevation;
- Existing ASS maps;
- Generic soil maps;
- Geological maps;
- Topographic and orthophoto maps; and
- Aerial photography.

Using desktop assessment, ASS are most likely to occur in:

- *general*: in coastal areas less than 5 m elevation - ASS layers are common at or less than 1.5 m above high tide level in south-east Queensland but may be buried by many metres of alluvial material when located in major river systems. Elsewhere in Queensland, differing coastal geomorphological histories result in ASS layers being found at even greater heights above high tide level¹;
- *specific*: river and estuarine floodplains, swamps and tidal flats; and
- incised river channels often many kilometres inland up to 5 m above mean high tide level.

The major constraint to desktop assessment as a primary indicative tool is that without supporting laboratory analysis it does not give an indication of the level of pyrite present within the soils. Additional information such as oxidation rates and leaching potential of ASS, and calculation of liming rates for their management are only possible after detailed laboratory and interpretative assessment.

Desktop investigation – determination of areas with the following characteristics:

- Land with elevation < 5 m AHD;
- “Recent” (Holocene) sediments (contain most pyritic material);
- Marine, estuarine, tidal sediments; coastal alluvial valleys;
- Low lying coastal wetlands, waterlogged or scalded areas; mangroves, saltcouch, paperbark, swamp oak; and
- Geological formations (bearing sulfide materials e.g. pyrite bands, coal deposits or marine shales, buried estuarine or Holocene sediments).

2.2 General site investigation

Observations to be made at each field site to determine the potential risk of ASS as well as soil chemical analysis include:

- Nature of disturbance;
- Specific location of disturbance;
- Total area of site;
- Volume of material to be disturbed; and
- Soil sampling and analysis (texture, colour mottling, pH; total oxidisable sulfur; neutralising capacity of soils; Chromium reducible sulfur - S_{CR} ; Acid volatile sulfides - S_{AV}).

2.3 Specific site selection and sampling

Twelve sites were broadly selected for study based upon the results of the desktop investigation. These were investigated during a field visit in late March, 2005. Appendix 1 shows site information sheets for each of the twelve sites. Visual observations were made at each site (Appendix 2), which resulted in three being considered for sediment sampling. The profile sampling strategy at each site was sympathetic to the nature of sediments, changes in lithology and depth to standing water.

Bulk samples were packed in airtight conditions, frozen and transported to the laboratory for characterisation.

2.4 Laboratory methods

2.4.1 Sediment chemical analysis

Upon return to Adelaide, each of the bulked sediment samples were sub-sampled in the following ways:

- Approximately 200 g retained and frozen; and
- 250 ml sample of wet soil placed in a plastic phial and freeze dried.

Once freeze dried, the samples were submitted for the following analytical determinations:

- Electrical conductivity;
- pH (1:5 soil:water);
- pH (0.01M CaCl₂);
- Chloride;
- Total soil carbon and total sulfur by LECO™ furnace;
- Carbonate carbon - to determine the neutralising capacity, i.e. there is sufficient capacity to neutralise all the potential acid if the CaCO₃ content is 3 times that of total sulfur;
- Sulfide sulfur – to determine how much reduced sulfur is present;
- Total sulfur/sulfide sulfur - to indicate the amount of sulfate sulfur present
- Total carbon/carbonate carbon - to estimate the amount of organic carbon present applicable as food for bacteria;
- Inorganic sulfur (Chromium reducible sulfur - S_{CR}); and
- Acid volatile sulfides – S_{AV}; and
- Total element analysis (Appendix 3).

Soil organic carbon was estimated by subtraction of carbonate carbon values from total carbon.

3 Results

3.1 Spatial analyses

Figure 5 shows the spatial extent of the City of Greater Geelong (in white).

