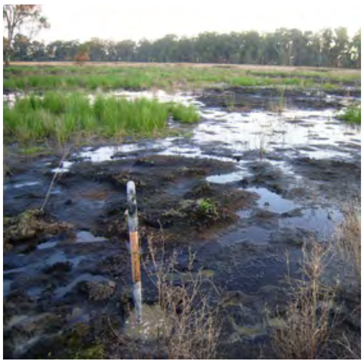
Assessment of Acid Sulfate Soil Materials in the Victorian Northern Flowing Rivers Region of the Murray-Darling Basin


Prepared for the Murray-Darling Basin Authority
October 2010

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

For: Murray Darling Basin Authority

OCTOBER, 2010

Project Name:	Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region
SMEC Project Number:	3001801
Report for:	Murray Darling Basin Authority

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
00 – Final	17/09/2010	Blake Dickson	Stephen Barnett	Rob Dobinson
01 – Final	07/10/2010	Blake Dickson	Stephen Barnett	Rob Dobinson

ISSUE REGISTER

Distribution List	Date Issued	Number of Copies
Murray Darling Basin Authority:	07/10/2010	1 – electronic + appendices
SMEC staff:	07/10/2010	1 – electronic + appendices
North Sydney Office Library (SMEC office location):	07/10/2010	1 – electronic + appendices
SMEC Project File:	07/10/2010	1 – electronic + appendices

SMEC COMPANY DETAILS

SMEC Australia Pty Ltd

PO BOX 1052, North Sydney, NSW 2059

Level 6, 76 Berry Street North Sydney, NSW 2060

Tel: 61 2 9925 5555

Fax: 61 2 9925 5566

Email: Blake.dickson@smec.com

www.smec.com

Copyright and Disclaimer

Cover Photographs

Selection of sites and soil materials from the Victorian Northern Flowing Rivers Region. Photographer: Blake Dickson.

Acknowledgements

The funding for this project was provided by MDBA.

We would like to thank Rob Kingham from the MDBA for his assistance in providing approvals for the sites within the Victorian Northern Flowing Rivers Region. We would like to thank Sandy Hodge, Tracey Rigney and John Clarke from the Barengi Gadjin Land Council for providing approvals and cultural heritage services for the Wimmera River fieldworks. We would like to thank the landholders at Buffalo Swamp wetland for providing access to their land and for their cooperation with the field survey team.
We would like to thank Melanie Watts from the North Central Catchment Management Authority for providing advice and previous environmental data for Bet Bet Creek and Avoca River wetland sites. We would like to thank Janet Holmes from the Department of Sustainability and Environment for providing advice regarding prescribed burns information and aerial photo data supply.

EXECUTIVE SUMMARY

The Victorian Northern Flowing Rivers priority region is a group of rivers and wetlands that flow north to the River Murray. The main river systems include the Goulburn River, tributary systems such as Gunbower Creek connected to the River Murray, Wimmera River and Avoca River. There are also smaller creeks and tributaries such as Bet Bet Creek, Richardson River and basins such as Round Lake near Swan Hill. There are a series of water control structures along several of these systems such as Goulburn Weir and irrigation channels within cropping farmlands throughout the region. The Victorian Northern Flowing Rivers priority region is spatially diverse with priority wetlands spread over a large area of central and northern Victoria. The majority of systems surveyed were either channels or cut off lagoons along the major river systems noted above.

The Murray-Darling Basin Authority (MDBA), in partnership with its Partner Governments and scientists, instigated the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project (MDB ASSRAP), which aims to assess the spatial extent of, and risks posed by acid sulfate soil materials in the Murray-Darling Basin. The MDB ASSRAP project also aims to identify and assess broad management options. The MDBA Acid Sulfate Soil Risk Assessment Advisory Panel prioritised 96 wetlands throughout the Murray-Darling Basin for detailed acid sulfate soil assessment. This report provides the results of Phase 1 of a two-phased detailed acid sulfate soil assessment procedure for priority wetlands in the Victorian Northern Flowing Rivers priority region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the Victorian Northern Flowing Rivers priority region wetlands.

This study identified the presence of acid sulfate soil materials in all 17 wetlands surveyed within the Victorian Northern Flowing Rivers region. Sixty seven sites out of the 74 surveyed contained acid sulfate materials within one, several or all layers sampled. Acid sulfate soil materials were observed in 196 out of the 338 (58%) soil layers sampled. The type and prevalence of acid sulfate soil materials observed in each wetland is summarised in the table below.

Type of Acid Sulfate Soil Material	Wetland ID (Number of Soil Layers)																
-	40304	40355	40383	40400	40416	40486	40553	40590	40851	40853	40855	40858	40859	40860	40861	40862	40863
Sulfuric	0	0	**3**	0	0	**1**	0	**1**	0	0	0	0	0	**2**	0	**1**	0
Hypersulfidic	0	**2**	**2**	**1**	0	**1**	0	**2**	**1**	0	0	0	0	**1**	0	0	0
Hyposulfidic ($S_{CR} \geq 0.10\%$)	**4**	0	0	**3**	0	**4**	0	0	0	0	**5**	**9**	**4**	**7**	**2**	**5**	**7**
Monosulfidic (observed)	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0
Monosulfidic (potential)	**9**	**1**	**12**	**2**	**4**	**5**	0	**4**	**2**	0	**7**	**3**	**4**	**4**	**4**	**2**	**2**
Hyposulfidic (S_{CR} < 0.10%)	8	2	13	5	25	14	2	8	3	3	13	1	2	10	14	1	3
Other acidic	0	6	37	0	11	0	4	9	4	13	6	0	0	0	1	0	0
Other soil	23	0	0	0	0	2	0	0	0	5	15	0	4	0	3	0	0

Note: Red data indicates materials of concern.

Sulfuric soil materials were observed at six sampling sites. The S_{CR} (reduced inorganic sulfur) values ranged between < 0.01 and 1.02% S. Sulfidic soil materials (i.e. $S_{CR} \geq$

0.01% S) were present in all 17 wetlands surveyed. Wetlands 40400, 40858, 40860, 40862 and 40863 had the highest percentage of sites containing sulfidic soil materials (i.e. 100% of soil materials). Hypersulfidic materials occurred in the soil profile at 10 of the 74 sampling sites. Sites where hypersulfidic materials occurred did not show a trend of occurrence and were encountered in both surface and subsoils at some wetland sites. Typically, hypersulfidic materials were a singular layer in the soil profile where encountered.

Monosulfidic soil materials were present in two of the 17 wetlands examined (Wetland ID 40355 and 40858), with only 2 materials of the 338 samples collected equal to or greater than the monosulfidic criterion ($S_{AV} \geq 0.01\%$ S). A total of 2 sites of the 74 sites examined contained observed monosulfidic soil materials. These results indicate that acidity could develop upon oxidation of sulfides in some of these materials. The surface soil layer (0-10cm) in 59 of the 74 sites (80%) surveyed had a water soluble SO_4 content exceeding the trigger value of 100 mg/L indicating the potential formation of monosulfidic materials. Other acidic soil materials often with a $pH_W < 5.0$ were observed at 9 wetlands and 13 sites also.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project there were six high priority sites based on the presence of sulfuric material, ten high priority sites based on hypersulfidic material, three high priority sites based on hyposulfidic ($S_{CR} \geq 0.10\%$) material and two high priority sites based on monosulfidic material. There were 49 moderate priority sites based on the presence of a hyposulfidic material with $S_{CR} < 0.10\%$. In addition, 59 sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation potential. All wetlands sampled in the Victorian Northern Flowing Rivers region receive a high priority ranking on at least one of the criteria with the exception of wetlands 40553 (Heppels Lagoon) and 40853 (Buffalo Swamp). The potential hazards at the wetland-scale posed by acid sulfate soil materials in priority wetlands in the Victorian Northern Flowing Rivers region are shown in the table below.

Wetland ID	Main Name	Acidification	De-oxygenation	Metal Mobilisation
40304	Round Lake	Low	Medium	Low
40355	Goulburn River	Low to medium	Medium	Low to medium
40383	Loch Garry	Medium	Medium	Medium
40400	Tullaroop Creek	Low to medium	Medium	Low to medium
40416	Gemmills Swamp	Low	Low	Low to medium
40486	Gunbower Creek	Medium	Medium to high	Medium
40553	Heppels Lagoon	Low	Low	Low
40590	Richardsons Lagoon	Medium	Medium	Medium
40851	Avoca River at Scollary Road Bridge	Low to medium	Low to medium	Low to medium
40853	Buffalo Swamp	Low	Low	Low
40855	Wimmera River	Low	Medium to high	Low
40858	Richardson River	Medium	High	Medium
40859	Richardson River	Medium	High	Medium
40860	Bet Bet Creek	High	Medium	High
40861	Bet Bet Creek	High	Medium	High
40862	Bet Bet Creek	High	Medium	High
40863	Bet Bet Creek	High	Medium	High

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Region Overview 1
1.2 Acid Sulfate Soils in the Murray-Darling Basin 2
1.3 Detailed Acid Sulfate Soil Assessments Using Two Phases 5
1.4 Methodologies Used To Assess Acid Generation Potential 6
1.5 Classification Of Soil Materials 7
2 METHODS AND MATERIALS 9
2.1 Field Sampling of Soils and Waters 9
2.2 Laboratory Soil Analysis Methods 11
2.3 Laboratory Water Analysis Methods 12
2.4 Quality Assurance and Quality Control 12
2.4.1 Site Selection and Sample Collection 12
2.4.2 Laboratory Analysis 13
2.5 Criteria For Ranking Soil Materials For Inclusion In Phase 2 Of The Detailed Assessment Process 14
3 RESULTS 15
3.1 Summary of Field and Laboratory Results 15
3.1.1 Soil pH Testing (pH_W, $pH_{PEROXIDE}$ and $pH_{INCUBATION}$) 15
3.1.2 Chromium Reducible Sulfur (S_{CR}) 17
3.1.3 Acid Neutralising Capacity (ANC) 18
3.1.4 Net Acidity 18
3.1.5 Water Soluble $S0_4$ 19
3.1.6 Titratable Actual Acidity (TAA) 19
3.1.7 Retained Acidity (RA) 20
3.1.8 Acid Volatile Sulfide (AVS) 20
3.2 Hydrochemistry 20
4 DISCUSSION 24
5 HAZARD ASSESSMENT 25
5.1 Interpretation of Soil and Water Data 25
6 CONCLUSIONS AND RECOMMENDATIONS 26
7 REFERENCES 28

LIST OF TABLES

Table 1 – Summary Of Parameters Exceeding The Assrap Trigger Values And Score Priority Level At The Victorian Northern Flowing Rivers Region Assessment Sites. ... 2
Table 2 – Study Area Size And Suggested Number Of Sites (Mdba 2010). ... 9
Table 3 – Summary Of Sites Sampled In The Victorian Northern Flowing Rivers Region. ... 10
Table 4 – Summary Of Site And Layer Selection For The Victorian Northern Flowing Rivers Region Priority Wetlands. ... 13
Table 5 – Summary Soil Data For Ph Testing And Sulfur Suite. ... 16
Table 6 – Summary Of The S_{cr} Content And Number Of Sulfidic Soil Materials (I.E. $S_{cr} \geq 0.01\%$ S) Observed Within Each Wetland In The Victorian Northern Flowing Rivers Priority Wetlands. ... 17
Table 7 – Summary Of The Net Acidity Data For All Soil Materials In Each Wetland In The Victorian Northern Flowing Rivers Priority Wetlands. ... 18
Table 8 – Summary Of Surface Water Hydrochemical Characteristics (Field). ... 21
Table 9 – Summary Of Groundwater Hydrochemical Characteristics (Field). ... 21
Table 10 – Summary Of Surface Water Hydrochemical Characteristics (Laboratory). ... 22
Table 11 – Summary Of Groundwater Hydrochemical Characteristics (Laboratory). ... 23
Table 12 – Type And Prevalence Of Acid Sulfate Soil Materials In Each Wetland. ... 24
Table 13 – Type And Prevalence Of Acid Sulfate Soil Materials In The Victorian Northern Flowing Rivers Priority Region. ... 25
Table 14 – Hazard Assessment For The Victorian Northern Flowing Rivers Region. ... 27

LIST OF FIGURES

Figure 1 – Map showing priority wetlands surveyed in the Murray-Darling Basin (source: MDBA, 2010).

Figure 2 – Victorian Northern Flowing Rivers priority region map overview.

Figure 3 – Depth profiles of soil pH for Richardson River (40858), showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 4 – Variation in TAA (mole H^+/tonne) with depth at sites 40383_1 – 40383_6 (Loch Garry).

Figure 5 – Variation in TAA (mole H^+/tonne) with depth at site 40416_1 – 40416_4 (Gemmills Swamp).

LIST OF APPENDICES

APPENDIX 1: ROUND LAKE (40304) SUMMARY REPORT

APPENDIX 2: GOULBURN RIVER (40355) SUMMARY REPORT

APPENDIX 3: LOCH GARY (40383) SUMMARY REPORT

APPENDIX 4: TULLAROOP CREEK (40400) SUMMARY REPORT

APPENDIX 5: GEMMILLS SWAMP (40416) SUMMARY REPORT

APPENDIX 6: GUNBOWER CREEK (40486) SUMMARY REPORT

APPENDIX 7: HEPPELS LAGOON (40553) SUMMARY REPORT

APPENDIX 8: RICHARDSONS LAGOON (40590) SUMMARY REPORT

APPENDIX 9: AVOCA RIVER AT SCOLLARY ROAD BRIDGE (40851) SUMMARY REPORT

APPENDIX 10: BUFFALO SWAMP (40853) SUMMARY REPORT

APPENDIX 11: WIMMERA RIVER (40855) SUMMARY REPORT

APPENDIX 12: RICHARDSON RIVER (40858 - 40859) SUMMARY REPORT

APPENDIX 13: BET BET CREEK (40860 - 40863) SUMMARY REPORT

APPENDIX 14: ASSRAP SCREENING CRITERIA

1 INTRODUCTION

1.1 Region Overview

The Victorian Northern Flowing Rivers priority region is a group of rivers and wetlands that flow north to the River Murray. The main river systems include the Goulburn River, tributary systems such as Gunbower Creek connected to the River Murray, Wimmera River and Avoca River. There are also smaller creeks and tributaries such as Bet Bet Creek, Richardson River and basins such as Round Lake near Swan Hill. There are a series of water control structures along several of these systems such as Goulburn Weir and irrigation channels within cropping farmlands throughout the region.

The Victorian Northern Flowing Rivers priority region is spatially diverse with priority wetlands spread over a large area of central and northern Victoria. The majority of systems surveyed were either channels or cut off lagoons along the major river systems noted above. Due to the spatial spread of the wetlands and associated landforms, discussion of characteristics is detailed in the summary reports provided in Appendix 1 – 13.

Salinity typically increased from east to west based on the detailed assessment surveys conducted. Vegetation die back of river red gums and increased prevalence of salt tolerant species were also noted to increase from east to west at the wetlands surveyed. Sulfuric sediment indicators (surface Fe mineralisation and jarosite) have previously been noted to occur in systems such as Bet Bet Creek, Richardson River and the Avoca River within the channel system during dryer conditions by the North Central Catchment Management Authority (NCCMA). Local landowners also provided information during this survey on wetland and channel characteristics at several wetlands during the dryer periods over the past decade. Typical comments included Fe staining of dry channels and odours emanating from drying wetlands and channel systems during drought conditions.

River monitoring data provided by the NCCMA indicates that several systems are saline to highly saline. Reported monitoring conductivities ranging from 6,210 µS/cm at Avoca River at Scollary Road Bridge to 18,100 µS/cm at Bet Bet Creek at Fremantles Bridge and over 200,000 µS/cm at Richardson River at Donald South Road. The high salinities provide a source of sulfate essential for sulfide accumulation and formation in these systems. Acidification of systems has also been reported at Bet Bet Creek in mid to late 2009 with surface water monitoring indicating pH levels between 3.30 – 3.70.

Wetlands in the Victorian Northern Flowing Rivers priority region were identified for acid sulfate soil assessment based on their environmental significance, regulated flows and the risk they may pose to surrounding waters.

Approximately 372 rapid on-ground assessments to determine the likelihood of ASS occurrence were completed throughout the Victorian Murray-Darling Basin as part of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project (MDB ASSRAP). A prioritization process identified the Victorian Northern Flowing Rivers Region as one of seven priority regions across the MDB for further assessment of ASS. Within the region a total of 17 wetlands were selected for further detailed assessment based on being identified as having a high priority as a result of soil and water parameters exceeding screening trigger values (see Appendix 14), and having a high to extreme risk priority profile.

The parameters exceeding the ASSRAP trigger values at the 17 sites selected for further detailed assessment and their score priority level are shown in Table 1 on the following page.

Table 1 – Summary of parameters exceeding the ASSRAP trigger values and score priority level at the Victorian Northern Flowing Rivers region assessment sites.

Wetland ID	Main Name	pH Soil	pH Water	EC Soil	EC Water	Sulfate Soil	Sulfate Water	Priority
40304	Round Lake	-	-	High	High	-	High	High
40355	Goulburn River	Extreme	-	-	-	-	Mod	Extreme
40383	Loch Garry	Extreme	-	-	-	Mod	-	Extreme
40400	Tullaroop Creek	Extreme	-	High	Mod	-	High	Extreme
40416	Gemmills Swamp	Extreme	High	-	-	Mod	Mod	Extreme
40486	Gunbower Creek	Mod	-	High	-	-	High	High
40553	Heppels Lagoon	Mod	-	Mod	-	High	-	High
40590	Richardsons Lagoon	Extreme	-	High	-	High	-	-
40851	Avoca River at Scollary Road Bridge	Extreme	-	High	-	High	-	-
40853	Buffalo Swamp	Extreme	-	-	-	-	-	-
40855	Wimmera River	Extreme	-	High	-	High	-	-
40858	Richardson River	Extreme	-	High	High	-	High	Extreme
40859	Richardson River	-	-	High	High	-	High	High
40860	Bet Bet Creek	Extreme	High	High	High	-	High	Extreme
40861	Bet Bet Creek	Extreme	High	High	High	-	High	Extreme
40862	Bet Bet Creek	Mod	High	High	High	-	High	High
40863*	Bet Bet Creek	-	-	-	-	-	-	-

1.2 Acid Sulfate Soils in the Murray-Darling Basin

Acid sulfate soil is the term commonly given to soil and sediment that contain iron sulfides, or the products of sulfide oxidation. Pyrite (FeS_2) is the dominant sulfide in acid sulfate soil, although other sulfides including the iron disulfide marcasite (Sullivan and Bush 1997; Bush 2000) and iron monosulfides (Bush and Sullivan 1997; Bush *et al.* 2000) can also be found.

Sulfidic sediments accumulate under waterlogged conditions where there is a supply of sulfate, the presence of metabolisable organic matter and iron containing minerals (Dent 1986). Under reducing conditions sulfate is bacterially reduced to sulfide, which reacts with reduced iron to form iron sulfide minerals. These sulfide minerals are generally stable under reducing conditions, however, on exposure to the atmosphere the acidity produced from sulfide oxidation can impact on water quality, crop production, and corrode concrete and steel structures (Dent 1986). In addition to the acidification of both ground and surface waters, a reduction in water quality may result from low dissolved oxygen levels (Sammut *et al.* 1993; Sullivan *et al.* 2002a; Burton *et al.* 2006), high concentrations of aluminium and iron (Ferguson and Eyre 1999; Ward *et al.* 2002), and the release of other potentially toxic metals (Preda and Cox 2001; Sundström et al. 2002; Burton *et al.* 2008a; Sullivan et al. 2008a).

Acid sulfate soils form naturally when sulfate in the water is converted to sulfide by bacteria. Changes to the hydrology in regulated sections of the Murray-Darling Basin (MDB) system (due to higher weir pool levels), and the chemistry of rivers and wetlands have caused significant accumulation of sulfidic material in subaqueous and wetland margin soils. If left undisturbed and covered with water, sulfidic material poses little or no threat of acidification. However, when sulfidic material is exposed to the air, the sulfides react with oxygen to form sulfuric acid (i.e. sulfuric materials with $pH < 4$). When these sulfuric materials are subsequently covered with water, significant amounts of sulfuric acid can be released into the water.

Other hazards associated with acid sulfate soil include: (i) mobilisation of metals, metalloids and non-metals, (ii) decrease in oxygen in the water column when monosulfidic materials are mobilised into the water column, and (iii) production of noxious gases. In severe cases, these risks can potentially lead to damage to the environment, and have impacts on water supplies, and human and livestock health.

Record low inflows and river levels in recent years have led to the drying of many wetlands in the MDB, resulting in the exposure of sulfidic material in acid sulfate soil, and soil acidification in many wetlands. The extent and potential threat posed by acid sulfate soil requires urgent assessment.

Despite decades of scientific investigation of the ecological (e.g. Living Murray Icon Site Environmental Management Plan: MDBC 2006a,b,c), hydrological, water quality (salinity) and geological features of wetlands in the MDB, we have only recently advanced far enough to appreciate the wide spectrum of acid sulfate soil subtypes and processes that are operating in these contemporary environmental settings - especially from continued lowering of water levels (e.g. Lamontagne *et al.* 2006; Fitzpatrick *et al.* 2008a,b; Shand *et al.* 2008a,b; Simpson *et al.* 2008; Sullivan *et al.* 2008a). Hence, the MDB Ministerial Council at its meeting in March 2008 directed the then Murray-Darling Basin Commission (MDBC) to undertake an assessment of acid sulfate soil risk at key wetlands in the MDB.

The MDBC (now the Murray-Darling Basin Authority – MDBA), in partnership with its Partner Governments and scientists, designed the MDB ASS Risk Assessment Project, which aims to assess the spatial extent of, and risks posed by acid sulfate soil in the Murray-Darling Basin. The project also aims to identify and assess broad management options.

Wetlands were identified for assessment based on their environmental significance as well as those that may pose a risk to surrounding waters. Through consultation with jurisdictions more than 19,000 wetlands within the MDB were identified. Due to their ecological significance, the decision was made to prioritise Ramsar-listed wetland complexes of the Murray-Darling Basin for immediate detailed acid sulfate soil assessment. In addition, due to the risk profile, wetlands along the Murray River between Blanchetown (Lock 1) and Wellington were also selected for immediate detailed acid sulfate soil assessment. For all other wetlands, a three tiered assessment process was developed, commencing with a desktop assessment, followed by on-ground rapid assessment and then detailed on-ground assessment at sites identified as high priority or having a risk profile. A total of 96 wetlands were identified and selected for further detailed assessment (shown in Figure 1). These wetlands were divided for logistical reasons into the following seven regions:

- Murray River, Lock 1 to Lock 3, SA (21 wetlands).
- Murray River, Lock 3 to Lock 5, SA (31 wetlands).
- Mildura region, NSW and Vic (8 wetlands).
- Edward and Wakool Rivers, NSW (12 wetlands).
- Murray River, Hume to Yarrawonga, NSW and Vic (6 wetlands).
- Talwood-Mungindi, Queensland (1 wetland).
- Victorian Northern Flowing Rivers (17 wetlands).

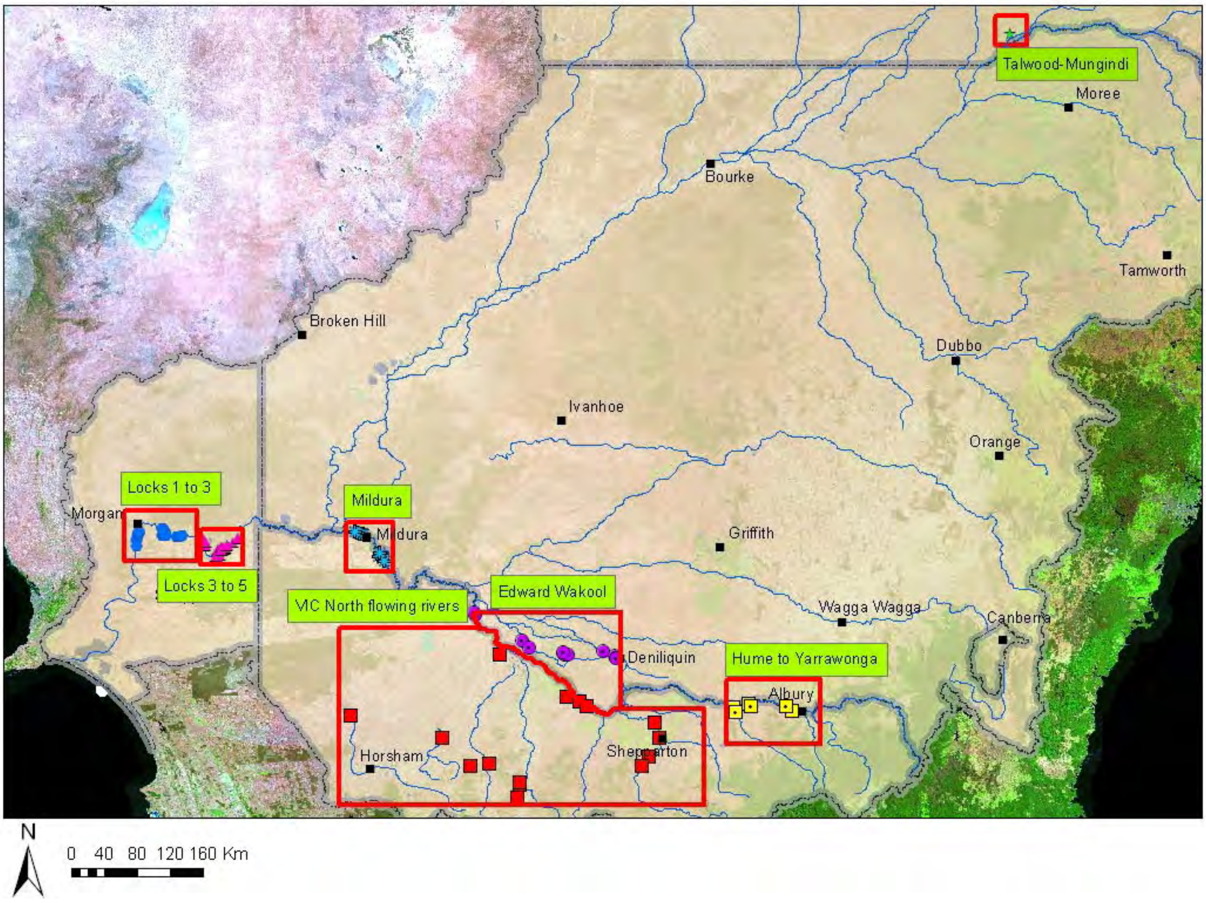


Figure 1 – Map showing priority wetlands surveyed in the Murray-Darling Basin (source: MDBA, 2010).

SMEC Australia Pty Ltd (SMEC) carried out a detailed assessment at 74 representative sites within 17 wetlands in the Victoria Northern Flowing Rivers region in April-May 2010 to determine whether acid sulfate soils were present, or if there was a potential for acid sulfate soils to form within these wetlands (Figure 2). This assessment included the determination of sulfide content within the soil profile at each site with a total of 338 soil layers described and sampled. Water-soluble sulfate was used as an indicator of the potential of monosulfide black ooze (MBO) formation in these wetland sites.

DATE 07/10/2010	SCALE 1:1,250,000	0 12.5 25 50 Km	PAGE SIZE A3	COORDINATE SYSTEM GDA 94	FIG NO. 1
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS				PROJECT NO. 3001801

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

FIGURE TITLE Priority Region Map - Overview

1.3 Detailed Acid Sulfate Soil Assessments Using Two Phases

The detailed assessment stage of the MDB ASS Risk Assessment Project involves comprehensive analysis using a set of established and tested field and laboratory methods to determine the presence and extent of acid sulfate soil and associated hazards, including potential for acidification, metal mobilisation and deoxygenation.

In summary the protocol developed by the MDB ASS Risk Assessment Project Scientific Reference Panel requires a two-phase procedure.

Phase 1 investigations determine whether or not acid sulfate soil materials are present (or absent) for the study area, and provide characterisation of the properties and types of acid sulfate soil materials.

Phase 1 activities include:

- Site selection.
- Site and profile description.
- Sample collection and storage.
- Laboratory analysis (of soil and water).
- Identification of acid sulfate soil materials.
- Prioritisation and selection of Phase 2 samples.
- Interpretation and reporting.

Phase 2 investigations will only be conducted if the acid sulfate soil materials from Phase 1 are determined to be a priority concern for the study area and, based on Phase 1 recommendations, samples will undergo further investigations to determine their nature and severity and the specific risks associated with the acid sulfate soil materials.

Phase 2 activities include:

- Laboratory analysis (of soil).
- Risk assessment.
- Interpretation and reporting, including discussion on broad acid sulfate soil management options.

The soil samples to be analysed for Phase 2 will have been collected as part of the Phase 1 field assessment and then put into storage. Based on the Phase 1 report recommendations the client will identify samples and the analyses to be conducted on each of the samples for Phase 2.

Following a request from the Murray-Darling Basin Authority (MDBA), SMEC were engaged to conduct a Phase 1 detailed assessment of acid sulfate soils at the Victoria Northern Flowing Rivers region wetlands.

1.4 Methodologies Used To Assess Acid Generation Potential

As detailed previously, sulfide minerals are generally stable under reducing conditions, however, on exposure to the atmosphere the acidity produced from sulfide oxidation can impact on water quality, crop production, and corrode concrete and steel structures (Dent 1986). In addition to the acidification of both ground and surface waters, a reduction in water quality may result from low dissolved oxygen levels (Sammut *et al.* 1993; Sullivan *et al.* 2002a; Burton et al. 2006), high concentrations of aluminium and iron (Ferguson and Eyre 1999; Ward *et al.* 2002), and the release of other potentially toxic metals (Preda and Cox 2001; Sundström *et al.* 2002; Burton *et al.* 2008a; Sullivan *et al.* 2008a).

In nature, a number of oxidation reactions of sulfide minerals (principally pyrite: FeS_2) may occur which produce acidity, including:

$$2FeS_2 + 7O_2 + 2H_2O \text{ ---> } 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

$$4FeS_2 + 15O_2 + 10H_2O \text{ ---> } 4FeOOH + 8H_2SO_4$$

A range of secondary minerals, such as jarosite, sideronatrite and schwertmannite may also form, which act as stores of acidity i.e. they may produce acidity upon dissolution (rewetting).

Acid-base accounting (ABA)

Acid-base accounting (ABA) is used to assess both the potential of a soil material to produce acidity from sulfide oxidation and also its ability to neutralise any acid formed (e.g. Sullivan *et al.* 2001, Sullivan *et al.* 2002b).

The standard acid based accounting applicable to acid sulfate soils is described in Ahern *et al.* (2004) and summarised here. The equation below shows the calculation of Net Acidity (NA).

Net Acidity (NA) = Potential Sulfidic Acidity (PSA) + Titratable Actual Acidity (TAA) + Retained Acidity (RA) – Acid Neutralising Capacity (ANC)/Fineness Factor (FF)

The components in this ABA are further discussed below and by Ahern *et al.* (2004).

- Potential Sulfidic Acidity (PSA) also known as the 'acid generation potential' (AGP) is most easily and accurately determined by assessing the Chromium reducible sulfur (S_{CR} or CRS) and then converting this to PSA (AGP) as described in Ahern *et al.* 2004.
- Titratable Actual Acidity (TAA) is a measure of the actual acidity in acid sulfate soil materials that have already oxidised. It measures the sum of both soluble and exchangeable acidity.
- Retained Acidity (RA) is the acidity 'stored' in minerals such as jarosite, schwertmannite and other hydroxy sulfate minerals. Although these minerals may be stable under acidic conditions, they can release acidity to the environment when these conditions change.
- Acid Neutralising Capacity (ANC) is measured in soils with pH_{KCl} values > 6.5. These soils may potentially have ANC in the form of (usually) carbonate minerals, principally of calcium, magnesium and sodium. The carbonate minerals present are estimated by titration and alkalinity present expressed in $CaCO_3$ equivalents. By accepted definition (Ahern *et al.* 2004), any acid sulfate soil material with a pH_{KCl} < 6.5 has a zero ANC.

Fineness Factor (FF) is defined by Ahern *et al.* (2004) as 'A factor applied to the acid neutralising capacity result in the acid base account to allow for the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime, but may be as high as 3.0 for coarser shell material'. Fine grinding of soil materials may lead to an over-estimate of ANC when carbonates are present in the form of hard nodules or shells. In the soil environment, they may provide little effective ANC as exposure to acid may result in the formation of surface crusts (iron oxides or gypsum), preventing or slowing further neutralisation reactions. For reasons including those above, the use of the Fineness Factor also applies to those naturally occurring alkalinity sources in soil materials as measured by the ANC methods.

1.5 Classification Of Soil Materials

Recently, the Acid Sulfate Soils Working Group of the International Union of Soil Sciences agreed to adopt in principle the following five descriptive terminology and classification definitions of acid sulfate soil materials proposed by Prof Leigh Sullivan and co-authors in a plenary lecture and Acid Sulfate Soils Working Group meeting at the 6th International Acid Sulfate Soil and Acid Rock Drainage Conference in September 2008 in Guangzhou, China (Sullivan *et al.* 2008). This new classification system for acid sulfate soil materials (Sullivan *et al.* 2009) has also been recently (October 2008) adopted by the Scientific Reference Panel of the Murray–Darling Basin Acid Sulfate Soil Risk Assessment Project for use in the detailed assessment of acid sulfate soils in the Murray–Darling Basin.
The criteria to define the soil materials are as follows:

1. **Sulfuric materials** – soil materials currently defined as sulfuric by the Australian Soil Classification (Isbell 1996). Essentially, these are soil materials with a pHw < 4 as a result of sulfide oxidation.
2. **Sulfidic materials*** – soil materials containing detectable sulfide minerals (defined as containing greater than or equal to 0.01% sulfidic S). The intent is for this term to be used in a descriptive context (e.g. sulfidic soil material or sulfidic sediment) and to align with general definitions applied by other scientific disciplines such as geology and ecology (e.g. sulfidic sediment). The method with the lowest detection limit is the Cr-reducible sulfide method, which currently has a detection limit of 0.01%; other methods (e.g. X-ray diffraction, visual identification, Raman spectroscopy or infra red spectroscopy) can also be used to identify sulfidic materials.

   **This term differs from previously published definitions in various soil classifications (e.g. Isbell, 1996).*
3. **Hypersulfidic material** – Hypersulfidic material is a sulfidic material that has a field pH of 4 or more and is identified by experiencing a substantial* drop in pH to 4 or less (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration of the incubation is either:
   a. until the soil pH changes by at least 0.5 pH unit to below 4; or
   b. until a stable** pH is reached after at least 8 weeks of incubation.

   **A substantial drop in pH arising from incubation is regarded as an overall decrease of at least 0.5 pH unit.*
   ****A stable pH is assumed to have been reached after at least 8 weeks of incubation when either the decrease in pH is < 0.1 pH unit over at least a 14 day period, or the pH begins to increase.*
4. **Hyposulfidic material** – Hyposulfidic material is a sulfidic material that (i) has a field pH of 4 or more and (ii) does not experience a substantial* drop in pH to 4 or

less (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration of the incubation is until a stable** pH is reached after at least 8 weeks of incubation

**A substantial drop in pH arising from incubation is regarded as an overall decrease of at least 0.5 pH unit.*
***A stable pH is assumed to have been reached after at least 8 weeks of incubation when either the decrease in pH is < 0.1 pH unit over at least a 14 day period, or the pH begins to increase.*

5. **Monosulfidic materials** – soil materials with an acid volatile sulfur content of 0.01%S or more.

Non-Acid Sulfate Soil materials

In addition the Scientific Reference Panel of the Murray–Darling Basin Acid Sulfate Soil Risk Assessment Project agreed to identify the other acidic soil materials arising from the detailed assessment of wetland soils in the Murray–Darling Basin, even though these materials may not be the result of acid sulfate soil processes (e.g. the acidity developed during ageing may be the result of Fe^{2+} hydrolysis, which may or may not be associated with acid sulfate soil processes). Also the acidity present in field soils may be due to the accumulation of acidic organic matter and/or the leaching of bases. Of course, these acidic soil materials may also pose a risk to the environment and would be identified during the present course of the Phase 1 detailed assessment. The definition of these other acidic soil materials for the detailed assessment of acid sulfate soils in the Murray–Darling Basin is as follows:

1. **Other acidic soil materials** – either:
    a. Non-sulfidic soil materials that acidify by at least a 0.5 pH_w unit to a pH_w of < 5.5 during moist aerobic incubation.
    b. Soil materials with a $pH_w \geq 4$ but < 5.5 in the field.
2. **Other soil materials** – soils that do not have acid sulfate soil or other acidic characteristics.

2 METHODS AND MATERIALS

2.1 Field Sampling of Soils and Waters

Field sampling of the 17 Victorian Northern Flowing Rivers region priority wetlands was undertaken between 13th April and 24th May 2010. A total of 338 soil layers were collected and analysed from 74 representative soil profiles within the Victorian Northern Flowing Rivers region to assess the current and potential environmental hazard due to the presence of acid sulfate soils (refer to Figure 2 for wetland locations).

The number of sites sampled within each wetland was dependant on the size of the wetland (Table 2). A summary of the number of sites sampled in each of the Victorian Northern Flowing Rivers priority wetlands is presented in Table 3. Sites were selected to ensure that the samples obtained were representative of each wetland for acid sulfate soil assessment. The rationale for site selection within each wetland is presented in Section 2.4.1.

Table 2 – Study area size and suggested number of sites (MDBA 2010).

Study Area Size (ha)	Number of Sample Sites
<5	2
5 – 20	4
20 – 100	8
100 – 500	12
>500	20

Table 3 – Summary of sites sampled in the Victorian Northern Flowing Rivers Region.

Wetland ID	State	CMA	Main Name	Area (m^2)	Area (ha)	No. of Sites
40304	VIC	NCCMA	Round Lake	406,350	41	8
40355	VIC	GBCMA	Goulburn River	11,915	1	3
40383	VIC	GBCMA	Loch Garry	2,062,423	206	12
40400	VIC	NCCMA	Tullaroop Creek	17,709	2	2
40416	VIC	GBCMA	Gemmills Swamp	681,150	68	8
40486	VIC	NCCMA	Gunbower Creek	126,626	13	4
40553	VIC	NCCMA	Heppels Lagoon	44,181	4	2
40590	VIC	NCCMA	Richardsons Lagoon	122,493	12	4
40851	VIC	NCCMA	Avoca River at Scollary Road Bridge	29,375	3	2
40853	VIC	GBCMA	Buffalo Swamp	82,873	8	5
40855	VIC	WCMA	Wimmera River	712,266	71	8
40858	VIC	NCCMA	Richardson River	1,273	<1	2
40859	VIC	NCCMA	Richardson River	2,462	<1	2
40860	VIC	NCCMA	Bet Bet Creek	125,067	13	4
40861	VIC	NCCMA	Bet Bet Creek	141,771	14	4
40862	VIC	NCCMA	Bet Bet Creek	15,177	2	2
40863*	VIC	NCCMA	Bet Bet Creek	-	<1	2

Note: *Site 40857 was removed and replaced with an additional site at Bet Bet Creek (40863) prior to fieldworks commencing.

At the majority of sites the soil profiles were sampled along a toposequence and where possible, the profiles were chosen to represent: (i) the lowest point in the landscape, (ii) a moderately elevated site just above the observed or interpreted normal flow level, and (iii) an elevated site above the normal flow level.

Soil samples were generally collected from at least five sampling depths (to a maximum depth of 110 cm) using a range of implements (i.e. spades, and augers). At dry site locations soil pits were dug using a spade to approximately 60 cm, and then a gouge or jarret auger was used to obtain soil samples below the base of the pit down to 110 cm or auger refusal. Soil samples were collected in two separate plastic jars (70 mL) with a screw top lid. Additional soil samples (500 g) were packed into plastic bags in which retained air was minimised for potential future Phase 2 laboratory analysis. Where soils were below the water, soil samples were obtained by using a shovel to grab the upper 20 cm and then a gouge or jarret auger was used to approximately 110 cm depth or to auger refusal. Where monosulfides were present the sample was collected into two jars (250 mL) with a screw top lid. All soil samples were maintained at ≤ 4^oC prior to analysis at the Environmental Analysis Laboratory, Southern Cross University.