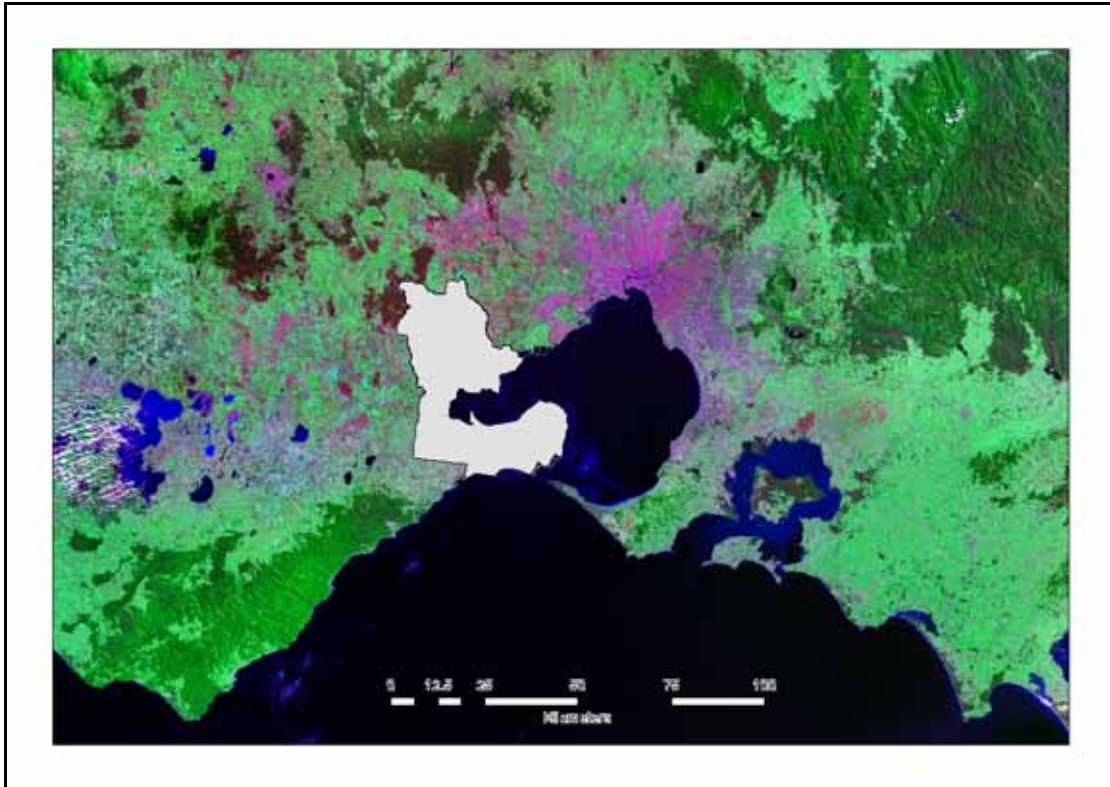


Figure 5. Location: City of Greater Geelong.

Figure 6 shows the planning zones for the City of Greater Geelong. This information was used to help in deciding where sampling for ASS should occur.

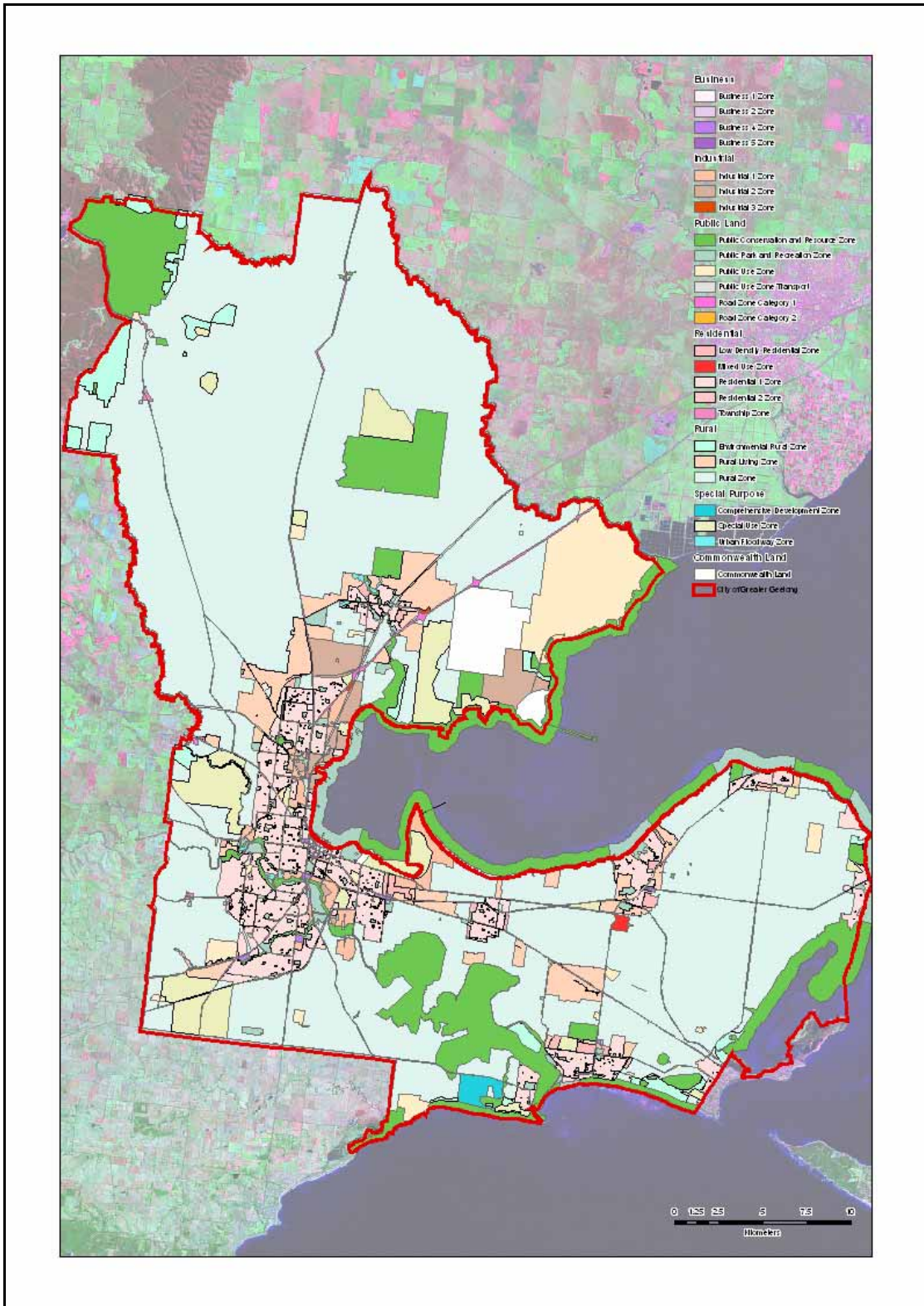


Figure 6. Planning zones.

Figure 7 shows areas within the City of Greater Geelong that are below both 2.5 m and 5 m AHD. One of the criteria for acid sulfate soils is that they are found below 5 m elevation (Ahern *et al.*, 1998; Queensland Government, 2002).