Soil samples from each depth at all sites were placed into two separate chip-trays. One tray was used in the determination of the pH following incubation ($pH_{INCUBATION}$) and the other was for long term archive storage.

Site and profile descriptions including global positioning system (GPS) coordinates are presented for each wetland summary report in Appendix 1 - 13. Digital photographs were also taken to document each site and soil profile characteristics (see Appendix 1 - 13).

Surface water and groundwater quality data was collected from 42 sites in the Victorian Northern Flowing Rivers region and are presented in Appendix 1 - 13. Water temperature, pH, specific electrical conductivity (SEC), dissolved oxygen (DO), turbidity and redox potential (ORP) were determined in the field using calibrated electrodes linked to a TPS 90-FLMV multi-parameter meter. Alkalinity was also determined in the field by alkalinity total (0-240mg/L).

Where water was present, filtered (0.45 µm) water samples were collected in 125 mL polyethylene bottles. Samples analysed for metals were acidified with a couple of drops of 0.5 % v/v high grade hydrochloric acid (HCl). Samples were stored at ≤ 4^oC and sent to the ALS Environmental, Melbourne for laboratory analysis.

Further details on the procedures followed in collection and storage of soil and water samples are presented in MDBA (2010).

2.2 Laboratory Soil Analysis Methods

All soil samples were oven-dried at 80^oC prior to analysis. Any coarse material (> 2 mm) present was removed by sieving, and then samples were ring mill ground.

The moisture content of each soil sample was determined following oven-drying at 80^oC (Ahern *et al.* 2004). Several parameters were examined to determine whether acid sulfate soil materials were likely to be present, or if there was a potential for acid sulfate soil materials to form. The parameters measured in this study included pH (pH_W, $pH_{PEROXIDE}$, pH_{KCl} and $pH_{INCUBATION}$), titratable actual acidity (TAA), water soluble sulfate, chromium reducible sulfur (S_{CR}), retained acidity (RA), acid neutralising capacity (ANC), and acid volatile sulfide (S_{AV}).

The existing acidity of each soil layer (pH_W) was assessed by measuring the pH in a saturated paste (1:1 soil:water mixture) (Rayment and Higginson, 1992). The $pH_{PEROXIDE}$

was determined following oxidation with 30 % hydrogen peroxide (H_2O_2) (Method 4E1) (Rayment and Higginson, 1992). The KCl extractable pH (pH_{KCl}) was measured in a 1:40 1.0 M KCl extract (Method Code 23A), and the titratable actual acidity (TAA) was determined by titration of the KCl extract to pH 6.5 (Method Code 23F) (Ahern *et al.* 2004). TAA is a measure of the actual acidity in soil materials, and the sum of soluble and exchangeable acidity. The pH following incubation ($pH_{INCUBATION}$) was determined on duplicate moistened soil materials placed in chip-trays (Fitzpatrick *et al.* 2008c; Sullivan *et al.* 2009). The duration of the incubation was until a stable pH was reached after at least 8 weeks of incubation.

Water soluble sulfate (1:5 soil:water extract) was conducted on surface soil samples and was prepared following the procedures described in Rayment and Higginson (1992). Water soluble sulfate was analysed by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). The pyritic sulfur content was quantified using the chromium reduction analysis method of Burton *et al.* (2008b). The acid volatile sulfide fraction was extracted using a cold diffusion procedure (Hsieh *et al.* 2002).

Retained acidity (RA) was determined from the difference between 4M HCl extractable sulfur (S_{HCl}) and 1M KCl extractable sulfur (S_{KCl}) when the sample pH_{KCl} was < 4.5 (Method Code 20J) (Ahern *et al.* 2004). The retained acidity identifies stored soil acidity in the form of jarosite and similar relatively insoluble iron and aluminium hydroxy sulfate compounds (Ahern *et al.* 2004). Acid Neutralising Capacity, measured by the ANC_{BT} method (Method Code 19A2) (Ahern *et al.* 2004), was determined for sulfidic samples with a $pH_{KCl} \geq 6.5$. The Net Acidity was estimated by the Acid-Base Account method of Ahern *et al.* (2004). The objective of each method is discussed further in MDBA (2010).

2.3 Laboratory Water Analysis Methods

The analysis of all water samples in this study was carried out by ALS Environmental, Melbourne. In house laboratory methods were equivalent to the recommended methods noted in MDBA (2010). The water quality parameters measured on filtered samples (0.45 µm) in this study included:

- Major cations (Na, K, Ca, Mg) and Si (APHA 3120 ICPOES) (APHA 2005).
- Dissolved bromide (APHA 4500 Br^-) and chloride (APHA 4500 Cl^-) (APHA 2005).
- Dissolved nitrate (NO_3^-) (APHA 4500 NO_3^-) (APHA 2005).
- Dissolved ammonia (NH_4) (APHA 4500 NH_3^-H) (APHA 2005).
- Dissolved phosphate (PO_4) (APHA 4500 P-E) (APHA 2005).
- Dissolved sulfate (SO_4^{2-}) (APHA 3120 ICPOES) (APHA 2005).
- Trace metals (Ag, Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Zn) (APHA 2005).
- Dissolved organic carbon (APHA 2005).

2.4 Quality Assurance and Quality Control

2.4.1 Site Selection and Sample Collection

The Soil Surveyor for all the sampling undertaken in the Victoria Northern Flowing Rivers priority wetlands was Blake Dickson. Sampling was undertaken between 13th April and 24th May 2010 by Blake Dickson, Steven Shaw, Simone d'Unienville and Andres

Grigaliunas. A summary of what was done to select the site locations and layers that were sampled is presented below in Table 4. The sampling team was unable to access certain wetland areas due to steep slopes, deep waters or soft compressible substrate.

Table 4 – Summary of site and layer selection for the Victorian Northern Flowing Rivers region priority wetlands.

Wetland ID	Main Name	Date Sampled	Comments on Site/Layer Selection
40304	Round Lake	21-22/04/10	8 sites, 2 transect moving from high to low points, sampled according to protocol.
40355	Goulburn River	13-14/04/10	3 sites, 1 transect moving from high to low points, sampled according to protocol.
40383	Loch Garry	16-17/04/10	12 sites, 3 transects within the generally dry channel, sampled according to protocol.
40400	Tullaroop Creek	20/05/10	2 sites, 1 transect with sampling within the channel and bank edges, sampled according to protocol.
40416	Gemmills Swamp	17/04/10	8 sites, 2 transect moving from high to low points, sampled according to protocol.
40486	Gunbower Creek	18/05/10	4 sites, 2 transect, sampled according to protocol.
40553	Heppels Lagoon	19/05/10	2 sites, 1 transect, sampled according to protocol.
40590	Richardsons Lagoon	19/05/10	4 sites, 2 transect within the dry channel and margin soils, sampled according to protocol.
40851	Avoca River at Scollary Road Bridge	23/05/10	2 sites, 1 transect within wet and dry section of the channel, sampled according to protocol.
40853	Buffalo Swamp	14-15/04/10	5 sites, 1 transect moving from high to low points with an additional site (5) within an inundation area. Sampled according to protocol with addition of 1 site.
40855	Wimmera River	24/05/10	8 sites, 4 transect sampling within the river channel and cut off channels, sampled according to protocol.
40858	Richardson River	23/05/10	2 sites, 1 transect within the channel with MBO observed, sampled according to protocol.
40859	Richardson River	23/05/10	3 sites, 1 transect within the channel with site 1 a water sample only, sampled according to protocol.
40860	Bet Bet Creek	22/05/10	4 sites, 2 transect within channel and banks, sampled according to protocol.
40861	Bet Bet Creek	22/05/10	4 sites, 1 transect within channel and banks, sampled according to protocol.
40862	Bet Bet Creek	21/05/10	2 sites, 1 transect within channel and banks, sampled according to protocol.
40863*	Bet Bet Creek	21/05/10	2 sites, 1 transect within channel and banks, sampled according to protocol.

Note: *Site 40857 was removed and replaced with an additional site at Bet Bet Creek (40863) prior to fieldworks commencing.

2.4.2 Laboratory Analysis

For all tests and analyses, the Quality Assurance and Quality Control procedures were equivalent to those endorsed by NATA (National Association of Testing Authorities). The standard procedures followed included the monitoring of blanks, duplicate analysis of at least 1 in 10 samples, and the inclusion of standards in each batch. Reagent blanks and method blanks were prepared and analysed for each method. All blanks examined were either at, or very close to, the limits of detection. On average, the frequencies of quality control samples processed were: 5% blanks, ≥ 10% laboratory duplicates, and 5% laboratory controls. The analytical precision was ±5% for all analyses. The Quality Assurance and Quality Control procedures were appropriate for the data quality objectives for the project regarding soil and water sampling and analysis.

2.5 Criteria For Ranking Soil Materials For Inclusion In Phase 2 Of The Detailed Assessment Process

The Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project agreed to recommend that soil materials be assigned the following priorities to undertake the Phase 2 detailed assessment:

High Priority

1) All sulfuric materials.
2) All hypersulfidic materials (as recognised by either 1) incubation of sulfidic materials or 2) a positive net acidity result with a Fineness Factor of 1.5 being used).
3) All hyposulfidic materials with S_{CR} contents ≥ 0.10%S.
4) All surface soil materials (i.e. within 0-20 cm) with water soluble sulfate (1:5 soil:water) contents >100 mg SO_4 L^{-1}.
5) All monosulfidic materials.

Moderate Priority

All hyposulfidic materials with S_{CR} contents < 0.10% S.

No Further Assessment

1) Other acidic soil materials.
2) All other soil materials.

It is important to note, while the criteria identifying samples for Phase 2 analysis is clearly defined, samples only go through to Phase 2 when consideration is given to the wetland as a whole.

3 RESULTS

3.1 Summary of Field and Laboratory Results

3.1.1 Soil pH Testing (pH_W, $pH_{PEROXIDE}$ and $pH_{INCUBATION}$)

The pH_W, $pH_{PEROXIDE}$ and $pH_{INCUBATION}$ data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 (summary reports) and summarised in Table 5. The pH_W values ranged between 3.63 and 9.43, with the majority (50%) ranging between 4.50 – 6.50 and 12% of pH_W values below 4.50 with the remaining 38% >6.50.

A total of eight sites from five wetlands within the Victorian Northern Flowing Rivers region were classified as containing sulfuric materials (i.e. pH_W < 4.0) including sites 40383_1.3 (30-50 cm), 40383_5.4 and 40383_5.5 (60-100 cm), 40486_1.2 (5-35 cm), 40590_3.3 (15-35 cm), 40860_2.3 and 40860_2.4 (20-60 cm), 40862_1.2 (15-35 cm). The sites and wetlands exhibiting low pH_W and sulfuric materials were typically dry or recently dry wetlands with cracking clay soils and Fe mineralisation within the soil matrix. None of the other soils in the Victorian Northern Flowing Rivers region wetlands are classified as sulfuric materials as they all had a pH_W > 4.0.

The $pH_{PEROXIDE}$ values ranged between 1.16 and 9.65. The majority of soils showed a pH drop after treatment with peroxide (97%), with a maximum decrease of 5.65 pH units (e.g. Figure 3). The $pH_{PEROXIDE}$ results also indicate that the majority (70%) of soil materials acidified to pH < 4.0 as a result of sample oxidation. However, the S_{CR} data shows that many of the layers which showed a substantial pH drop (>2.0 pH units) after treatment with peroxide contained no detectable sulfide (i.e. S_{CR} < 0.01% S). While decreases in pH after treatment with peroxide are often used to indicate the presence of sulfide, the S_{CR} data from this survey suggest that pH decreases after peroxide treatment are often due to non-acid sulfate soil factors such as the oxidation of organic matter or other Fe related compounds. The peroxide reaction strength and speed may be a more beneficial assessment tool to determine if sulfide minerals are present in the soil in addition to pH decreases for inland systems due to organic matter influences.

The $pH_{INCUBATION}$ values ranged between 2.55 and 8.34. Nineteen of the 193 sulfidic soil materials (10%) (i.e. S_{CR} ≥ 0.01% S) acidified to pH < 4.0 after at least 8 weeks of incubation (i.e. site layers from 40355_2.3, 40355_3.1, 40383_1.3, 40383_2.3, 40383_2.4, 40383_5.2, 40383_7.2, 40383_11.3, 40400_2.3, 40486_1.2, 40486_4.2, 40590_2.2, 40590_2.3, 40590_3.3, 40590_3.4, 40851_2.4, 40860_2.2, 40860_2.3 and 40862_1.2). In addition, 37 out of the 338 (11%) non-sulfidic soils (i.e. other acidic) acidified to pH < 4.0 over the 8 week incubation period (refer to Appendix 1 – 13 summary reports).

Table 5 – Summary soil data for pH testing and sulfur suite.

Parameter	Units	Minimum	Median	Maximum	n[1]
pH_W[2]	pH unit	3.63	5.64	9.43	337
$pH_{PEROXIDE}$[3]	pH unit	1.16	2.94	9.65	337
pH_{KCl}[4]	pH unit	3.36	5.27	9.62	337
$pH_{INCUBATION}$[5]	pH unit	2.55	4.89	8.34	337
TAA[6]	mole H^+/t	0.00	26.02	165.54	337
Water Soluble SO_4[7]	mg SO_4/L	9.00	315.00	131550.00	83
S_{CR}[8]	Wt. %S	<0.01	<0.01	1.02	337
S_{AV}[9] (DW)	Wt. %S	0.0000	0.0338	0.2518	3
RA[10]	mole H^+/t	0.00	0.00	244.41	337
ANC[11]	$\%CaCO_3$	0.24	2.01	59.25	66
NA[12]	mole H^+/t	-7790.71	44.92	610.12	337

[1] n: number of samples. [2] pH_W: pH in saturated paste with water. [3] $pH_{PEROXIDE}$: pH after treatment with 30% H_2O_2. [4] pH_{KCl}: pH of 1:40 1 M KCl extract. [5] $pH_{INCUBATION}$: pH after at least 8 weeks of incubation. [6] TAA: Titratable Actual Acidity. [7] Water Soluble sulfate: in 1:5 soil:water extract. [8] S_{CR}: Chromium Reducible Sulfur. [9] S_{AV}: Acid Volatile Sulfide. [10] RA: Retained Acidity. [11] ANC: Acid Neutralising Capacity: by definition, where pH_{KCl} < 6.5 ANC = 0. [12] NA: Net Acidity.

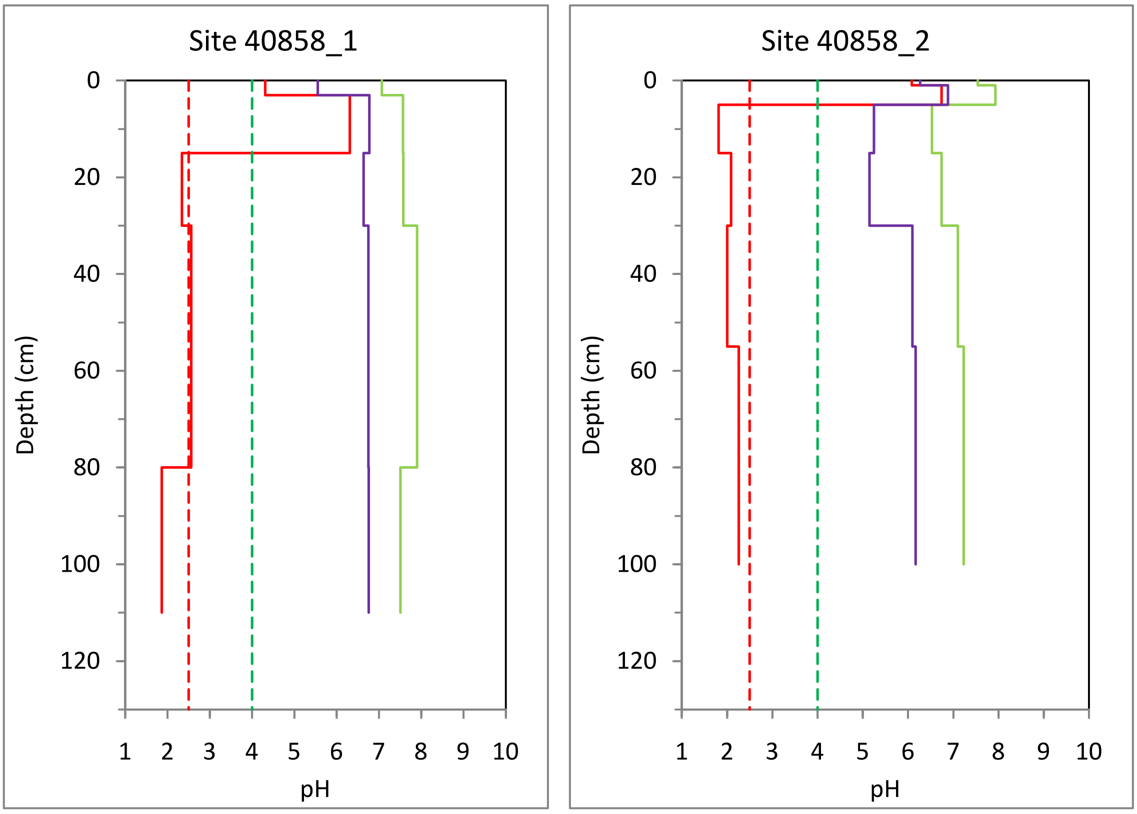


Figure 3 – Depth profiles of soil pH for Richardson River (40858), showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple

line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

3.1.2 Chromium Reducible Sulfur (S_{CR})

The chromium reducible sulfur (S_{CR}) data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 6. The S_{CR} values ranged between < 0.01 and 1.02% S. Sulfidic soil materials (i.e. S_{CR} ≥ 0.01% S) were present in all 17 wetlands examined, with 193 soil materials of the 338 samples collected equal to or greater than the sulfidic criterion (57%).

A summary of the S_{CR} content and number of sulfidic soil materials observed in each wetland is shown in Table 6. Wetlands 40400, 40858, 40860, 40862 and 40863 had the highest percentage of sites containing sulfidic soil materials (i.e. 100% of soil materials). Further information on the distribution of sulfidic sediments within each wetland is provided in each summary report (Appendix 1 – 13).

Table 6 – Summary of the S_{CR} content and number of sulfidic soil materials (i.e. S_{CR} ≥ 0.01% S) observed within each wetland in the Victorian Northern Flowing Rivers priority wetlands.

Wetland ID	Main Name	S_{CR} Range (%S)	*No. of sulfidic sites	No. of sulfidic layers	*Sulfidic Site No.
40304	Round Lake	<0.01 - 0.16	0 (0%)	12 (34%)	n/a
40355	Goulburn River	<0.01 - 0.10	0 (0%)	5 (45%)	n/a
40383	Loch Garry	<0.01 - 0.01	2 (17%)	15 (27%)	7, 11
40400	Tullaroop Creek	0.01 - 0.17	1 (50%)	8 (100%)	2
40416	Gemmills Swamp	<0.01 - 0.02	0 (0%)	25 (69%)	n/a
40486	Gunbower Creek	<0.01 - 0.95	1 (25%)	18 (86%)	4
40553	Heppels Lagoon	<0.01 - 0.01	0 (0%)	2 (33%)	n/a
40590	Richardsons Lagoon	<0.01 - 0.05	2 (50%)	11 (55%)	2, 3
40851	Avoca River at Scollary Road Bridge	<0.01 - 0.03	1 (50%)	4 (50%)	2
40853	Buffalo Swamp	<0.01 - 0.01	0 (0%)	3 (14%)	n/a
40855	Wimmera River	<0.01 - 0.31	0 (0%)	18 (46%)	n/a
40858	Richardson River	0.04 - 1.02	0 (0%)	11 (100%)	n/a
40859	Richardson River	<0.01 - 0.86	0 (0%)	6 (60%)	n/a
40860	Bet Bet Creek	0.01 - 0.65	0 (0%)	18 (90%)	n/a
40861	Bet Bet Creek	<0.01 - 0.15	0 (0%)	16 (80%)	n/a
40862	Bet Bet Creek	0.07 - 0.16	0 (0%)	6 (86%)	n/a
40863	Bet Bet Creek	0.02 - 0.65	0 (0%)	10 (100%)	n/a

Note: Red data indicates at a level of high concern.

* Refers to the Australian Acid Sulfate Soil Identification Key classification (Appendix 3, MDBA 2010).

3.1.3 Acid Neutralising Capacity (ANC)

The acid neutralising capacity (ANC) data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. The measured ANC ranged between 0.24 and 59.25 %$CaCO_3$. The highest ANC results were encountered at wetland 40304 with all soil layers containing ANC. Eight of the wetlands had no ANC in the soil profile (i.e. Wetland ID 40355, 40383, 40416, 40553, 40590, 40851, 40853 and 40861).

3.1.4 Net Acidity

The net acidity data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. Acid-base accounting calculations showed the net acidity ranged between -7,790 and 610 mole H^+/tonne, with a median net acidity of 45 mole H^+/tonne. The net acidity thresholds used to characterise the acid sulfate soil materials in this assessment include low net acidity (< 19 mole H^+/tonne), moderate net acidity (19 - 100 mole H^+/tonne) and high net acidity (> 100 mole H^+/tonne). A summary of the net acidity data for each wetland is given in Table 7, and shows the presence of soil materials with moderate to high net acidities in all wetlands except 40304 Round Lake which has high alkalinity and salinity.

Negative net acidities were typically encountered at saline to highly saline wetlands such as 40304, 40855, 40858 and 40859. Where S_{CR} data was low (e.g. <0.01 – 0.01% S) and the wetland was dry, TAA results were often above the high net acidity threshold (e.g. 40383 and 40590). Only two out of ten hypersulfidic material layers had a high net acidity with the remaining eight having moderate net acidity values. All eight sulfuric (pH_W <4.0) material layers had high net acidity values. The positive net acidities in the non-sulfidic samples were due to the presence of TAA and the lack of any ANC, although some materials also contained retained acidity (refer to Appendix 1 – 13).

Table 7 – Summary of the net acidity data for all soil materials in each wetland in the Victorian Northern Flowing Rivers priority wetlands.

Wetland ID	Main Name	Net Acidity (mole H^+/tonne)		
	-	Minimum	Median	Maximum
40304	Round Lake	-7791	-643	-123
40355	Goulburn River	38	48	125
40383	Loch Garry	6	83	153
40400	Tullaroop Creek	6	33	82
40416	Gemmills Swamp	29	53	136
40486	Gunbower Creek	-542	17	610
40553	Heppels Lagoon	30	52	63
40590	Richardsons Lagoon	29	51	158
40851	Avoca River at Scollary Road Bridge	15	33	61
40853	Buffalo Swamp	0	49	94
40855	Wimmera River	-188	5	130
40858	Richardson River	-179	199	556
40859	Richardson River	-937	3	161
40860	Bet Bet Creek	8	69	544
40861	Bet Bet Creek	0	18	118
40862	Bet Bet Creek	65	71	145
40863	Bet Bet Creek	17	113	243

Note: Red data indicates at a level of high concern i.e. >100 mole H^+/tonne.

3.1.5 Water Soluble $S0_4$

The water soluble SO_4 data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. The water soluble SO_4 in the surface soils (i.e. 0-10 cm) in the Victorian Northern Flowing Rivers region ranged between 9 and 131,550 mg/L. The surface soil layer in 59 of the 74 sites (80%) examined had a water soluble SO_4 content exceeding the trigger value of 100 mg/L indicating the potential formation of monosulfidic materials. The two wetlands with a water soluble SO_4 content less than the trigger value included sites 40553 and 40853.

3.1.6 Titratable Actual Acidity (TAA)

The titratable actual acidity (TAA) data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. The TAA ranged between zero and 165 mole H^+/tonne, with a median TAA of 26 mole H^+/tonne. An increase in the TAA with depth was observed at some of the currently dry wetland sites surveyed (e.g. Figure 4). However, this was reversed in some wetlands that contained water (e.g. Figure 5) with TAA decreasing with depth.

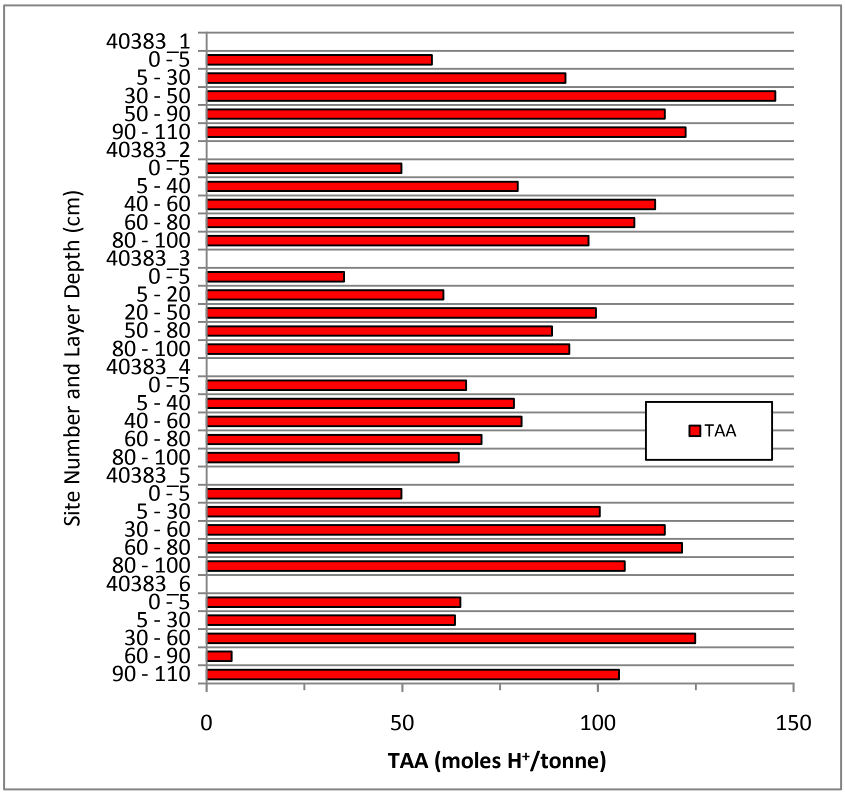


Figure 4 – Variation in TAA (mole H^+/tonne) with depth at sites 40383_1 – 40383_6 (Loch Garry).

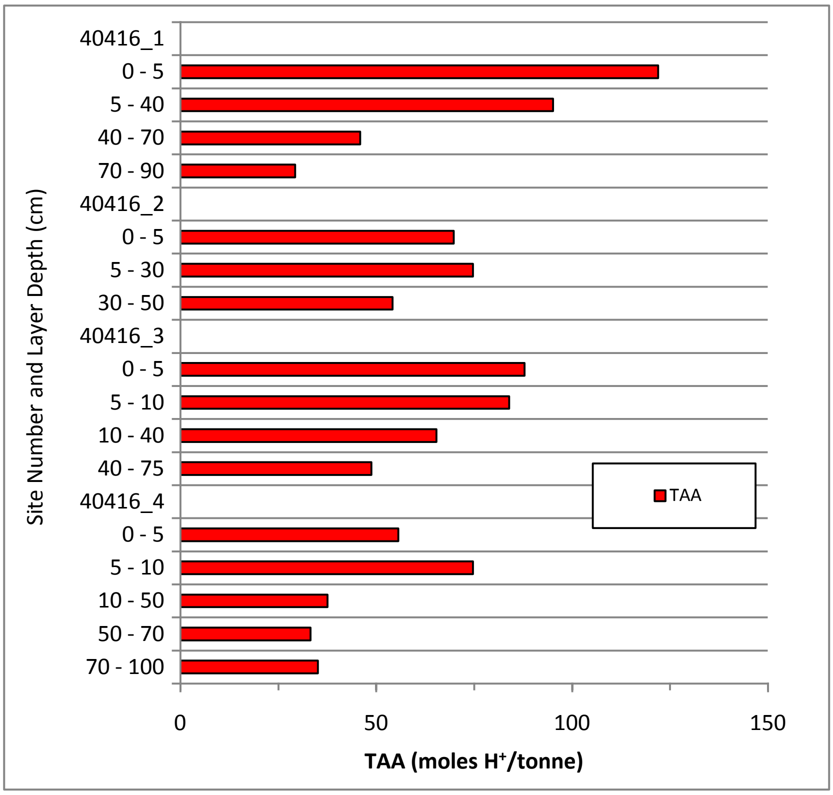


Figure 5 – Variation in TAA (mole H^+/tonne) with depth at site 40416_1 – 40416_4 (Gemmills Swamp).

3.1.7 Retained Acidity (RA)

The retained acidity data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. The retained acidity ranged between zero and 244 mole H+/tonne, with the majority of soil layers having no retained acidity (i.e. 264 materials of the 338 samples collected, 78%). Retained acidity was only detected in samples collected from nine of the wetlands (i.e. Wetland ID 40355, 40383, 40416, 40486, 40590, 40553, 40853, 40860 and 40862). Dry wetland sites generally contained retained acidity throughout the soil profile such as 40383 and 40590.

3.1.8 Acid Volatile Sulfide (AVS)

The acid volatile sulfide (S_{AV}) data for the wetland sites examined in the Victorian Northern Flowing Rivers region are presented in Appendix 1 – 13 and summarised in Table 5. The S_{AV} values ranged between < 0.001 and 0.2518 % S. Monosulfidic soil materials (i.e. S_{AV} ≥ 0.01% S) were present in two of the 17 wetlands examined (i.e. Wetland ID 40355 and 40858), with only 2 materials of the 338 samples collected equal to or greater than the monosulfidic criterion. A total of 2 sites of the 74 sites examined contained monosulfidic soil materials. Further information on the distribution of monosulfidic sediments within each wetland is given in Appendix 1 – 13.

3.2 Hydrochemistry

The hydrochemical characteristics of the surface water and groundwater in the Victorian Northern Flowing Rivers region were measured to provide an indication of the baseline water chemistry at the time of survey. Some of the chemical parameters measured may show temporal and seasonal variations, and therefore the data collected only represents a snapshot of the water quality in the Victorian Northern Flowing Rivers region.

Surface water quality data was collected from 25 sites in the Victorian Northern Flowing Rivers region priority wetlands. Surface water sampling and measurements occurred at all wetlands with the exception of 40590 which was dry. Groundwater data was collected from 17 locations in the Victorian Northern Flowing Rivers region priority wetlands. Groundwater sampling and measurements occurred at all wetlands with the exception of 40486, 40553, 40590, 40858 and 40859. A summary of the surface water and groundwater characteristics measured in the field are presented below in Tables 8 and 9.

The field pH of the surface waters ranged between 5.46 and 10.09 (Table 8), with high salinity wetlands typically above the upper trigger value (e.g. 40304 and 40855) and the remaining typically lower (e.g. 40383) and outside the most relevant ANZECC/ARMCANZ (2000) trigger values for aquatic ecosystems of 6.5 and 8.0. The water data indicates that the surface water at site 40383 has been affected by acidification (site 40383_9) with a pH value of 5.46, respectively.

The surface waters were often saline to highly saline with a median SEC of 2,530 µS/cm. Salinity typically increased moving east to west for the wetlands surveyed. The results of the field analysis and interpretation are presented in Appendix 1 – 13 for each wetland.

A summary of the surface water and groundwater laboratory analysis results are presented below in Tables 10 and 11. Typically, where results were noted to be above the ANZECC/ARMCANZ (2000) guideline trigger value it related to nutrients (i.e. NO_3, NH_4, PO_4), and dissolved metals (i.e. Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn). The results and interpretation of laboratory results are presented in Appendix 1 – 13 for each wetland.

Table 8 – Summary of surface water hydrochemical characteristics (field).

Surface Water	pH (pH units)	SEC (µS/cm)	DO (mg/L)	Eh (Mv)	Turbidity (NTU)	Alkalinity (mg/L as HCO_3)
Minimum	5.46	17.1	1.88	-120	0	0
Median	6.94	2530	9	101	30	100
Maximum	10.09	199700	14.57	272	982	>240
n[1]	25	25	25	25	25	25

Note: [1] n: number of samples.

Table 9 – Summary of groundwater hydrochemical characteristics (field).

Ground Water	pH (pH units)	SEC (µS/cm)	DO (mg/L)	Eh (Mv)	Turbidity (NTU)	Alkalinity (mg/L as HCO_3)
Minimum	4.86	271	0.08	-220	0	0
Median	6.17	4720	1.06	120	381.5	100
Maximum	7.62	78600	3.38	212	2650	>240
n[1]	17	17	17	17	17	17

Note: [1] n: number of samples.

Table 10 – Summary of surface water hydrochemical characteristics (Laboratory).

Cations, Anions, Nutrients and Other												
-	Na	K	Ca	Mg	Si	Br	Cl	NO_{3-}	NH_4	PO_4	SO_4	DOC
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Minimum	5	3	3.6	3	0.1	<5	5	<0.01	<0.1	<0.01	<1	6
Median	350	16	57	96	4.5	<5	710	0.03	0.2	0.01	230	22
Maximum	99000	860	820	16000	30	<50	150000	15	34	1.2	23000	100
n[1]	19	19	19	19	19	19	19	19	19	19	19	19

Dissolved Metals													
-	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Minimum	<1	<10	<1	<0.2	<1	<1	<1	<20	1	<1	<1	<1	1
Median	<1	50	3	<0.2	1	1	1	1285	170	5	1	1	4
Maximum	<1	660	22	0.8	69	4	5	72000	2700	27	14	17	72
n[1]	19	19	19	19	19	19	19	19	19	19	19	19	19

Note: [1] n: number of samples.

Table 11 – Summary of groundwater hydrochemical characteristics (Laboratory).

Cations, Anions, Nutrients and Other												
-	Na	K	Ca	Mg	Si	Br	Cl	NO_{3-}	NH_4	PO_4	SO_4	DOC
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Minimum	40	4	16	13	15	<5	47	0.02	0.1	0.01	47	8
Median	640	18.5	205	240	35.5	<5	1450	0.745	1.55	0.01	1450	24.5
Maximum	16000	320	1100	1800	80	<5	36000	12	41	0.05	4900	170
n[1]	12	12	12	12	12	12	12	12	12	12	12	12

Dissolved Metals													
-	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Minimum	<1	<10	<1	<0.2	<1	<1	<1	<20	5	2	<1	<1	2
Median	<1	55	3	0.2	22.5	1	1	1250	3750	20	1	2	22
Maximum	<1	13000	30	3	2300	20	30	1400000	160000	1100	1	80	1600
n[1]	12	12	12	12	12	12	12	12	12	12	12	12	12

Note: [1] n: number of samples.

4 DISCUSSION

A detailed assessment was undertaken in the Victorian Northern Flowing Rivers region in April and May 2010 to determine whether acid sulfate soils were present, or if there was a potential for acid sulfate soils to form within these wetlands.

This study identified the presence of acid sulfate soil materials in all 17 wetlands surveyed within the Victorian Northern Flowing Rivers region. Sixty seven sites out of the 74 surveyed contained acid sulfate materials within one, several or all layers sampled. Acid sulfate materials were observed in 196 out of the 338 (58%) soil layers sampled. The water soluble sulfate contents of 65 out of the 83 (78%) surficial soil (e.g. 0-10cm) materials sampled were equal to or exceeded the trigger value of 100 mg/L indicating the potential formation of monosulfidic materials.

The type and prevalence of acid sulfate soil materials observed in each wetland is summarised in Table 12. Sulfuric materials were observed within 8 soil layers in five of the wetlands. All sulfuric soil materials had high net acidities (i.e. > 100 mol H^+/tonne). Hypersulfidic materials were observed within 10 soil layers in seven of the wetlands. Two out of the 10 hypersulfidic material layers had a high net acidity (i.e. Loch Garry - 40383_11.3 and Bet Bet Creek 40860_2.2) with the remaining eight soil layers having moderate net acidity values.

Hyposulfidic soil materials were observed in all 17 of the wetlands surveyed. Hyposulfidic material with S_{CR} >0.10% S were identified within 48 soil layers with hyposulfidic materials S_{CR} < 0.10% S identified at 127 soil layers. A total of two sites in two of the wetlands (40355 and 40858) examined contained monosulfidic soil materials.

The potential formation of monosulfidic materials was identified in the surface soils at all of the wetlands examined with the exception of 40553 and 40853. Other acidic soil materials often with a pH_W < 5.0 were observed at 9 wetlands and 13 sites, and soil acidity may be sufficient for mobilisation of aluminium at some sites.

Table 12 – Type and prevalence of acid sulfate soil materials in each wetland.

Type of Acid Sulfate Soil Material	Wetland ID (Number of Soil Layers)																
-	40304	40355	40383	40400	40416	40486	40553	40590	40851	40853	40855	40858	40859	40860	40861	40862	40863
Sulfuric	0	0	**3**	0	0	**1**	0	**1**	0	0	0	0	0	**2**	0	**1**	0
Hypersulfidic	0	**2**	**2**	**1**	0	**1**	0	**2**	**1**	0	0	0	0	**1**	0	0	0
Hyposulfidic (S_{CR} ≥ 0.10%)	**4**	0	0	**3**	0	**4**	0	0	0	0	**5**	**9**	**4**	**7**	**2**	**5**	**7**
Monosulfidic (observed)	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0
Monosulfidic (potential)	**9**	**1**	**12**	**2**	**4**	**5**	0	**4**	**2**	0	**7**	**3**	**4**	**4**	**4**	**2**	**2**
Hyposulfidic (S_{CR} < 0.10%)	8	2	13	5	25	14	2	8	3	3	13	1	2	10	14	1	3
Other acidic	0	6	37	0	11	0	4	9	4	13	6	0	0	0	1	0	0
Other soil	23	0	0	0	0	2	0	0	0	5	15	0	4	0	3	0	0

Note: Red data indicates materials of concern.

5 HAZARD ASSESSMENT

5.1 Interpretation of Soil and Water Data

Sulfuric soil materials were observed at six sites and hypersulfidic materials at 10 sites (refer to Table 13). Sites where hypersulfidic materials occurred did not show a trend of occurrence and were encountered in both surface and subsoils at some wetland sites. Typically, hypersulfidic materials were a singular layer in the soil profile where encountered.

The data indicates that in eight of the 17 wetlands surveyed the degree of acidification hazard is low or low to medium (see Appendix 1 – 13). In five of the 17 wetlands surveyed the degree of acidification hazard is medium. However, four of the wetlands assessed (i.e. Wetland ID 40860, 40861, 40862 and 40863) contained acid sulfate soil materials with high net acidities (sulfuric and hypersulfidic materials) that represent a high acidification hazard.

Hyposulfidic soil materials with S_{CR} ≥ 0.10% S and S_{CR} < 0.10% S were present at 20 and 49 sampling sites, respectively (Table 13). In addition, other acidic soil materials often with a pH < 5.0 were observed at an additional 35 sites, and soil acidity at this level may be sufficient for mobilisation of aluminium at some sites under the right environmental conditions.

Monosulfidic soil materials (S_{AV} ≥ 0.01%) occurred in the soil profile at 2 sampling locations (Table 12 and 13). High monosulfide concentrations in surface soils at Richardson River (40858) represent a high deoxygenation hazard. The water soluble sulfate contents of 59 surficial soil materials sampled were equal to or exceeded the trigger value of 100 mg/L indicating the potential formation of monosulfidic materials (Table 13). The potential formation of monosulfidic materials was identified in the surface soils at all of the wetlands examined with the exception of 40553 and 40853.

The water data indicates that the surface water at the majority of sites has not been significantly affected by acidification. However, water data indicates that the surface water at site 40383 has been affected by acidification (site 40383_9) with a pH value of 5.46. This wetland also contains sulfuric and hypersulfidic materials in some soil layers which suggest acidification as a result of sulfide oxidation may have occurred to some degree (refer to Appendix 1 – 13).

Table 13 – Type and prevalence of acid sulfate soil materials in the Victorian Northern Flowing Rivers Priority Region.

Type of Acid Sulfate Soil Material	Number of sampling sites containing sulfuric or sulfidic materials (Total sites = 74)	Proportion of total sampling sites (%)
Sulfuric	6	8
Hypersulfidic	10	14
Hyposulfidic (S_{CR} ≥ 0.10%)	20	27
Monosulfidic (observed)	2	3
Monosulfidic (potential)	58	78
Hyposulfidic (S_{CR} < 0.10%)	49	66
Other acidic	35	47
Other soil	22	30

6 CONCLUSIONS AND RECOMMENDATIONS

This report provides the results of Phase 1 of a two-phased detailed assessment procedure to determine the hazards posed by acid sulfate soil materials in priority wetlands in the Victorian Northern Flowing Rivers region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the Victorian Northern Flowing Rivers region priority wetlands.