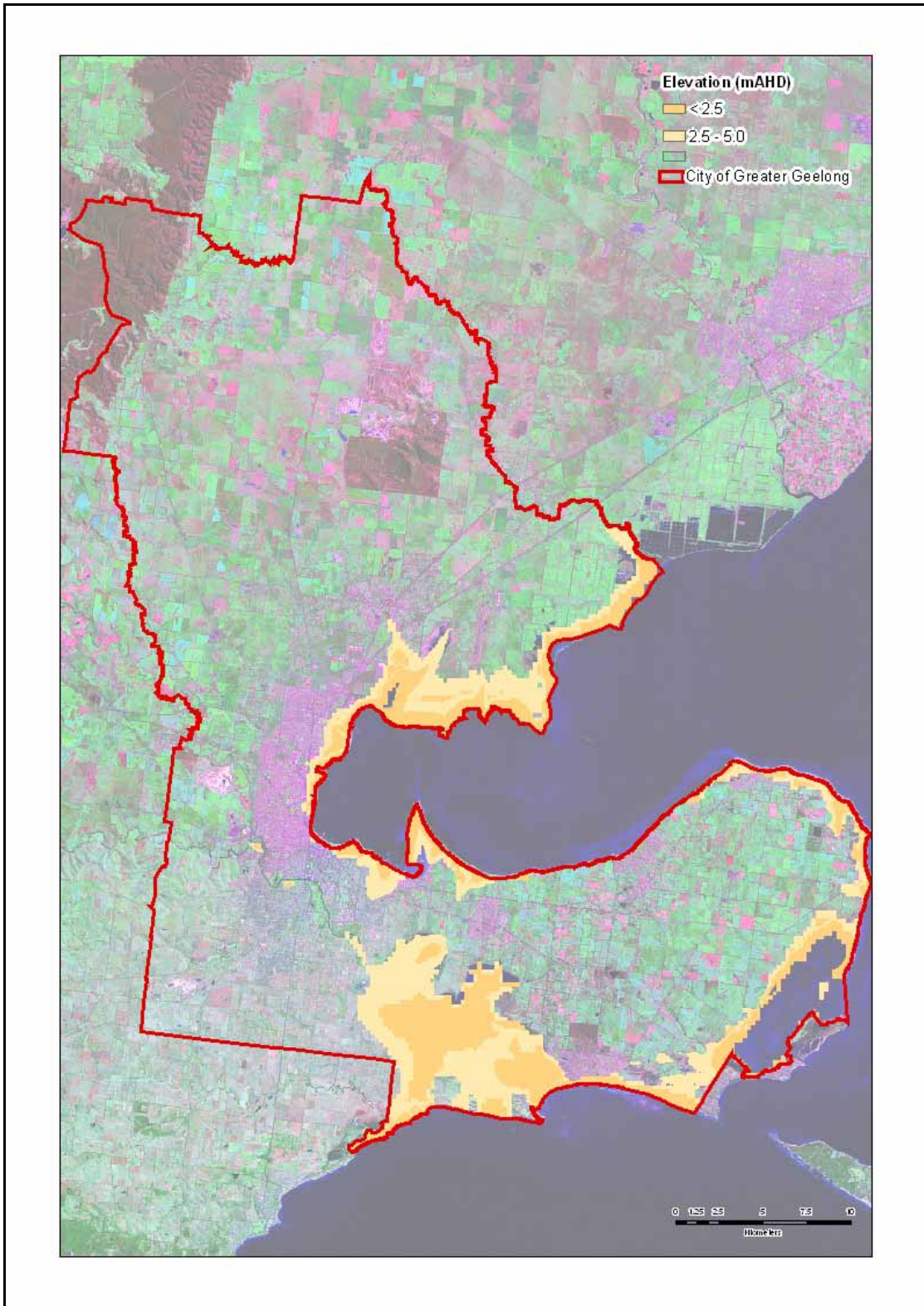


Figure 7. Map of land with elevation < 2.5 and < 5.0 m AHD.

Figure 8 shows areas within the City of Greater Geelong that have Holocene epoch sediments. Holocene epoch sediments can be high in pyrite material in Australia and are thus areas where acid sulfate soils may be likely to have formed (White *et al.*, 1997; Graham and Larson, 2000).