Sulfuric soil materials were observed at six of the sampling sites. The S_{CR} (reduced inorganic sulfur) values ranged between < 0.01 and 1.02% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were present in all 17 wetlands examined. Wetlands 40400, 40858, 40860, 40862 and 40863 had the highest percentage of sites containing sulfidic soil materials (i.e. 100% of soil materials). Hypersulfidic materials occurred in the soil profile at 10 of the 74 sampling locations. Sites where hypersulfidic materials occurred did not show a trend of occurrence and were encountered in both surface and subsoils at some wetland sites. Typically, hypersulfidic materials were a singular layer in the soil profile where encountered.

Monosulfidic soil materials were present in two of the 17 wetlands examined (Wetland ID 40355 and 40858), with only 2 materials of the 338 samples collected equal to or greater than the monosulfidic criterion. A total of 2 sites of the 74 sites examined contained observed monosulfidic soil materials. These results indicate that acidity could develop upon oxidation of sulfides in some of these materials.

The surface soil layer in 59 of the 74 sites (80%) examined had a water soluble SO_4 content exceeding the trigger value of 100 mg/L indicating the potential formation of monosulfidic materials. Other acidic soil materials often with a $pH_W < 5.0$ were observed at 13 sites across 9 wetlands.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project there were six high priority sites based on the presence of sulfuric material, ten high priority sites based on hypersulfidic material, three high priority sites based on hyposulfidic ($S_{CR} \geq 0.10\%$) material and two high priority sites based on monosulfidic material. There were 49 moderate priority sites based on the presence of a hyposulfidic material with $S_{CR} < 0.10\%$. In addition, 59 sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard. All wetlands in the Victorian Northern Flowing Rivers region receive a high priority ranking on at least one of the criteria with the exception of wetlands 40553 (Heppels Lagoon) and 40853 (Buffalo Swamp).

The potential hazards at the wetland-scale posed by acid sulfate soil materials in priority wetlands in the Victorian Northern Flowing Rivers region are shown in Table 14 on the following page.

Table 14 – Hazard Assessment for the Victorian Northern Flowing Rivers Region.

Wetland ID	Main Name	Acidification	De-oxygenation	Metal Mobilisation
40304	Round Lake	Low	Medium	Low
40355	Goulburn River	Low to medium	Medium	Low to medium
40383	Loch Garry	Medium	Medium	Medium
40400	Tullaroop Creek	Low to medium	Medium	Low to medium
40416	Gemmills Swamp	Low	Low	Low to medium
40486	Gunbower Creek	Medium	Medium to high	Medium
40553	Heppels Lagoon	Low	Low	Low
40590	Richardsons Lagoon	Medium	Medium	Medium
40851	Avoca River at Scollary Road Bridge	Low to medium	Low to medium	Low to medium
40853	Buffalo Swamp	Low	Low	Low
40855	Wimmera River	Low	Medium to high	Low
40858	Richardson River	Medium	High	Medium
40859	Richardson River	Medium	High	Medium
40860	Bet Bet Creek	High	Medium	High
40861	Bet Bet Creek	High	Medium	High
40862	Bet Bet Creek	High	Medium	High
40863	Bet Bet Creek	High	Medium	High

7 REFERENCES

Ahern CR, Sullivan LA, McElnea AE (2004) Laboratory methods guidelines 2004 - acid sulfate soils. In 'Queensland Acid Sulfate Soil Technical Manual'. (Department of Natural Resources, Mines and Energy: Indooroopilly, Queensland).

ANZECC/ARMCANZ (2000) 'Australian and New Zealand guidelines for fresh and marine water quality.' (Australian and New Zealand Environment and Conservation Council, Agricultural and Resource Management Council of Australia and New Zealand: Canberra).http://hermes.erin.gov.au/pls/crg_public/!CRGPPUBLIC.PSTART?strAction=SearchByChemi cal

APHA (2005) 'Standard methods for the examination of water and wastewater (21st Ed.).' (American Public Health Association - American Water Works Association: Baltimore, USA).

Burton ED., Bush RT, Sullivan, LA (2006) Acid-volatile sulfide oxidation in coastal floodplain drains: iron-sulfur cycling and effects on water quality. *Environmental Science & Technology* 40, 1217 –1222.

Burton, ED, Bush RT, Sullivan L A, Johnston SG, Hocking, RK (2008a) Mobility of arsenic and selected metals during re-flooding of iron- and organic-rich acid sulfate soil. *Chemical Geology* 253, 64 – 73.

Burton ED, Sullivan LA, Bush RT, Johnston SG, Keene AF (2008b) A simple and inexpensive chromium-reducible sulfur method for acid-sulfate soils. *Applied Geochemistry* 23, 2759-2766.

Bush RT (2000) Iron sulfide micromorphology and mineralogy in acid sulfate soils: Their formation and behaviour. Unpublished Ph.D., University of NSW.

Bush RT, Sullivan LA (1997) Morphology and behaviour of greigite from a Holocene sediment in eastern Australia. *Australian Journal of Soil Research* 35, 853-861.

Bush RT, Sullivan LA, Lin C (2000) Iron monosulfide distribution in three coastal floodplain acid sulfate soils, eastern Australia. *Pedosphere* 10, 237-245.

Dent D (1986) 'Acid sulphate soils: a baseline for research and development.' (International Institute for Land Reclamation and Improvement ILRI, Wageningen, The Netherlands).

Ferguson A, Eyre B (1999) Behaviour of aluminium and iron in acid runoff from acid sulphate soils in the lower Richmond River catchment. *Journal of Australian Geology & Geophysics* 17, 193-201.

Fitzpatrick RW, Marvanek S, Shand P, Merry RH, Thomas, M (2008a) Acid sulfate soil maps of the River Murray below Blanchetown (Lock 1) and Lakes Alexandrina and Albert when water levels were at pre-drought and current drought conditions. CSIRO Land and Water Science Report 12/08.

Fitzpatrick RW, Merry RH, Raven MD, Shand P (2008b) Acid sulfate soil materials and salt efflorescences in subaqueous and wetland soil environments at Tareena Billabong and Salt Creek, NSW: Properties, risks and management. CSIRO Land and Water Science Report 07/08.

Fitzpatrick RW, Shand P, Thomas M, Merry RH, Raven MD, Simpson SL (2008c) Acid sulfate soils in subaqueous, waterlogged and drained soil environments of nine wetlands below Blanchetown (Lock 1), South Australia: properties, genesis, risks and management. Report prepared for South Australian Murray-Darling Basin Natural Resources Management Board. CSIRO Land and Water Report Number 42/08. CSIRO Land and Water Glen Osmond, SA.

Hsieh YP, Chung SW, Tsau YJ, Sue CT (2002) Analysis of sulfides in the presence of ferric minerals by diffusion methods. *Chemical Geology* 182, 195-201.

Isbell RF (1996) 'The Australian Soil Classification.' (CSIRO Publishing, Melbourne, Vic).

Lamontagne S, Hicks WS, Fitzpatrick RW, Rogers S (2004) Survey and description of sulfidic materials in wetlands of the Lower River Murray floodplains: Implications for floodplain salinity management Technical Report 28/04. CSIRO Land and Water. Adelaide, Australia.

MDBA (2010) 'Detailed assessment of acid sulfate soils in the Murray-Darling Basin: Protocols for sampling, field characterisation, laboratory analysis and data presentation.' MDBA Publication No. 57/10, 58 pp.

Rayment GE, Higginson FR (1992) 'Australian laboratory handbook of soil and water chemical methods.' (Inkata Press: Melbourne, Vic).

Sammut J, Callinan RB, Fraser GC (1993) The impact of acidified water on freshwater and estuarine fish populations in acid sulphate soil environments. In 'Proceedings National Conference on Acid Sulphate Soils'. Coolangatta, NSW. 24-25 June 1993. (Ed. RT Bush) pp. 26-40. (CSIRO, NSW Agriculture, Tweed Shire Council).

Shand P, Edmunds WM (2008a) The baseline inorganic chemistry of European groundwaters. In, WM Edmunds & P Shand (Eds.), Natural Groundwater Quality, 21-58. Blackwell Publishing, Oxford.

Shand P, Merry RH, Fitzpatrick, RW (2008b) Acid sulfate soil assessment of wetlands associated with Lock 8 and Lock 9 weir pools. CSIRO Land and Water Science Report 40/08.

Simpson S, Angel B, Spadarol D, Fitzpatrick RW, Shand P, Merry RH, Thomas M. (2008) Acid and Metal Mobilisation Following Rewetting of Acid Sulfate Soils in the River Murray, South Australia. CSIRO Land and Water Science Report 27/08.

Sullivan LA, Burton ED, Bush RT, Watling K, Bush M (2008a) Acid, metal and nutrient mobilisation dynamics in response to suspension of MBOs in freshwater and to freshwater inundation of dried MBO and sulfuric soil materials. Southern Cross GeoScience, Report Number 108.

Sullivan LA, Bush RT (1997) Quantitative elemental microanalysis of rough-surfaced soil specimens in the scanning electron microscope using a peak-to-background method. *Soil Science* 162, 749-757.

Sullivan LA, Bush RT, Ward NJ (2002a) Sulfidic sediments and salinisation in the Murray-Darling basin. In 'Proceedings of the 5th International Acid Sulfate Soils Conference. Sustainable Management of Acid Sulfate Soils. Conference Abstracts, Poster Papers'. Tweed Heads, NSW. 25-30 August 2002. (Eds BCT Macdonald, AF Keene, G Carlin, LA Sullivan) pp. 196-197. (Tweed Shire Council: Murwillumbah, NSW).

Sullivan LA, Fitzpatrick RW, Burton ED, Bush RT, Shand P (2008b) Assessing environmental hazards posed by acid sulfate soil materials and other inorganic sulfide containing soil materials: classification issues. Plenary Paper, Joint Conference of the 6th International Symposium in Acid Sulfate Soils and the Acid Rock Drainage Symposium. Guangzhou, China, 16-20 September 2008.

Sullivan LA, Fitzpatrick RW, Bush RT, Burton ED, Shand P, Ward NJ (2010) The classification of acid sulfate soil materials: further modifications. Southern Cross GeoScience Technical Report No. 310. April 2010. Lismore, NSW.

Sullivan LA, Ward NJ, Bush RT (2001) Chemical analysis for acid sulfate soil management. *In* 'Proceedings of the 2nd Australia and New Zealand Conference on Environmental Geotechnics - Geoenvironment 2001. Newcastle, November 28-30 2001) (Australian Geomechanics Society Inc. Newcastle) pp. 109-120. (Australian Geomechanics Society Inc. Newcastle).

Sullivan LA, Ward NJ, Bush RT, Burton ED (2009) Improved identification of sulfidic soil materials by a modified incubation method. *Geoderma* 149, 33-38.

Sullivan LA, Ward NJ, Bush RT, Lin, C (2002b) Evaluation of approaches to the chemical analysis of acid sulfate soil. *In* 'Acid sulfate soils in Australia and China.' (Eds C. Lin, M. Melville and L.A Sullivan) pp. 72-82. (Science Press, Beijing).

Sundström R, Aström M, Österholm P (2002) Comparison of metal content in acid sulfate soil runoff and industrial effluents in Finland. *Environmental Science & Technology* 36, 4269- 4272.

Ward NJ, Sullivan LA, Bush RT (2002) Sulfide oxidation and acidification of acid sulfate soil materials treated with CaCO3 and seawater-neutralised bauxite refinery residue. *Australian Journal of Soil Research* 40, 1057-1067.

APPENDIX 1: ROUND LAKE (40304) SUMMARY REPORT

APPENDIX 1:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40304
Wetland Name:	Round Lake

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 ROUND LAKE 3

1.1 Location and Setting Description 3

1.2 Soil Profile Description and Distribution 3

1.3 Summary of Field and Laboratory Results 7

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 7

1.3.2 Acid Base Accounting 10

1.3.3 Titratable Actual Acidity (TAA) 10

1.3.4 Chromium Reducible Sulfur (S_{CR}) 10

1.3.5 Acid Volatile Sulfur (AVS) 10

1.3.6 Retained Acidity (RA) 10

1.3.7 Acid Neutralising Capacity (ANC) 10

1.3.8 Net Acidity 10

1.3.9 Water soluble SO_4 11

1.4 Hydrochemistry 12

1.5 Discussion 12

1.6 Summary of Key Findings for Round Lake 13

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Round Lake Sites. 4
Table 2 – Summary Of Key Findings 13
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Round Lake. 14
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Round Lake. 17
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Round Lake. 18
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Round Lake. 19
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Round Lake. 21

LIST OF FIGURES

Figure 1 – Round Lake 40304 Site Plan

Figure 2 – Round Lake Conceptual Hydrotoposequence Cross Section – 40304

Figure 3 – Photographs of site 40304_1, showing the water surface (water column of 2.30m), and the chip tray soil profile of dark grey wet soft clayey sand.

Figure 4 – Photographs of site 40304_2, showing the edge of water surface condition and the laid out soil profile of grey to dark grey soft loamy clayey sand overlying reddish brown soft clayey sand.

Figure 5 – Photographs of site 40304_3, showing the surface condition and the soil profile of grey loose loamy sand overlying reddish brown very weak clayey sand.

Figure 6 – Photographs of site 40304_4, showing the surface condition and the soil profile of dark greyish brown loose loamy sand overlying reddish brown very weak clayey sand.

Figure 7 – Photographs of site 40304_5, showing the surface condition and the soil profile of dark greyish brown loose loamy sand overlying reddish brown very weak clayey sand.

Figure 8 – Photographs of site 40304_6, showing the surface condition and the soil profile of dark greyish brown loose and very weak clayey sand.

Figure 9 – Photographs of site 40304_7, showing the edge of water surface condition and the chip tray soil profile grey to dark grey soft clayey sand overlying reddish brown soft sandy clay.

Figure 10 – Photographs of site 40304_8, showing the water surface (water column of 0.25m) and the laid out soil profile of dark grey wet soft sandy clay overlying reddish brown soft silty clay.

Figure 11 – Depth profiles of soil pH for Round Lake, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 12 (continued) – Depth profiles of soil pH for Round Lake, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 13 – Acid base accounting depth profiles for Round Lake. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

Figure 14 – Acid base accounting depth profiles for Round Lake. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 ROUND LAKE

1.1 Location and Setting Description

Round Lake is situated on the southern side of the River Murray, approximately 2km South West of the township of Lake Boga. The wetland is accessed from Lalbert Road or Ultima Lake Boga Road off the Murray Valley Highway. The wetland is circular in shape, 1 kilometre in length East to West and 600 metres North to South, with a total area of 41 hectares.

The wetland is bounded by relatively flat agricultural land with some minor gradual hill slopes surrounding the Lake. There is a bund/channel around the periphery of the Lake with a water connection point at the Northern point of the wetland and culvert traversing Ultima Lake Boga Road. The culvert inlet appeared relatively moist to dry during the soil survey conducted in April 2010. At the time when the soil survey was conducted, the surface water covered the majority of the wetland.

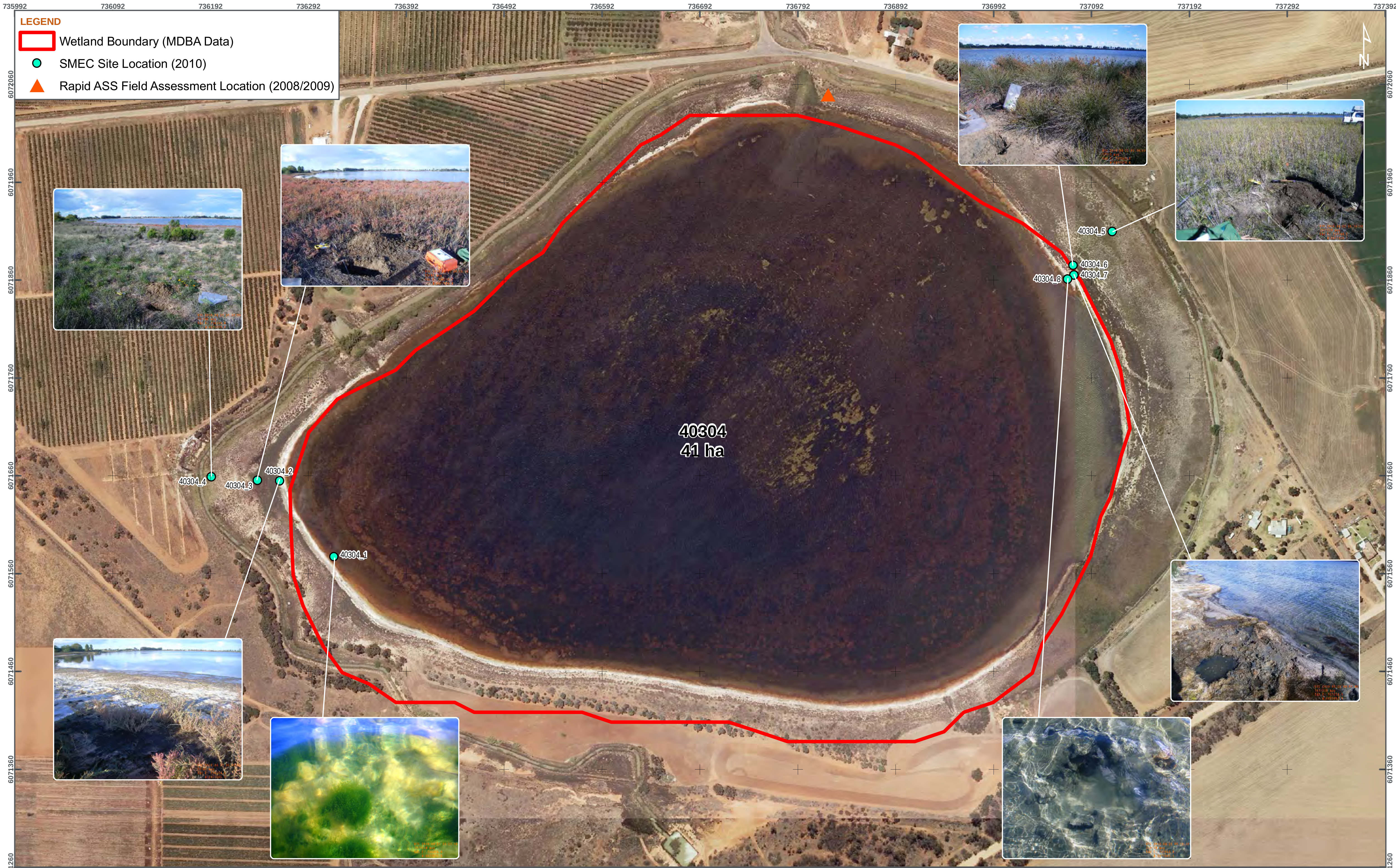
Aquatic vegetation was observed within the central portions of the wetland where surface water was present. The water line was generally covered with a thin matting (2 – 5cm) of decomposing rushes and water margin vegetation. The lower banks around the periphery of the wetland contained low grasses, weeds and rushes. On the upper banks of the wetland and above the bund/channel margins medium sized trees were growing, principally around the Southern periphery of the wetland. Eight sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Eight sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at two different areas of the wetland with four sites chosen for each transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 10** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

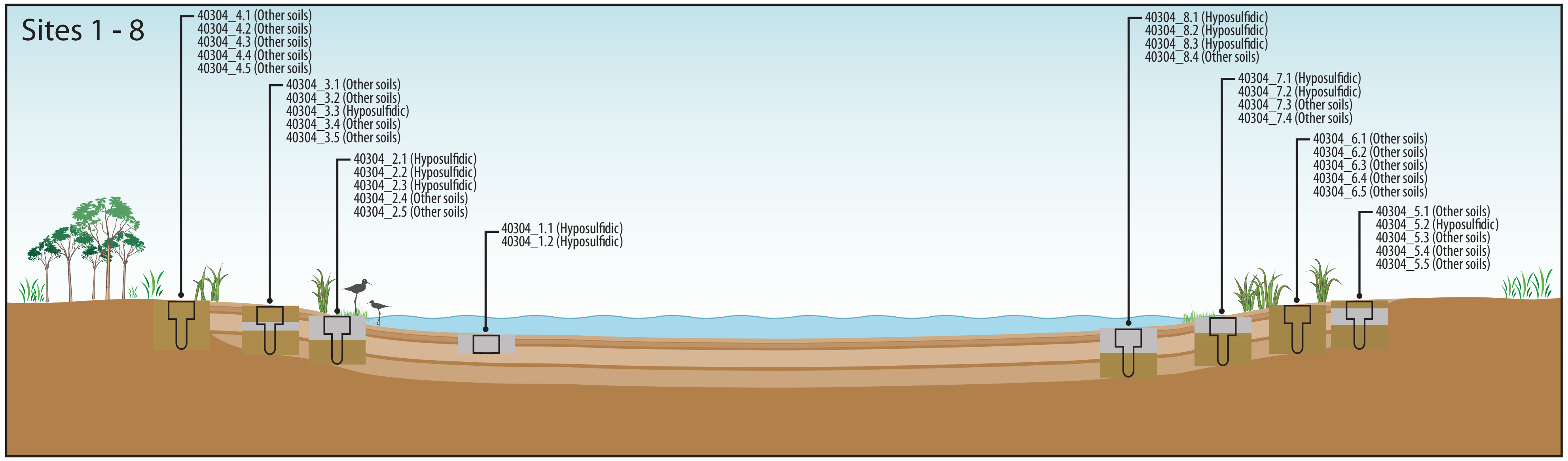
- 40304_1: water surface, subaqueous sediments and the soil consisted of dark grey wet soft clayey sand.
- 40304_2: water logged surface, edge of water line and the soil consisted of grey to dark grey soft loamy clayey sand overlying reddish brown soft clayey sand.
- 40304_3: loose surface, some low salt tolerant bushes and rushes, soil consisted of grey loose loamy sand overlying reddish brown very weak clayey sand.
- 40304_4: loose surface, low grasses and rushes, soil consisted of dark greyish brown loose loamy sand overlying reddish brown very weak clayey sand.
- 40304_5: loose surface, low rushes, soil consisted of dark greyish brown loose sandy loam overlying dark greyish brown very weak sandy clay.
- 40304_6: loose surface, low rushes, soil consisted of dark greyish brown loose and very weak clayey sand.



DATE 09/07/2010	SCALE 1:3,500	0 37.5 75 150 Meters	PAGE SIZE A3	COORDINATE SYSTEM GDA 94	FIG NO. 1 PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS				PROJECT NO. 3001801 FIGURE TITLE Round Lake 40304 - CMA: NCCMA

Note: Inset Photos show Surface Condition of Site

SMEC

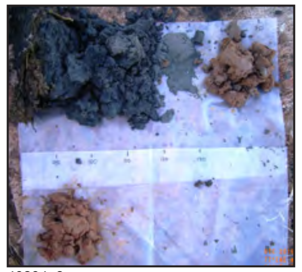


LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils


40304_2


40304_2

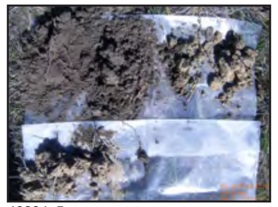

40304_3


40304_3

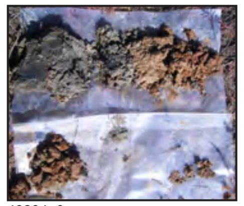

40304_4


40304_4

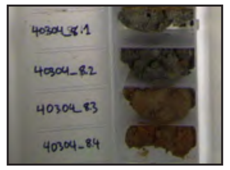

40304_5


40304_5


40304_6


40304_6


40304_7


40304_8


40304_8

DATE 15/07/2010

SCALE Not to Scale

FIG NO. 2

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart

LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801

FIGURE TITLE Conceptual Hydrotoposequence Cross Section, Round Lake 40304

- 40304_7: water logged surface, edge of water line and the soil consisted of grey to dark grey soft clayey sand overlying reddish brown soft sandy clay.
- 40304_8: water surface, subaqueous sediments and the soil consisted of dark grey wet soft sandy clay overlying reddish brown soft silty clay.

Table 1 – Soil Identification, subtype and general location description for Round Lake Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40304_1	191880	6069393	Subaqueous soil	Low point, subaqueous sediments
40304_2	191820	6069467	Hydrosol - sandy or loamy	Low point, edge of water line
40304_3	191797	6069466	Hydrosol - sandy or loamy	Mid point, salt bush vegetation change
40304_4	191750	6069467	Hydrosol - sandy or loamy	High point, previous high water mark
40304_5	192654	6069773	Hydrosol - sandy or loamy	High point, previous high water mark
40304_6	192616	6069736	Hydrosol - sandy or loamy	Mid point, sandy surface layer, near surface water
40304_7	192617	6069727	Hydrosol - sandy or loamy	Low point, edge of water line
40304_8	192611	6069722	Subaqueous soil	Low point, subaqueous sediments

Figure 3 – Photographs of site 40304_1, showing the water surface (water column of 2.30m), and the chip tray soil profile of dark grey wet soft clayey sand.

Figure 4 – Photographs of site 40304_2, showing the edge of water surface condition and the laid out soil profile of grey to dark grey soft loamy clayey sand overlying reddish brown soft clayey sand.

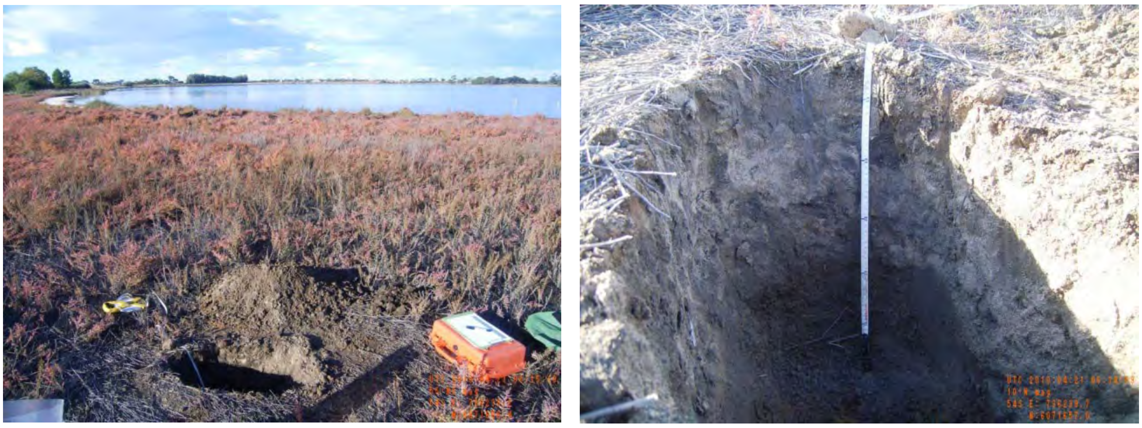


Figure 5 – Photographs of site 40304_3, showing the surface condition and the soil profile of grey loose loamy sand overlying reddish brown very weak clayey sand.

Figure 6 – Photographs of site 40304_4, showing the surface condition and the soil profile of dark greyish brown loose loamy sand overlying reddish brown very weak clayey sand.

Figure 7 – Photographs of site 40304_5, showing the surface condition and the soil profile of dark greyish brown loose loamy sand overlying reddish brown very weak clayey sand.

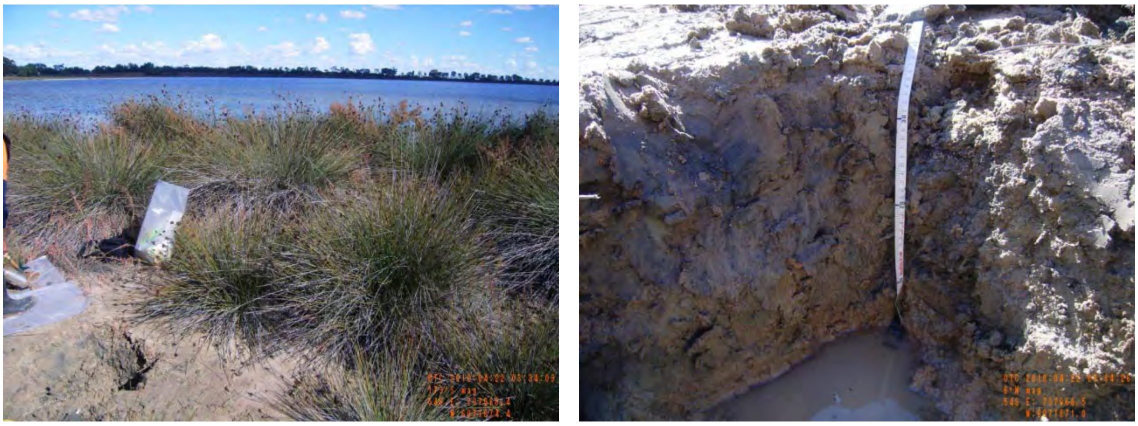


Figure 8 – Photographs of site 40304_6, showing the surface condition and the soil profile of dark greyish brown loose and very weak clayey sand.

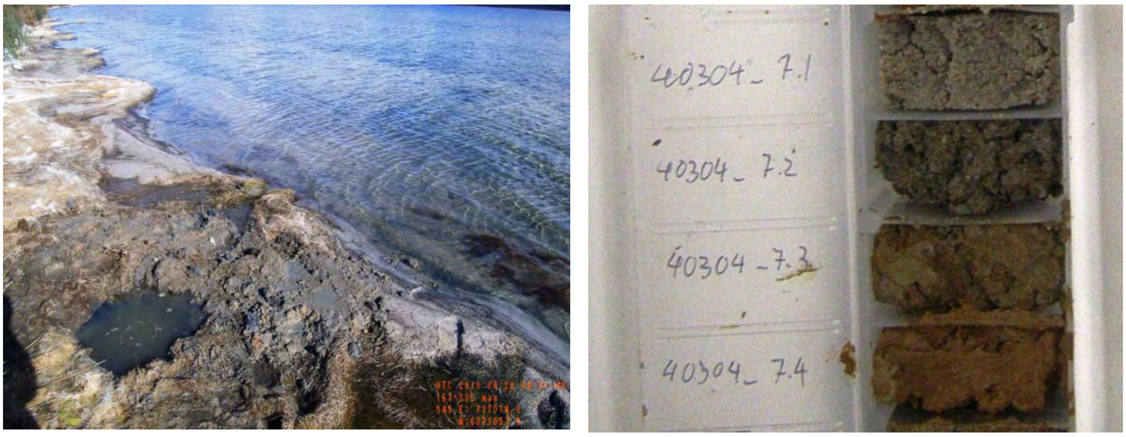


Figure 9 – Photographs of site 40304_7, showing the edge of water surface condition and the chip tray soil profile grey to dark grey soft clayey sand overlying reddish brown soft sandy clay.

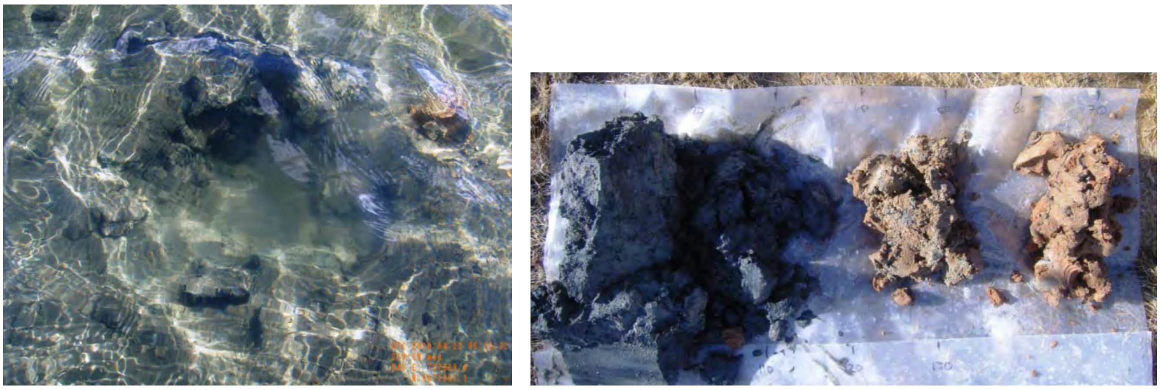


Figure 10 – Photographs of site 40304_8, showing the water surface (water column of 0.25m) and the laid out soil profile of dark grey wet soft sandy clay overlying reddish brown soft silty clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figures 11 and 12** on the following pages. Summary soil pH profile results indicate:

- 40304_1: all subaqueous samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.96 – 9.19.
- 40304_2: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.49 – 8.90.
- 40304_3: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.84 – 9.43.
- 40304_4: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.19 – 9.02.
- 40304_5: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 7.85 – 8.54.
- 40304_6: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.35 – 9.30.
- 40304_7: all samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.32 – 9.34.
- 40304_8: all subaqueous samples have $pH_w > 7.0$ and $pH_{incubation} > 7.0$ indicating other soils or hyposulfidic conditions. pH_w ranged between 8.69 – 9.36.
- All samples analysed had a $pH_{peroxide}$ greater than 6.00 with the majority >6.50 after oxidation.

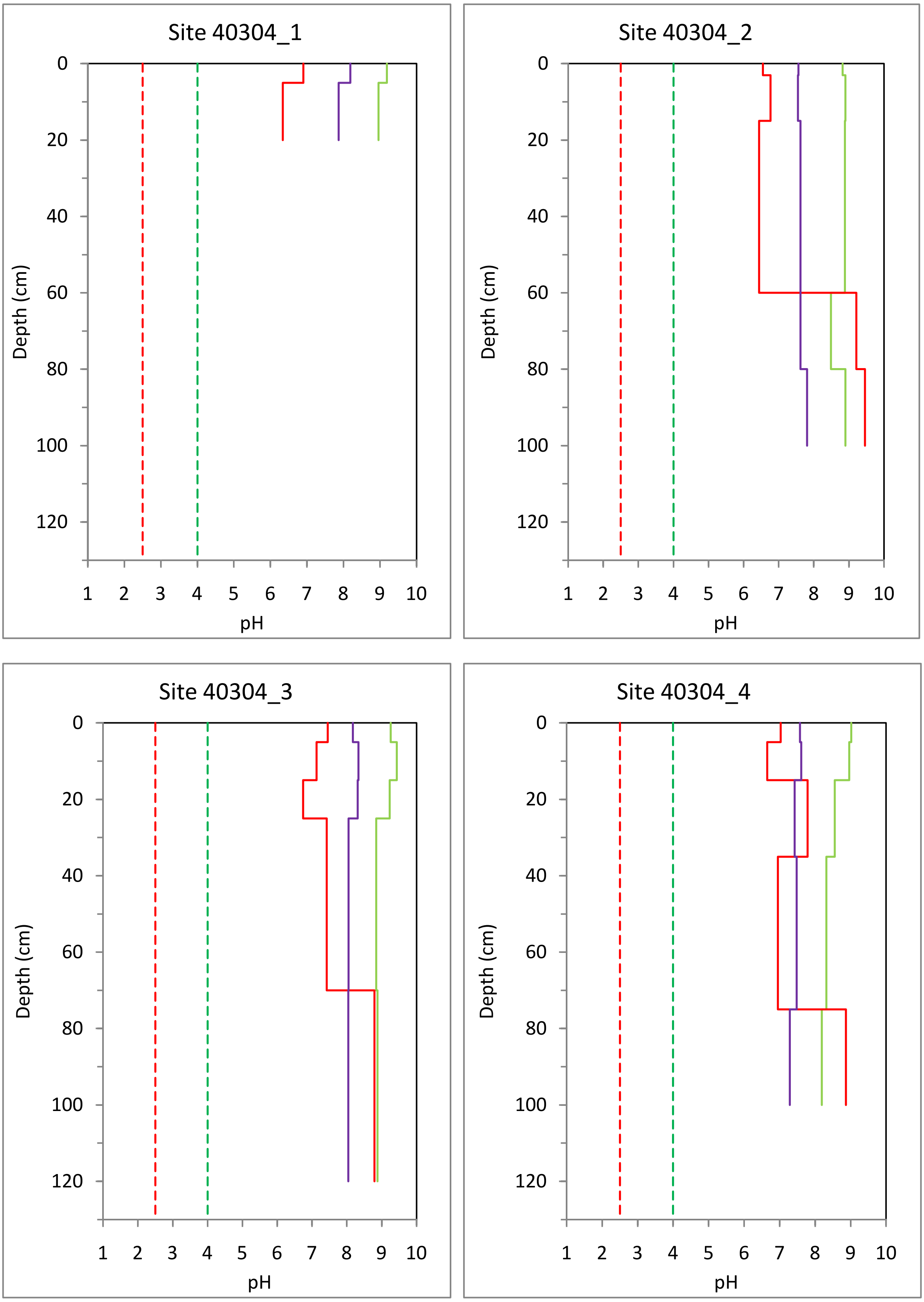


Figure 11 – Depth profiles of soil pH for Round Lake, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

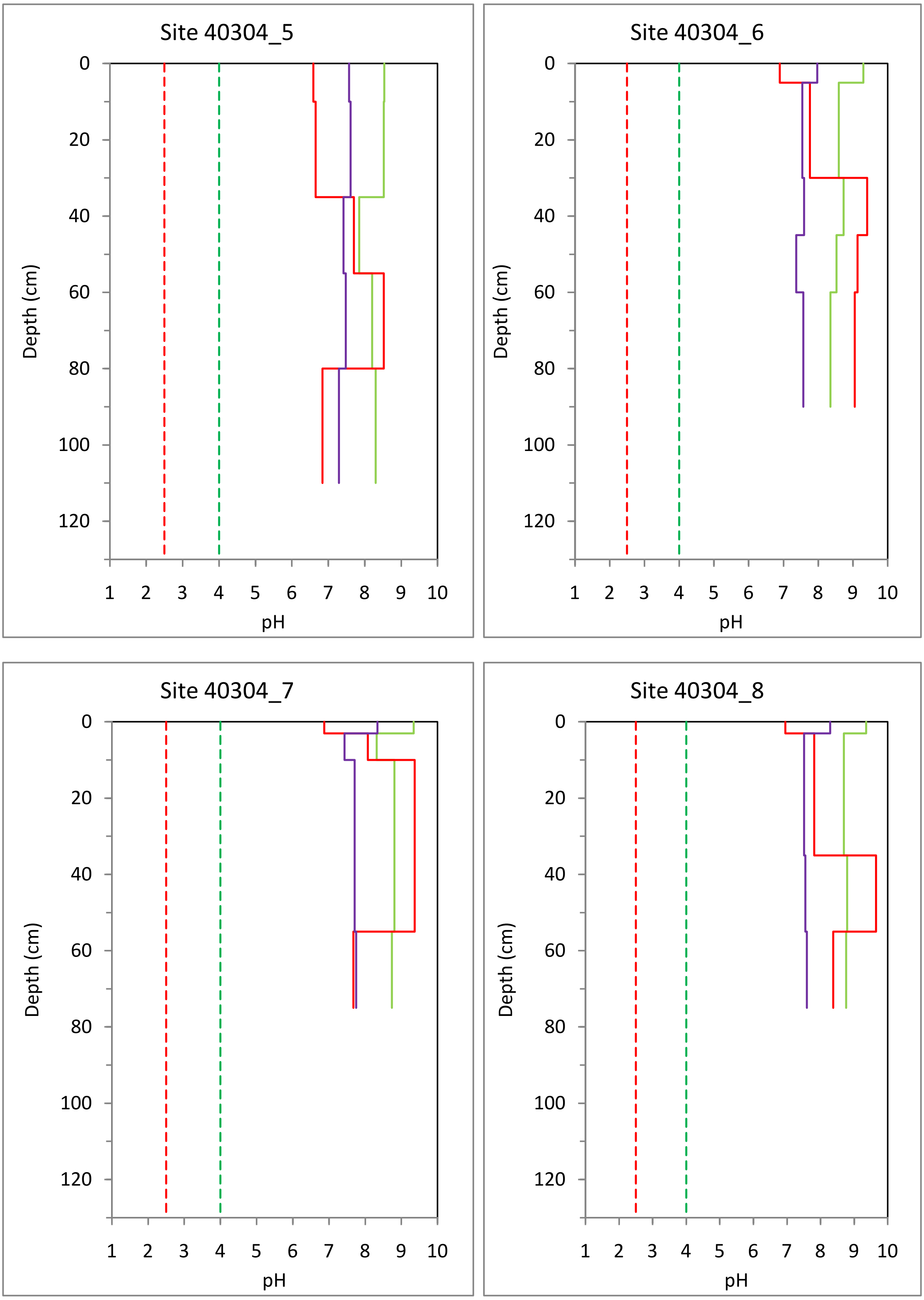


Figure 12 – Depth profiles of soil pH for Round Lake, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 13 and 14** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 35 soil samples collected were analysed for titratable actual acidity (TAA). All TAA results were reported as 0 mol H+/tonne for samples analysed. This is likely due to the high pH_W values (all >6.50) and high water alkalinity of the wetland.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 35 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Results ranged from <0.01 (limit of detection) and 0.16 %S. Results above 0.01%S are primarily located at subaqueous and surface water margin sites within surface soils (40304_1, 40304_2, 40304_7 and 40304_8). All other sites within the mid to high points of the wetland indicated values at or below detection limits (<0.01 to 0.01%S).