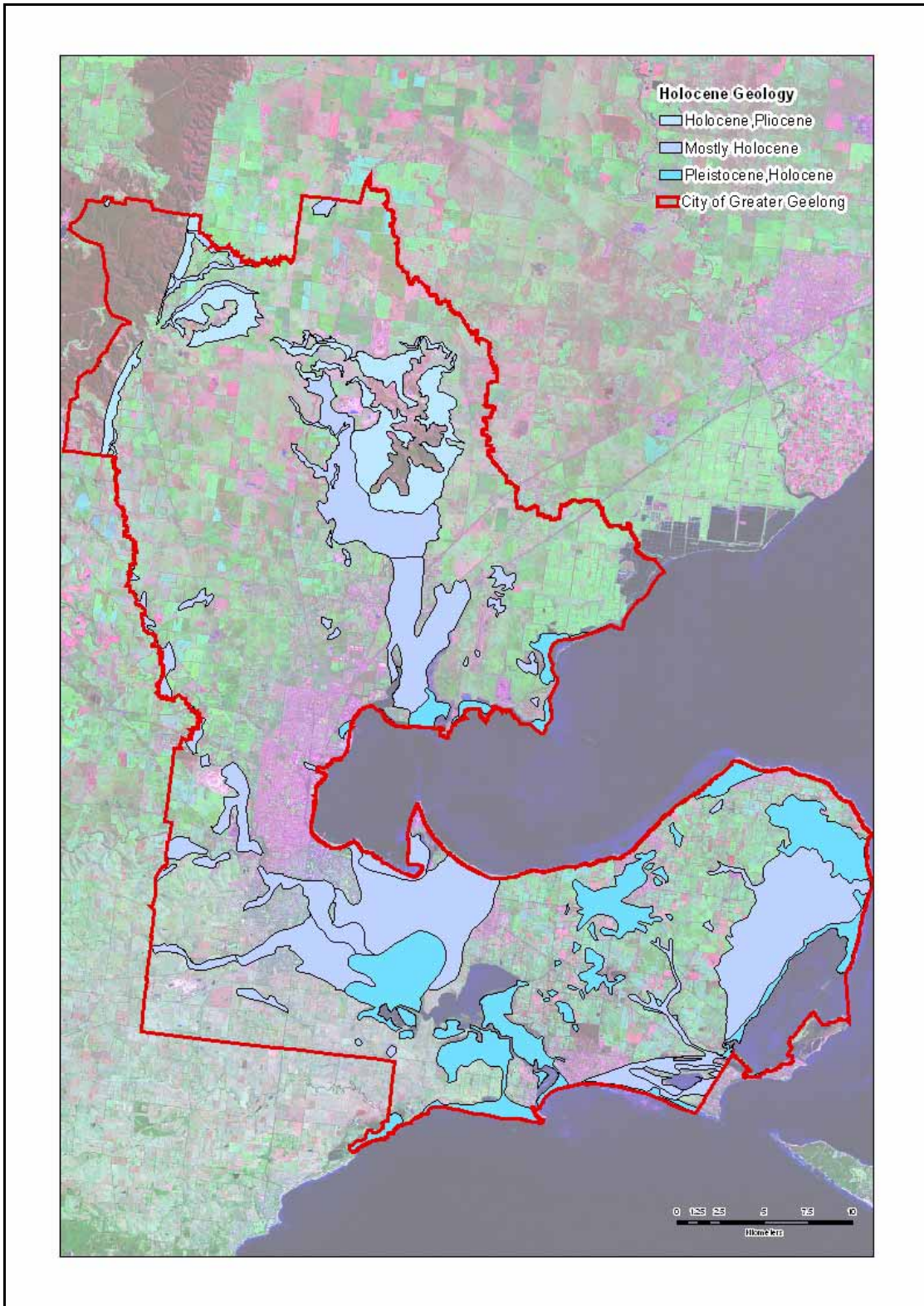


Figure 8. Holocene sediments.

Figure 9 shows wetland areas in the City of Greater Geelong. Acid sulfate soils may occur naturally in these environments.

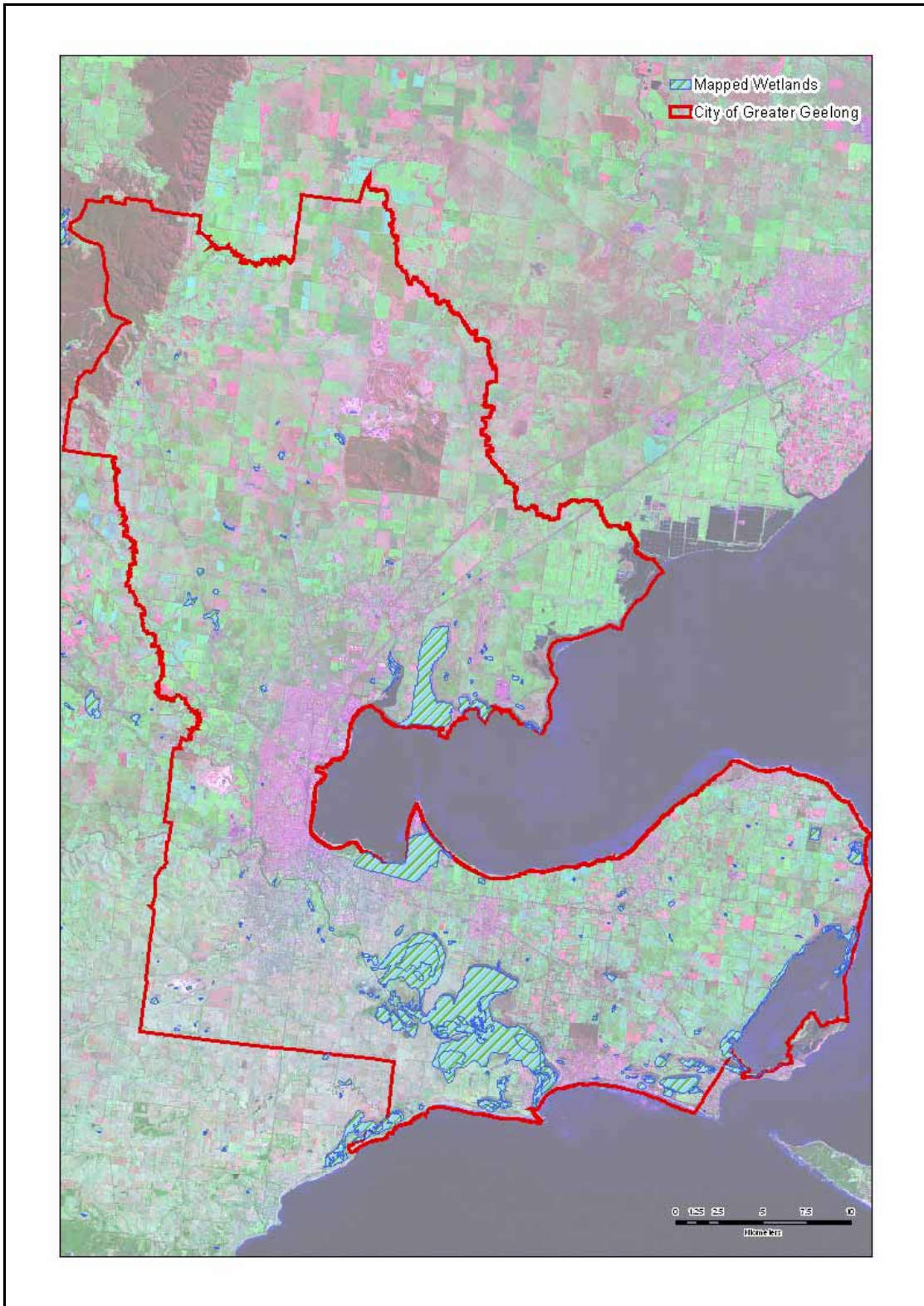


Figure 9. Mapped wetland areas.

Figure 10 shows those areas predicted as possibly having ASS, based on GIS overlay modelling of the various spatial criteria for occurrence of ASS. The results show an areal extent of 4.7% of ASS within the City of Greater Geelong, compared to 9.2% as mapped by Rampant *et al.* (2003).

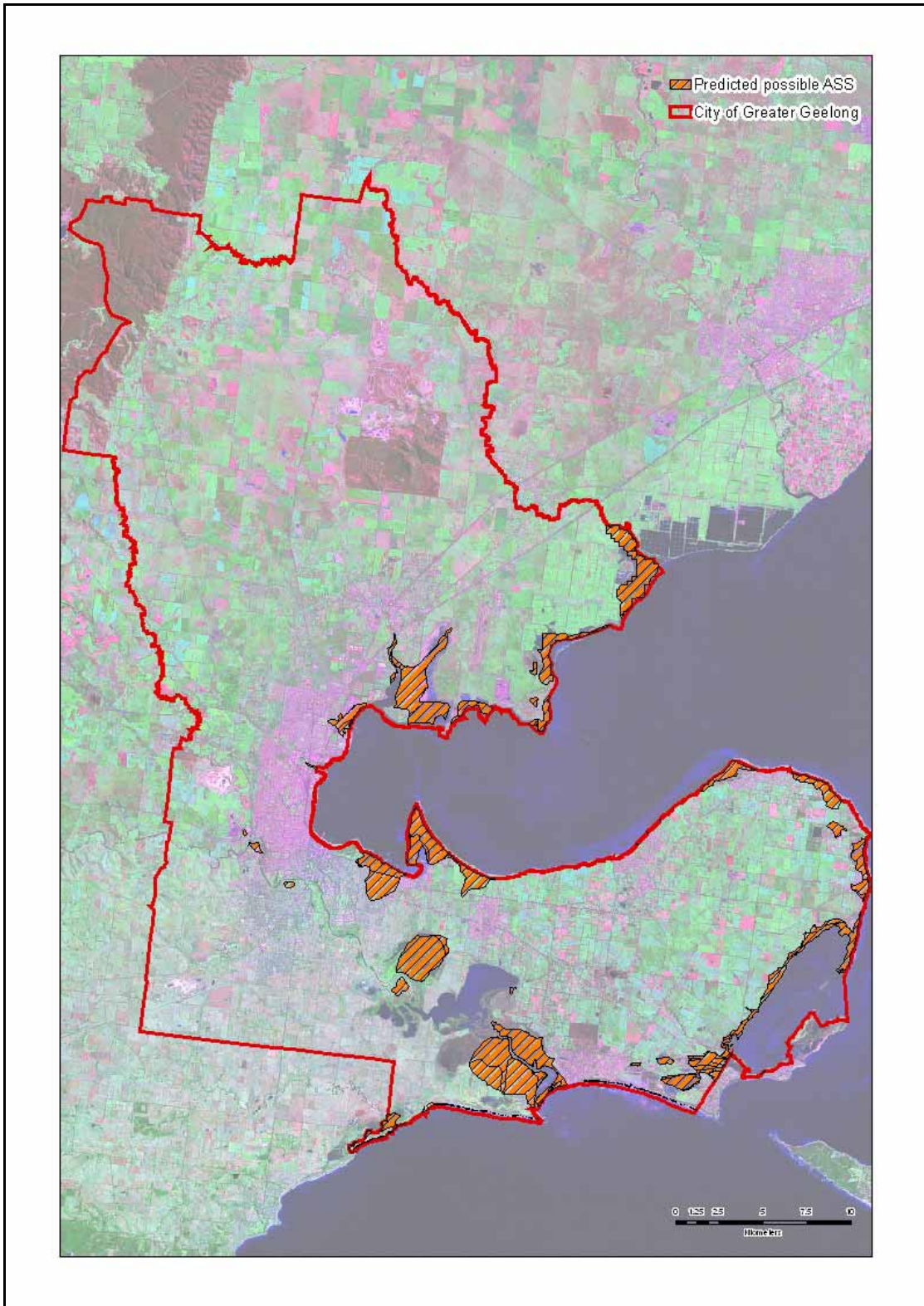


Figure 10. Assessment of predicted possible ASS distribution.

Figure 11 shows the location of twelve sites chosen for investigation where it was thought that acid sulfate soils may have an impact on future development in the City of Greater Geelong.