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Round Lake.

1.3.6 Retained Acidity (RA)

No pH_{KCL} results were below the threshold of 4.50 for retained acidity analysis. Therefore, no samples were analysed for Retained Acidity (RA).

1.3.7 Acid Neutralising Capacity (ANC)

All 35 soil samples collected were analysed for Acid Neutralising Capacity (ANC). Results ranged from 1 – 59 %$CaCO_3$. Spatially and vertically, results were variable throughout the sites. There may be a higher concentration of ANC at sites near the wetland surface water edge and where groundwater pit inflow occured in higher elevation transect sites (40304_3, 40304_4, 40304_5 and 40304_6).

1.3.8 Net Acidity

Net acidity results for all sites and samples were negative values and ranged between -7,791 to -123 mol H+/tonne. The negative ANC values are likely to be associated with the high alkalinity and salinity at Round Lake, providing buffering capacity to potential acidity present in soils.

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

All materials collected had a low net acidity (all negative net acidity).

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 53 to 3,930 mg/L for surface soil samples collected (i.e. 0 – 10cm). Ten surface soil samples were analysed for water soluble sulfate in total.

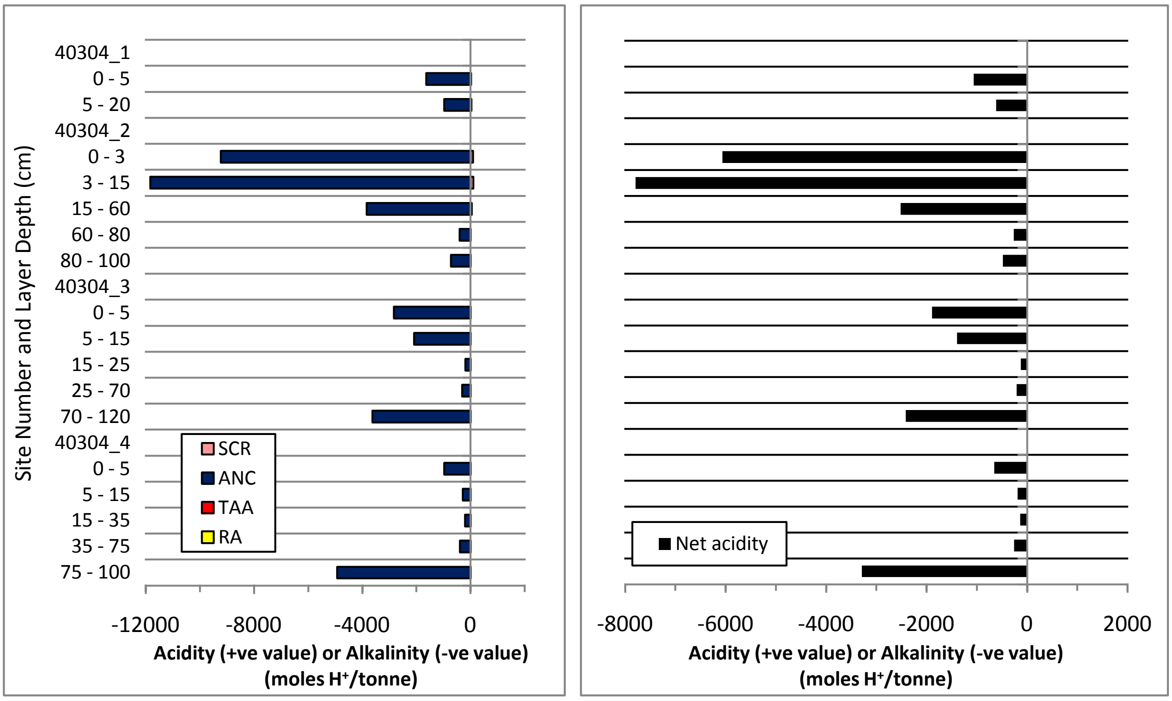


Figure 13 – Acid base accounting depth profiles for Round Lake. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

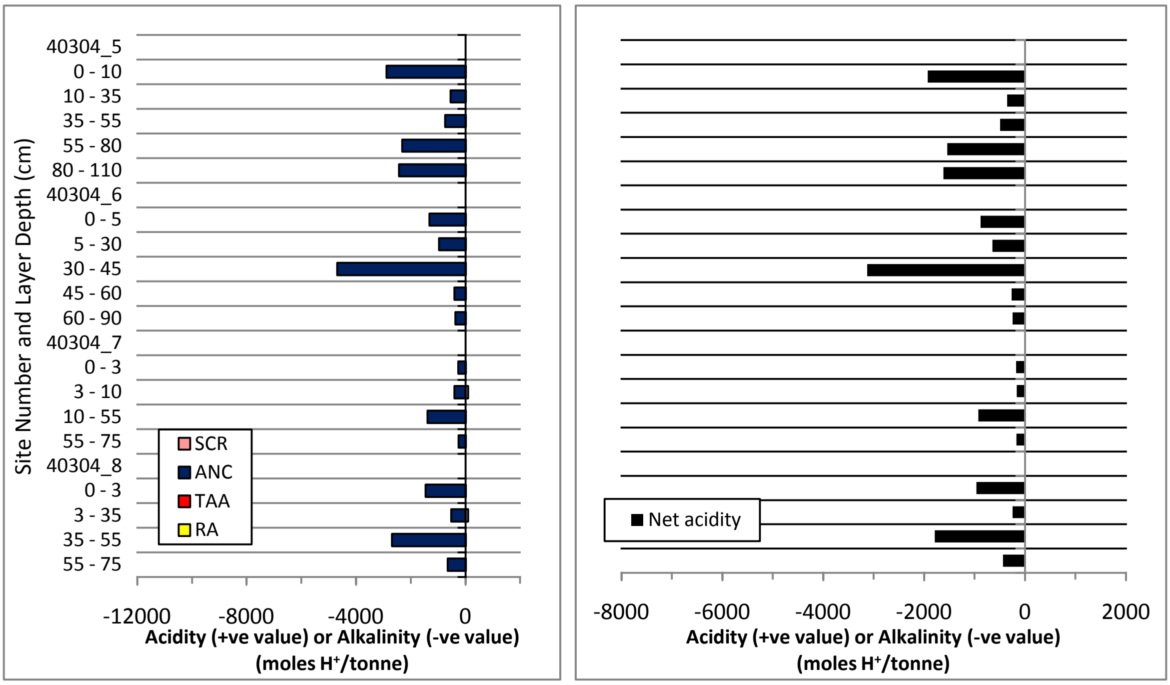


Figure 14 – Acid base accounting depth profiles for Round Lake. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at six out of the eight sites from Round Lake. Four measurements were from pit inflow waters and two from wetland surface waters. Four water samples were collected for laboratory analysis including two from pit inflow waters and two from wetland surface waters.

The wetland margin pit inflow water at site 40304_2 had concentrations higher than the ANZECC 2000 trigger values for nutrients (NH_4 3.1 mg/L, criterion of 0.01 mg/L), (PO_4 0.01 mg/L, criterion of 0.005 mg/L) and some dissolved metals (Co - 6 µg/L, criterion of 2.8 µg/L), (Cu - 5 µg/L, criterion of 1.4 µg/L), (Mn - 3,800 µg/L, criterion of 1,700 µg/L) and (Ni - 12 µg/L, criterion of 11 µg/L). The four other sites sampled and analysed also had concentrations higher than the ANZECC 2000 trigger values for Cu ranging between 3 - 4 µg/L with a criterion of 1.4 µg/L.

The wetland surface waters were alkaline (pH 9.95 - 10.09) and pit inflow waters were near neutral (pH 6.93 – 7.62). All sites had high SEC values (>30,000µS/cm) with the exception of Site 5 (3,240 µS/cm) which was located at a higher point in the survey transect. Alkalinity (as HCO_3) was also high at all sites (>240 HCO_3). All sites had oxidising conditions with the exception of both water's edge wetland margin sites (40304_2 and 40304_7) where reducing conditions dominated (-183 to -220 Eh). Wetland surface waters (40304_1) were over saturated (DO 10.69 mg/L), however the other sites had lower DO values (0.08 – 2.46 mg/L).

The water data indicates that the surface and pit inflow water has not been affected by acidification and is high in alkalinity and buffering capacity.

1.5 Discussion

Acid sulfate soils within Round Lake occurred as areas of hyposulfidic soil material forming in low elevated areas near water that may increase in area in subaqueous areas of the wetland. Hyposulfidic soil typically was encountered at the water line margin of the wetland and typically within the upper 40cm of the soil profile.

The highest S_{CR} was 0.16%S and was encountered at both of the water line margin sites (40304_2 and 40304_7). Both of these sites contained surface soil materials that are classified as hyposulfidic. No sulfuric or monosulfidic materials were encountered at the wetland. Typically, deeper soil materials (>50cm) were classified as "other soil" (non acidic).

The highest water soluble sulfate results for surface samples were encountered either within subaqueous soils or wetland margin soils. Water soluble sulfate results decreased in concentration moving away from the centre of the wetland. The majority of samples exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results for water soluble sulfate ranged between 53 – 3,930 mg/L and indicate that MBO could form under the right environmental conditions.

All materials collected had a low (negative value) net acidity.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are seven high priority sites based on the presence of hyposulfidic materials with S_{CR} >0.10% and water soluble sulfate results above the trigger criterion of 100 mg/L. Site 40304_ is classified as "no further assessment". Seven out of the eight sampled sites have a high priority.

Due to low net acidity values at all sites (negative values) and the high alkalinity and buffering capacity within the wetland soils and waters, the requirement for Phase 2 laboratory analysis may not be warranted. The potential hazards at a wetland scale posed by acid sulfate soil materials at the Round Lake are:

- Acidification hazard: low level of concern based on the low (negative values) net acidities and sulfidic results (from S_{CR}) with 65% of samples <0.01%S. The degree of acidification potential from sulfidic sources only appears to be low. In addition, the wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results for the majority of surface soil materials exceeded the trigger value for monosulfide formation, although no MBO materials were observed in subaqueous areas that were sampled.

- Metal mobilisation: The low acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation. The wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources and therefore reduce the risk of metals being liberated from sulfidic sources.

1.6 Summary of Key Findings for Round Lake

The summary of key findings for Round Lake is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Sulfidic materials identified included: o hyposulfidic (Site 1, 2, 3, 5, 7 and 8) typically surface soils (upper 50 cm). o Hyposulfidic soil materials S_{CR} value ranged between 0.01 - 0.16%S. • Other soils (Site 4 and 6). • Net acidities ranged between -7,791 to -123 mol H+/tonne. • All soil materials had a low (negative value) net acidity.
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Hydrosol – sandy or loamy occurring at water edge and wetland margin soils. • Site 3: Hydrosol – sandy or loamy occurring at wetland margin soils. • Site 4: Hydrosol – sandy or loamy occurring at high point of transect at edge of wetland high water mark. • Site 5: Hydrosol – sandy or loamy occurring at high point of transect at edge of wetland high water mark. • Site 6: Hydrosol – sandy or loamy occurring near water edge and wetland margin soils. • Site 7: Hydrosol – sandy or loamy occurring at water edge and wetland margin soils. • Site 8: Subaqueous soil occurring under current standing water level in the wetland.
Hazard assessment:	• Acidification hazard – low level of concern • De-oxygenation hazard – medium level of concern • Metal mobilisation hazard – low level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Round Lake.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40304_1.1	40304_1	0	5	0.1244	0.0827	34	9.19	6.90	8.19	1460
40304_1.2	40304_1	5	20	0.1379	0.1047	24	8.96	6.34	7.87	935
40304_2.1	40304_2	0	3	0.1181	0.0733	38	8.82	6.55	7.56	2835
40304_2.2	40304_2	3	15	0.1108	0.0688	38	8.90	6.77	7.55	-
40304_2.3	40304_2	15	60	0.1246	0.0883	29	8.89	6.44	7.62	-
40304_2.4	40304_2	60	80	0.1405	0.1134	19	8.49	9.21	7.62	-
40304_2.5	40304_2	80	100	0.1486	0.1232	17	8.90	9.46	7.81	-
40304_3.1	40304_3	0	5	0.0802	0.0692	14	9.26	7.45	8.17	2715
40304_3.2	40304_3	5	15	0.1061	0.0926	13	9.43	7.13	8.33	1500
40304_3.3	40304_3	15	25	0.1293	0.1163	10	9.23	6.74	8.31	-
40304_3.4	40304_3	25	70	0.1296	0.1093	16	8.84	7.42	8.05	-
40304_3.5	40304_3	70	120	0.0978	0.0813	17	8.88	8.79	8.04	-
40304_4.1	40304_4	0	5	0.0762	0.0718	6	9.02	7.03	8.23	53
40304_4.2	40304_4	5	15	0.1043	0.0995	5	8.96	6.65	8.07	-
40304_4.3	40304_4	15	35	0.1014	0.0936	8	8.55	7.79	7.84	-
40304_4.4	40304_4	35	75	0.0813	0.0730	10	8.32	6.95	7.65	-
40304_4.5	40304_4	75	100	0.0902	0.0808	10	8.19	8.87	7.76	-
40304_5.1	40304_5	0	10	0.0641	0.0564	12	8.54	6.59	7.57	171
40304_5.2	40304_5	10	35	0.1018	0.0934	8	8.52	6.65	7.61	-
40304_5.3	40304_5	35	55	0.0807	0.0648	20	7.85	7.70	7.42	-
40304_5.4	40304_5	55	80	0.0982	0.0802	18	8.20	8.52	7.48	-
40304_5.5	40304_5	80	110	0.1202	0.1004	16	8.30	6.84	7.29	-
40304_6.1	40304_6	0	5	0.1146	0.1017	11	9.30	6.89	7.97	3930
40304_6.2	40304_6	5	30	0.1044	0.0833	20	8.59	7.76	7.54	-
40304_6.3	40304_6	30	45	0.0822	0.0668	19	8.73	9.41	7.59	-
40304_6.4	40304_6	45	60	0.1261	0.0992	21	8.53	9.13	7.37	-
40304_6.5	40304_6	60	90	0.1251	0.0972	22	8.35	9.05	7.57	-
40304_7.1	40304_7	0	3	0.1401	0.1171	16	9.34	6.87	8.34	629
40304_7.2	40304_7	3	10	0.1314	0.0981	25	8.32	8.07	7.43	-
40304_7.3	40304_7	10	55	0.1229	0.0932	24	8.81	9.37	7.71	-
40304_7.4	40304_7	55	75	0.1183	0.0883	25	8.74	7.67	7.75	-

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40304_8.1	40304_8	0	3	0.1464	0.1163	21	9.36	6.95	8.29	657
40304_8.2	40304_8	3	35	0.1316	0.0975	26	8.69	7.81	7.51	-
40304_8.3	40304_8	35	55	0.1354	0.1043	23	8.79	9.65	7.55	-
40304_8.4	40304_8	55	75	0.1373	0.1066	22	8.76	8.38	7.59	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Round Lake.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40304_1.1	40304_1	0	5	9.20	0	0.04	0	8	-1065	-	Hyposulfidic
40304_1.2	40304_1	5	20	8.97	0	0.06	0	5	-614	-	Hyposulfidic
40304_2.1	40304_2	0	3	8.98	0	0.15	0	46	-6061	-	Hyposulfidic
40304_2.2	40304_2	3	15	9.14	0	0.16	0	59	-7791	-	Hyposulfidic
40304_2.3	40304_2	15	60	9.01	0	0.07	0	19	-2516	-	Hyposulfidic
40304_2.4	40304_2	60	80	8.65	0	<0.01	0	2	-268	-	Other soils
40304_2.5	40304_2	80	100	8.75	0	<0.01	0	4	-483	-	Other soils
40304_3.1	40304_3	0	5	9.40	0	<0.01	0	14	-1891	-	Other soils
40304_3.2	40304_3	5	15	9.43	0	<0.01	0	10	-1393	-	Other soils
40304_3.3	40304_3	15	25	9.23	0	0.01	0	1	-123	-	Hyposulfidic
40304_3.4	40304_3	25	70	9.02	0	<0.01	0	2	-208	-	Other soils
40304_3.5	40304_3	70	120	9.08	0	<0.01	0	18	-2416	-	Other soils
40304_4.1	40304_4	0	5	9.29	0	<0.01	0	5	-652	-	Other soils
40304_4.2	40304_4	5	15	9.19	0	<0.01	0	1	-189	-	Other soils
40304_4.3	40304_4	15	35	8.81	0	<0.01	0	1	-139	-	Other soils
40304_4.4	40304_4	35	75	8.62	0	<0.01	0	2	-263	-	Other soils
40304_4.5	40304_4	75	100	8.69	0	<0.01	0	25	-3288	-	Other soils
40304_5.1	40304_5	0	10	8.96	0	<0.01	0	14	-1926	-	Other soils
40304_5.2	40304_5	10	35	8.93	0	0.01	0	3	-357	-	Hyposulfidic
40304_5.3	40304_5	35	55	8.39	0	<0.01	0	4	-495	-	Other soils
40304_5.4	40304_5	55	80	8.52	0	<0.01	0	12	-1543	-	Other soils
40304_5.5	40304_5	80	110	8.69	0	<0.01	0	12	-1618	-	Other soils

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	%$CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40304_6.1	40304_6	0	5	8.98	0	<0.01	0	7	-882	-	Other soils
40304_6.2	40304_6	5	30	9.01	0	<0.01	0	5	-643	-	Other soils
40304_6.3	40304_6	30	45	8.88	0	<0.01	0	23	-3126	-	Other soils
40304_6.4	40304_6	45	60	8.66	0	<0.01	0	2	-268	-	Other soils
40304_6.5	40304_6	60	90	8.60	0	<0.01	0	2	-244	-	Other soils
40304_7.1	40304_7	0	3	9.62	0	0.01	0	1	-173	-	Hyposulfidic
40304_7.2	40304_7	3	10	8.68	0	0.16	0	2	-167	-	Hyposulfidic
40304_7.3	40304_7	10	55	8.72	0	<0.01	0	7	-923	-	Other soils
40304_7.4	40304_7	55	75	8.47	0	<0.01	0	1	-171	-	Other soils
40304_8.1	40304_8	0	3	9.57	0	0.01	0	7	-965	-	Hyposulfidic
40304_8.2	40304_8	3	35	8.88	0	0.16	0	3	-244	-	Hyposulfidic
40304_8.3	40304_8	35	55	8.76	0	0.01	0	13	-1789	-	Hyposulfidic
40304_8.4	40304_8	55	75	8.74	0	<0.01	0	3	-438	-	Other soils