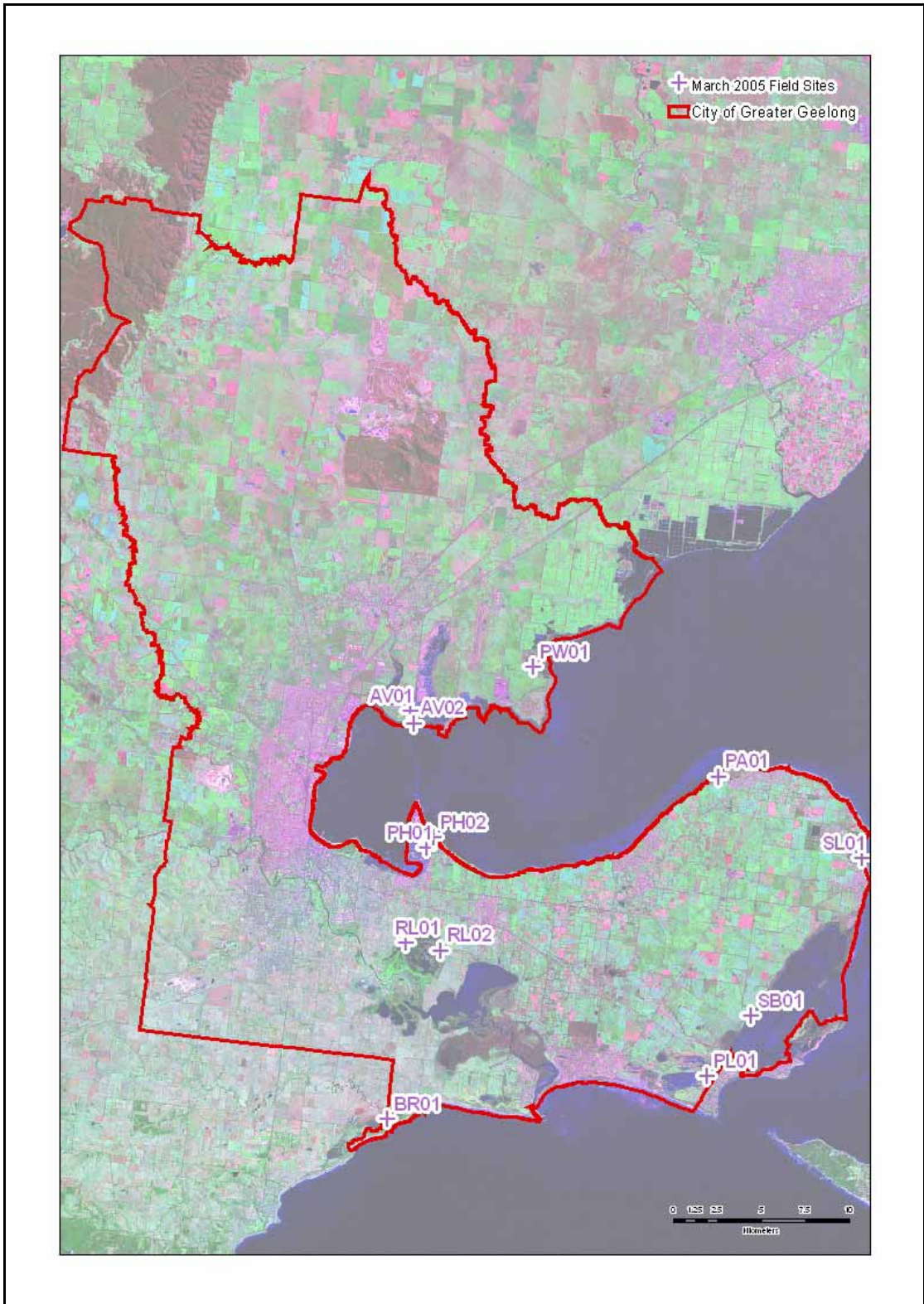


Figure 11. Location of field sites visited March, 2005.

3.2 Laboratory analyses

Of the 12 sites which were visited, only three were thought to contain ASS and pose a problem for future development. To determine if PASS/ASS did occur at these sites, soil samples were collected from site AV02, 0-20 cm; site PH02, 0-2 cm, 2-20 cm, 20-35 cm, and 25-50 cm; and site RL01, 5 to 10 cm, 20-30 cm and 30-35 cm).

Table 1 summarises the results of laboratory analyses on samples that were collected and includes calculations of gross acid production potential (APP) and gross acid neutralising capacity (ANC). Based upon these calculations, the ANC provided by the abundance of CaCO_3 , is more than sufficient to account for any potential acidification in all the samples.

One sample from Point Henry (PH02.3) can be considered marginally ASS, with an net acid generating potential (NAGP) = 0.3. However, the majority of this profile has overwhelming acid neutralising capacity (ANC). An acid-base account of the whole profile would most likely indicate a minimal ASS risk.

A sample from Avalon (AV02.1) has a high S_{CR} which indicates a potential for production of noxious smells, should the site ever be dried out and developed in the future. The high amounts of CaCO_3 found in this sample are in keeping with it being a “closed” system. i.e. there is no opportunity for seawater flushing of carbonates, which would increase the risk of potential ASS.

Table 1. Summary results of sediment analysis.

Sample ^a	Depth	Moisture	EC (1:5 soil:H ₂ O)	pH (1:5 soil: H ₂ O)	pH (0.01M CaCl ₂)	Cl	Total C	Org. C	CO ₃ as CaCO ₃	Total S	S _{CR} ^b	S _{AV} ^c	Gross APP	Gross ANC
	cm	%	dS/m			mg/kg	%	%	%	%			eq/g	eq/g
AV02.1	0 - 20	61.7	55.3	8.2	8.2	150000	8.4	5.7	21.8	1.39	0.50	0.04	3.00	43.6
PH02.1	0 - 2	73.6	57.7	7.3	7.3	159000	18.3	18.1	2.3	1.74	0.28		1.70	4.6
PH02.2	2 - 20	63.6	35.5	7.5	7.4	72600	6.6	6.2	3.1	0.51	0.03		0.18	6.2
PH02.3	20 - 35	73.7	46.6	7.5	7.5	116000	10.8	10.6	1.9	1.68	0.69		4.10	3.8
PH02.4	35 - 50	23.6	7.3	9.2	8.9	12600	0.8	0.2	4.5	0.01	0.03		0.18	9.0
RL01.1	5 - 10	49.4	3.1	5.8	5.5	4640	8.3	8.2	0.5	0.13	0.03		0.18	1.0
RL01.2	20 - 30	35.8	4.1	7.0	6.8	5180	3.3	3.3	< 0.5	0.10	0.02		0.02	< 1.0
RL01.3	30 - 35	17.1	1.9	8.1	7.9	2280	0.1	0.1	< 0.5	0.01	0.00		0.00	< 1.0

a Sample numbers relate to site location (refer Figure 11) and layer depth.

b Chromium-reducible sulfur. As per the method of Sullivan *et al.*, 2000. A value > 0.05 may signify ASS, depending on buffering capacity of the soil.

c Acid-volatile sulfur. Indicates those metal monosulfide materials (e.g. FeS) that evolve hydrogen sulfide when treated with hydrochloric acid.

Conclusions

Although ASS are found throughout the City of Greater Geelong, they are mostly confined to Public Conservation and Resource areas. Exceptions to this were the sites of a disused salt evaporation pond at Avalon (AV02) and tidal flat adjacent to the smelting plant at Point Henry (PH02).

The site at Avalon has potential to produce foul odours, if it were ever redeveloped, due to the high S_{CR} of the soil. However the large ANC of the soil should guard against issues of acidification, should the site be disturbed through excavation.

The site at Point Henry was the only one tested which had any acid sulfate soil potential and this was considered marginal at most. A total element analysis of sediments from this site (Appendix 3), supports previous findings of soil pollution from the nearby smelting operation (reference?).

Appendix 1. Site information sheets

Link to [*site_sheets_with_links.pdf*](#). For final report this will be included as part of overall .pdf of whole report.

Appendix 2. Acid sulfate soils - site characteristics

<i>Soil Type</i>	<i>Soil Characteristics</i>	<i>Water Characteristics</i>	<i>Other Characteristics</i>
Actual Acid Sulfate Soil	<ul style="list-style-type: none"> • field pH \leq 4; • jarositic horizons (pale yellow mineral deposits). Where the watertable fluctuates, jarosite may precipitate along cracks or root fissures in the soil); • iron oxide mottling in soil left exposed to air (e.g. excavated or dredged material); • presence of shell. 	<ul style="list-style-type: none"> • pH < 5.5 in surface ponding, drains, ground water or adjacent streams; • clear or milky blue-green water flowing within or from the site (aluminium released from acid sulfate soils can act as a flocculating agent); • iron stains on drain or pond surfaces, or iron-stained water deposits. 	<ul style="list-style-type: none"> • scalded or bare low-lying areas; • corrosion of concrete and/or steel structures.
Potential Acid Sulfate Soil	<ul style="list-style-type: none"> • pH usually neutral but may be acidic – positive peroxide test; • waterlogged soils –bluegrey or dark greenish grey unripe muds, mid to dark grey estuarine silty sands or sands or dark grey estuarine/tidal lake bottom sediments; • presence of shell. 	<ul style="list-style-type: none"> • pH usually neutral but may be acidic. 	

[Ahern *et al.*, 1998]

Appendix 3. Analytical results for total element analysis of sediments

Sample	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm
AV02.1	17.73	2.9	1.871	7.98	0.1517	1.445	18.16	0.776	7.415	0.1516	0.00455	0.00146	0.03064	1.003	< 2.0	4.9	15.7	71.1	< 0.5	< 0.4
PH02.1	15.02	2.75	2.232	5.475	0.1625	1.306	17.02	0.7499	0.8124	0.1364	0.0059	0.00183	0.01975	0.9185	< 2.0	46.4	28.2	258.4	< 0.5	< 0.4
PH02.2	10.08	2.099	3.133	9.336	0.204	0.6247	10.13	0.9562	1.76	0.2145	0.01186	0.01668	0.07981	21.45	< 2.0	< 0.8	< 0.6	4279	< 0.5	61.6
PH02.3	11.05	2.246	3.411	11.79	0.1047	1.545	12.24	1.144	0.7878	0.257	0.01348	0.00467	0.01975	1.752	44	< 0.8	21.9	342.2	6.9	8.3
PH02.4	0.66	0.75	7.767	22.35	0.0312	0.1645	0.4006	1.52	0.343	0.5471	0.01283	0.01058	0.05309	3.565	< 2.0	62.9	19.5	69.7	23.5	25
RL01.1	2.18	0.0878	0.0968	18.74	0.0407	0.2555	3.07	0.219	2.543	0.08218	< 0.0015	0.01106	0.0147	0.1086	13	< 0.8	9.7	12.1	< 0.5	< 0.4
RL01.2	0.56	0.701	7.836	20.21	0.0709	0.1516	0.3947	1.673	0.3237	0.6397	0.01434	0.01042	0.02879	3.648	< 2.0	36.4	23.2	85.2	8.9	< 0.4
RL01.3	0.47	< 0.0100	0.601	36.89	0.0164	0.0761	0.3874	0.2211	0.04598	0.162	< 0.0015	0.00126	0.01594	0.1539	37	< 0.8	2.6	28.8	1.5	< 0.4

Appendix 3. (continued)

Sample	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	Sn	Sb	I	Cs	Ba	La	Ce	Nd	Pb	Th	U
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
AV02.1	1.8	724.3	56.5	569.9	4.6	40.3	5.4	12.7	0.7	3	< 0.8	48.6	< 1.5	64.4	< 2.0	6.8	< 3.0	38.7	12.3	< 0.9
PH02.1	< 0.4	1069	77.6	119.1	3.5	62.4	3	10.3	1	3.7	< 0.8	110.2	< 1.5	32.1	11.1	12.5	< 3.0	133.7	23.3	< 0.9
PH02.2	< 0.4	713.6	45.6	145.7	12.4	77.5	< 0.8	7.4	0.4	1148	15	< 1.5	< 1.5	55.4	18.6	17.2	< 3.0	994	48.5	< 0.9
PH02.3	4	1242	92.8	122.9	15.4	137.5	11.4	22.8	0.5	< 0.5	1.2	149.2	< 1.5	83.9	15.9	21	< 3.0	27.5	14.6	7.8
PH02.4	1.6	115.4	125	94.4	31.5	173.8	16.4	2.7	< 0.3	< 0.5	< 0.8	< 1.5	7.5	233.6	25.9	45.3	< 3.0	24.8	18	11.2
RL01.1	< 0.4	52.5	10.9	67.3	7.7	173.3	10.1	7.8	0.4	1.4	< 0.8	< 1.5	< 1.5	52.7	< 2.0	< 2.5	< 3.0	2.2	7.3	< 0.9
RL01.2	1	143.5	125	101.4	36.6	171.8	15.9	1	0.4	6.4	26.2	< 1.5	6.8	330.1	35.3	53.2	34.4	670.6	64.8	6.3
RL01.3	< 0.4	4.6	11.7	18.1	12.6	245.5	12.2	< 0.5	< 0.3	1.5	< 0.8	< 1.5	4.6	53.3	12.3	< 2.5	< 3.0	7.6	10.6	< 0.9

Glossary

Acid Sulfate Soil (ASS) – a soil or soil horizon which contains sulfides or an acid soil horizon affected by oxidation of sulfides. Acid sulfate soils are the common name given to naturally occurring sediments and soils containing iron sulfides (principally iron sulfide or iron disulfide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid.

Note: The term acid sulfate soil generally includes both actual and potential acid sulfate soils. Actual and potential acid sulfate soils are often found in the same soil profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons.

Actual acid sulfate soils (AASS) – soils containing highly acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides, primarily sulfide. This oxidation produces hydrogen ions in excess of sediment's capacity to neutralise the acidity resulting in soils of pH of 4 or less when measured in dry season conditions. These soils can usually be identified by the presence of yellow mottles and coatings of jarosite.

Potential acid sulfate soils (PASS) – soils which contain iron sulfides or sulfidic material which have not been exposed to air or oxidised. The field pH of these soils in their undisturbed state can be pH 4 or more and may be neutral or slightly alkaline. However, they pose a considerable environmental risk when disturbed, as they will become very acidic when exposed to air and oxidised.

AHD (Australian Height Datum) – mean sea level based on official tide gauges around the coastline.

Alluvial – material deposited by a stream of running water.

Alluvial Origin – deposited by water action.

ANC - Acid Neutralising Capacity. A measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH.

AVS – Acid volatile sulfides (S_{AV}). Reactive reduced sulfur phases (such as iron 'monosulfides') that oxidise readily on contact with air. They are often associated with organic-rich sediments, drains and lake bottoms, and oxidise rapidly when exposed to oxygen.

CRS – Chromium-reducible sulfur (S_{CR}). Provides a measure of reduced inorganic sulfide content. This method is not subject to interferences from organic sulfur.

Estuarine - of, or pertaining to an estuary.

Estuary – a simple geomorphological definition of an estuary is "...a funnel shaped opening of a river in the sea" (Reinick and Singh 1980). Other definitions include criteria such as being tidally effected and dilution of marine and fresh water. A generally accepted definition is that of Pritchard (1967) who describes an estuary as "...a semi-enclosed coastal body of water which has free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage". A more recent geologically orientated definition by Dalrymple, Zaitlin and Boyd (1992) has recognised that estuaries form by the drowning of river valleys as sea level rises, and recognise the limits of an estuary by sedimentary criteria. They define an estuary as "...the seaward portion of a drowned valley system which receives sediment from both fluvial and marine sources and which contains facies influenced by tide, wave and fluvial processes. The estuary is considered to extend from the landward limit of tidal facies at its head to the seaward limit of coastal facies at its mouth".

Fluvial – of, or pertaining to a river or rivers.

Holocene – a period of time from about 10,000 years ago to the present, an epoch of the Quaternary period.

Holocene transgression – Holocene is the name of a geological time period (or ‘epoch’) commencing ~10,000 years ago and extending to present. Transgression is the term used to describe the progressive marine incursion of the land surface as sea level rises.

Horizon - with reference to soils, a layer of soil, approximately parallel to the land surface, with morphological properties different from layers below and/or above it.

Iron Flocc – particulate deposits of iron (ferric) compounds which form a ‘coat’ on all surfaces.

Jarosite – ochre-yellow or brown hydrous potassium iron sulfate mineral: $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$.

Monosulfides – (FeS) Fe III is reduced to Fe II by bacterial action and then combines with dissolved sulfides to form FeS.

Oxidise - the process of reacting with oxygen.

pHFOX – Field pH. (pH of soil and hydrogen peroxide).

pH(1:5 soil: H₂O) –pH of a 1:5 solution of soil and deionised water.

pH(0.01M CaCl₂) – pH of a 1:5 solution of soil and 0.01 molar CaCl₂.

Pleistocene – the name of a geological time period (or ‘epoch’) commencing 1.8 million years ago and extending to ~10,000 years ago, it is an epoch of the Quaternary period.

Pyrite – pale-bronze or brass-yellow, isometric mineral: FeS_2 ; the most widespread and abundant of the sulfide minerals.

Quaternary – a geological time period extending from 1.8 million years ago to present time; incorporates both the Pleistocene and Holocene epochs.

Tertiary – a period of time between sixty five and three million years ago, prior to the Quaternary period.

Tidal land – includes reefs shoals and other land permanently or periodically submerged by waters subject to tidal influence.

Transgression – the spread or extension of the sea over land areas.

Watertable – portion of the ground saturated with water, often used specifically to refer to the upper limit of the saturated ground.

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