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Round Lake.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40304_1.W1	40304_2.W1	40304_5.W1	-	-	40304_8.W1
Site ID	(number)	-	-	40304_1	40304_2	40304_5	40304_6	40304_7	40304_8
Wetland ID	(code)	-	-	40304	40304	40304	40304	40304	40304
Site Number	(number)	-	-	1	2	5	6	7	8
Upper depth	cm	-	-	-30	30	90	40	5	-25
Lower depth	cm	-	-	0	40	100	50	15	0
Temperature	(deg C)	-	-	20.8	19.4	21.2	21.4	22.9	25.5
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	30300	39000	3240	45000	36300	22410
Dissolved Oxygen	(%)	-	-	123	0.7	14.9	12.7	3.8	112.9
Dissolved Oxygen	(mg/l)	-	-	10.69	0.08	2.46	1.4	0.28	9.1
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	10.09	7.11	7.27	6.93	7.62	9.95
Redox potential	Eh	-	-	22	-183	170	146	-220	-120
Turbidity	(NTU)	*6 - 50*	*1 - 20*	-0.5	2650	12.1	292	78.2	9
HCO_3	(mg/l)	-	-	>240	>240	>240	>240	>240	>240
Comment	-	-	-	SW	PW	PW	PW, no sample collected	PW, no sample collected	SW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Round Lake.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	22-04-10	21-04-10	22-04-10	22-04-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2167907	2167906	2167908	2167909
Sample ID	(number)	-	40304_1.W1	40304_2.W1	40304_5.W1	40304_8.W1
Site ID	(number)	-	40304_1 (SW)	40304_2 (PW)	40304_5 (PW)	40304_8 (SW)
Wetland ID	(code)	-	40304	40304	40304	40304
Site Number	(number)	-	1	2	5	8
Upper depth	cm	-	-30	30	90	-25
Lower depth	cm	-	0	40	100	0
Na	mg l^{-1}	-	4200	6800	140	5300
K	mg l^{-1}	-	210	320	38	260
Ca	mg l^{-1}	-	80	190	560	95
Mg	mg l^{-1}	-	740	1100	59	880
Si	mg l^{-1}	-	0.7	26	15	0.6
Br	mg l^{-1}	-	<50 LDIL	<50 LDIL	<5	<50 LDIL
Cl	mg l^{-1}	-	10000	13000	150	9700
NO_3	mg l^{-1}	0.7	0.13	0.02	0.08	0.01
NH_4-N[K]	mg l^{-1}	0.01	<0.1	3.1	0.1	0.1
PO_4-P[E]	mg l^{-1}	0.005	<0.01	0.01	<0.01	<0.01
SO_4	mg l^{-1}	-	2200	2900	1400	2200
Ag	µg l^{-1}	0.05	<1	<1	<1	<1
Al[A]	µg l^{-1}	55	<10	<10	<10	<10
As[B]	µg l^{-1}	13	8	12	<1	7
Cd	µg l^{-1}	0.2	<0.2	<0.2	<0.2	<0.2
Co	µg l^{-1}	2.8	<1	6	<1	<1
Cr[C]	µg l^{-1}	1	<1	<1	<1	<1
Cu[H]	µg l^{-1}	1.4	4	5	3	3
Fe	µg l^{-1}	300	<20	40	<20	<20
Mn	µg l^{-1}	1700	1	3800	5	1
Ni[H]	µg l^{-1}	11	<1	12	2	<1
Pb[H]	µg l^{-1}	3.4	<1	<1	<1	<1
Se	µg l^{-1}	11	2	2	<1	1
Zn[H]	µg l^{-1}	8	1	3	2	1
DOC	mg l^{-1}	-	14	22	8	15

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A] *Trigger value for Aluminium in freshwater where pH > 6.5.*

[B] *Trigger value assumes As in solution as Arsenic (AsV).*

[C] *Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E] *Guideline is for filterable reactive phosphorous (FRP).*

[H] *Hardness affected (refer to Guidelines).*

[K] *Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Round Lake.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40304_1	40304	1	22-04-10	54	191880	6069393
40304_2	40304	2	21-04-10	54	191820	6069467
40304_3	40304	3	21-04-10	54	191797	6069466
40304_4	40304	4	21-04-10	54	191750	6069467
40304_5	40304	5	22-04-10	54	192654	6069773
40304_6	40304	6	22-04-10	54	192616	6069736
40304_7	40304	7	22-04-10	54	192617	6069727
40304_8	40304	8	22-04-10	54	192611	6069722

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40304_1	-230	water	marine grasses and aquatic vegetation	low point, subaqueous	Subaqueous sediment samples	30	Subaqueous soil	strong H_2S odours present in softer surface layers in the shallow areas with dark sediment disturbance
40304_2	30	water logged, vegetation matting on surface	decomposed rushes matting with low salt bushes	edge of water line, very wet to moist	edge of water, H2S odours, organic decayed materials	5	Hydrosol - sandy or loamy	Similar conditions around the periphery of the water line based on visual assessment
40304_3	90	loose	edge of salt bush, some decayed rushes on surface	Mid point	Change in vegetation	5	Hydrosol - sandy or loamy	
40304_4		loose	Low grass, rushes, weeds	High point	Previous high water mark	10	Hydrosol - sandy or loamy	No water evident
40304_5	90	loose	Low rushes	High point	Previous high water mark	10	Hydrosol - sandy or loamy	Near a bund wall that that appears to go around the periphery of the lake
40304_6	40	loose	bare, surrounding low rushes	Mid point	Change of soil surface to sandy	5	Hydrosol - sandy or loamy	-

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40304_7	5	water logged, vegetation matting on surface	decomposed rushes matting	edge of water line, very wet to moist	edge of water, H2S odours, organic decayed materials	5	Hydrosol - sandy or loamy	-
40304_8	-25	water	bare	low point, subaqueous	Subaqueous sediment samples	30	Subaqueous soil	strong H_2S odours present in softer surface layers in the shallow areas with dark sediment disturbance

Table 7 - Profile description data for acid sulfate soil assessment of Round Lake.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40304_1.1	SS	0	5	10YR52	Clayey sand	Sandy	Wet	9.08	1:1
40304_1.2	SS	5	20	10YR42	Clayey sand	Sandy	Wet	8.89	1:1
40304_2.1	SS	0	3	10YR42	Loam	MDP material	Moist	8.50	1:1
40304_2.2	SS	3	15	10YR52	Loamy sand	Sandy	Moist	8.61	1:1
40304_2.3	SS	15	60	2.5Y41	Sandy loam	Sandy	Wet	8.66	1:1
40304_2.4	SA	60	80	5YR54	Clayey sand	Sandy	Wet	8.44	1:1
40304_2.5	SA	80	100	5YR56	Clayey sand	Sandy	Wet	8.75	1:1
40304_3.1	SS	0	5	10YR32	Loamy sand	Sandy	Moist	8.90	1:1
40304_3.2	SS	5	15	10YR42	Loamy sand	Sandy	Moist	9.20	1:1
40304_3.3	SS	15	25	5YR54	Sandy loam	Sandy	Moist	8.96	1:1
40304_3.4	SA	25	70	5YR56	Clayey sand	Sandy	Moist	9.12	1:1
40304_3.5	SA	70	120	5YR56	Clayey sand	Sandy	Wet	8.60	1:1
40304_4.1	SS	0	5	10YR42	Loamy sand	Sandy	Moderately	8.90	1:1
40304_4.2	SS	5	15	10YR52	Loamy sand	Sandy	Moderately	9.11	1:1
40304_4.3	SS	15	35	2.5Y41	Sandy loam	Sandy	Moderately	8.52	1:1
40304_4.4	SA	35	75	5YR54	Clayey sand	Sandy	Moderately	8.14	1:1
40304_4.5	SA	75	100	10YR64	Clayey sand	Sandy	Moist	8.63	1:1
40304_5.1	SS	0	10	10YR52	Sandy loam	Loamy	Moderately	8.32	1:1
40304_5.2	SS	10	35	10YR52	Sandy loam	Loamy	Moist	8.52	1:1
40304_5.3	SS	35	55	10YR52	Clayey sand	Sandy	Moist	7.95	1:1
40304_5.4	SA	55	80	2.5Y41	Sandy clay	Clayey	Moist	8.07	1:1
40304_5.5	SA	80	110	10YR52	Sandy clay	Clayey	Moist	8.10	1:1
40304_6.1	SS	0	5	10YR42	Sand	Sandy	Moist	8.51	1:1
40304_6.2	SS	5	30	10YR52	Clayey sand	Sandy	Moist	8.30	1:1
40304_6.3	SS	30	45	2.5Y41	Clayey sand	Sandy	Wet	8.15	1:1
40304_6.4	SA	45	60	5YR54	Sandy clay	Clayey	Wet	8.10	1:1
40304_6.5	SA	60	90	5YR56	Clayey sand	Sandy	Wet	7.88	1:1
40304_7.1	SS	0	3	10YR72	Sand	Sandy	Wet	8.98	1:1
40304_7.2	SS	3	10	10YR52	Clayey sand	Sandy	Wet	8.76	1:1
40304_7.3	SS	10	55	2.5Y41	Sandy clay	Clayey	Wet	7.75	1:1
40304_7.4	SA	55	75	5YR54	Silty clay	Clayey	Wet	8.42	1:1

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40304_8.1	SS	0	3	10YR42	Sand	Sandy	Wet	9.17	1:1
40304_8.2	SS	3	35	10YR52	Sandy clay	Clayey	Wet	8.87	1:1
40304_8.3	SA	35	55	2.5Y41	Silty clay	Clayey	Wet	8.55	1:1
40304_8.4	SA	55	75	5YR54	Silty clay	Clayey	Wet	8.38	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Round Lake.

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40304_1.1	0	-	-	-	-	0	VS	minor organics
40304_1.2	0	-	-	-	-	0	VS	minor organics
40304_2.1	0	-	-	-	-	0	VS	decomposed organic matting on surface
40304_2.2	0	-	-	-	-	0	VS	organics, H_2S odour
40304_2.3	0	-	-	-	-	0	VS	minor shell fragments
40304_2.4	30	FM	10R58	MAT	-	0	VS	
40304_2.5	30	FM	10R58	MAT	-	0	VS	
40304_3.1	0	-	-	-	SG	1	L	plant roots
40304_3.2	0	-	-	-	SG	1	L	
40304_3.3	0	-	-	-	MA	1	VW	minor plant roots
40304_3.4	30	FM	10R58	MAT	-	-	VW	minor plant roots
40304_3.5	30	FM	10R58	MAT	-	-	VW	
40304_4.1	0	-	-	-	SG	1	L	plant roots
40304_4.2	0	-	-	-	MA	1	L	
40304_4.3	0	-	-	-	MA	1	VW	minor plant roots
40304_4.4	30	FM	10R58	MAT	-	-	VW	minor plant roots
40304_4.5	0	-	-	-	-	-	F	some cemented fragments of soil, cemented sand
40304_5.1	0	-	-	-	GR	1	L	minor rootlets
40304_5.2	0	-	-	-	GR	1	L	minor plant roots
40304_5.3	2	FM	5Y58	RPO	MA	1	VW	-

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40304_5.4	0	-	-	-	-	-	VW	-
40304_5.5	0	-	-	-	-	-	VW	-
40304_6.1	0	-	-	-	GR	1	L	-
40304_6.2	0	-	-	-	GR	1	L	minor plant roots
40304_6.3	2	FM	5Y58	RPO	MA	1	VW	minor plant roots
40304_6.4	30	FM	10R58	MAT	-	-	VW	
40304_6.5	30	FM	10R58	MAT	-	-	VW	
40304_7.1	0	-	-	-	SG	1	S	decomposed organic matting on surface
40304_7.2	0	-	-	-	MA	1	S	organics, H_2S odour
40304_7.3	20	FM	10R58	MAT	MA	1	S	-
40304_7.4	30	FM	10R58	MAT	-	-	S	-
40304_8.1	0	-	-	-	SG	1	S	minor shell fragments
40304_8.2	0	-	-	-	MA	1	S	stong H_2S odour, very strong reaction to peroxide
40304_8.3	20	FM	10R58	MAT	MA	1	VW	-
40304_8.4	30	FM	10R58	MAT	-	-	VW	-

APPENDIX 2: GOULBURN RIVER (40355) SUMMARY REPORT

APPENDIX 2:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40355
Wetland Name:	Goulburn River

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 GOULBURN RIVER ... 2
1.1 Location and Setting Description ... 2
1.2 Soil Profile Description and Distribution ... 2
1.3 Summary of Field and Laboratory Results ... 4
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) ... 4
1.3.2 Acid Base Accounting ... 4
1.3.3 Titratable Actual Acidity (TAA) ... 5
1.3.4 Chromium Reducible Sulfur (S_{CR}) ... 5
1.3.5 Acid Volatile Sulfur (AVS) ... 5
1.3.6 Retained Acidity (RA) ... 5
1.3.7 Acid Neutralising Capacity (ANC) ... 5
1.3.8 Net Acidity ... 5
1.3.9 Water soluble SO_4 ... 5
1.4 Hydrochemistry ... 6
1.5 Discussion ... 7
1.6 Summary of Key Findings for Goulburn River ... 8

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Goulburn River Sites. ... 2
Table 2 – Summary Of Key Findings ... 8
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Goulburn River. ... 9
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Goulburn River. ... 10
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Goulburn River ... 11
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Goulburn River. ... 12
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Goulburn River. ... 13

LIST OF FIGURES

Figure 1 – Goulburn River 40355 Site Plan.

Figure 2 – Goulburn River Conceptual Hydrotoposequence Cross Section – 40355.

Figure 3 – Photographs of site 40355_1, showing the water surface (water column of 1.20m), and the chip tray soil profile of dark grey soft, decomposed organics, soft silty clay collected with small sediment grabber.

Figure 4 – Photographs of site 40355_2, showing the edge of waterline, and the chip tray soft soil profile of silty clay loam overlying very dark grey silty clay loam.

Figure 5 – Photographs of site 40355_3, showing the high point firm vegetated surface, and the shallow (0 – 50cm) soil profile of dark yellowish brown, silty clay loam overlying very dark grey silty clay loam.

Figure 6 – Depth profiles of soil pH for Goulburn River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 7 – Acid base accounting depth profiles for Goulburn River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 GOULBURN RIVER

1.1 Location and Setting Description

Goulburn River is situated on the western side of the Goulburn River, approximately 4km North East of the township of Murchison, VIC. The wetland is accessed from Mooroopna Murchison Road. The wetland is oval in shape, and approximately 100m by 150m in dimension, with a total area of 1 hectare.

The wetland is connected to the Goulburn River at times of higher water levels and is bounded by short, steep bank slopes on the Northern side of the wetland. There is a small incised, grassed channel that runs from the wetland to the Goulburn River which was dry at the time of inspection in April 2010. At the time when the soil survey was conducted in April 2010, the wetland had surface water covering the majority of the wetland.

Water within the wetland was brown and slightly turbid and the bottom or lowest point could not be seen visually through the water column. The water line and lower shallow banks around the periphery of the wetland contained low grasses and rushes. The higher banks of the wetland contained medium sized trees. Three sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Three sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at the wetland for the three sites chosen. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 5** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

- 40355_1: water surface, subaqueous sediments and the soil consisted of dark grey, wet, decomposed organics, soft silty clay.
- 40355_2: water logged surface, edge of water line; soil consisted of dark yellowish brown, soft, silty clay loam overlying very dark grey silty clay loam.
- 40355_3: firm surface, some low grass and reeds, soil consisted of dark yellowish brown, silty clay loam overlying very dark grey silty clay loam.

Table 1 – Soil Identification, subtype and general location description for Goulburn River Sites.

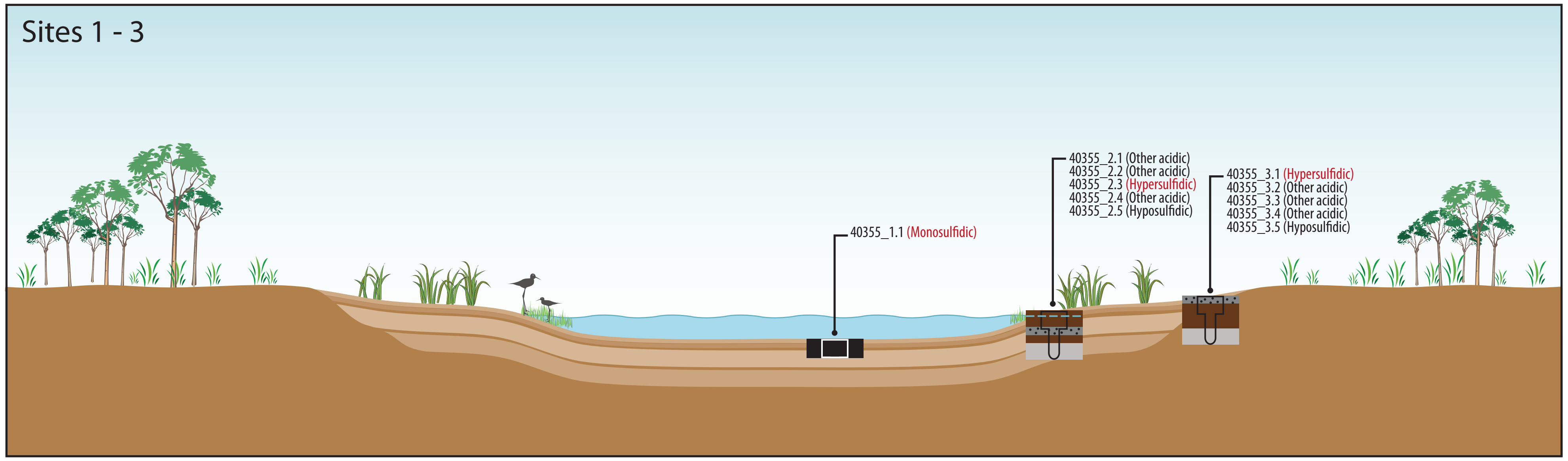
Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40355_1	343537	5949101	Subaqueous soil	Low point, subaqueous sediments
40355_2	343486	5949068	Hydrosol - sandy or loamy	Midpoint, edge of water line, low grass and reeds
40355_3	343483	5949067	Hydrosol - sandy or loamy	High point, low grass and reeds, change, dryer site above water

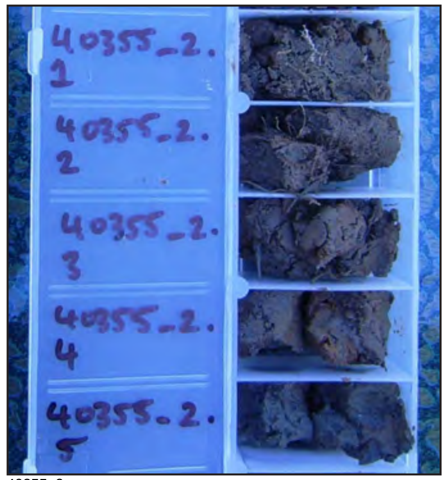
DATE 09/07/2010	SCALE 1:600 (0 5 10 20 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 55	FIG NO. 1	PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS			PROJECT NO. 3001801	FIGURE TITLE Goulburn River 40355 - CMA: GBCMA

Note: Inset Photos show Surface Condition of Site

LEGEND
Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils





40355_2


40355_3

DATE 15/07/2010	**SCALE** Not to Scale	**FIG NO.** 2	**PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS	**PROJECT NO.** 3001801	**FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Goulburn River 40355

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

SMEC

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Figure 3 - Photographs of site 40355_1, showing the water surface (water column of 1.20m), and the chip tray soil profile of dark grey soft, decomposed organics, soft silty clay collected with small sediment grabber

Figure 4 – Photographs of site 40355_2, showing the edge of waterline, and the chip tray soft soil profile of silty clay loam overlying very dark grey silty clay loam.

Figure 5 – Photographs of site 40355_3, showing the high point firm vegetated surface, and the shallow (0 – 50cm) soil profile of dark yellowish brown, silty clay loam overlying very dark grey silty clay loam.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the three sites are presented in **Figure 6** below. Summary soil pH profile results indicate:

- 40355_1: acidic pH_w (5.59) that dropped to 4.28 after $pH_{incubation}$ indicating possible monosulfidic or other acid source such as organics from decomposed plant materials.
- 40355_2: all samples have $pH_w > 4.5$ and $pH_{incubation}$ generally between 4.0 – 4.5 indicating other acidic or hyposulfidic conditions. One surface layer had a $pH_{incubation}$ of 3.93 indicating likely hypersulfidic conditions.
- 40355_3: Surface samples indicate $pH_w > 4.5$ and $pH_{incubation}$ below 4.0 indicating either hyper or hyposulfidic conditions. Deeper samples indicate $pH_w > 4.5$ and $pH_{incubation}$ below 4.0 indicating other acid conditions.

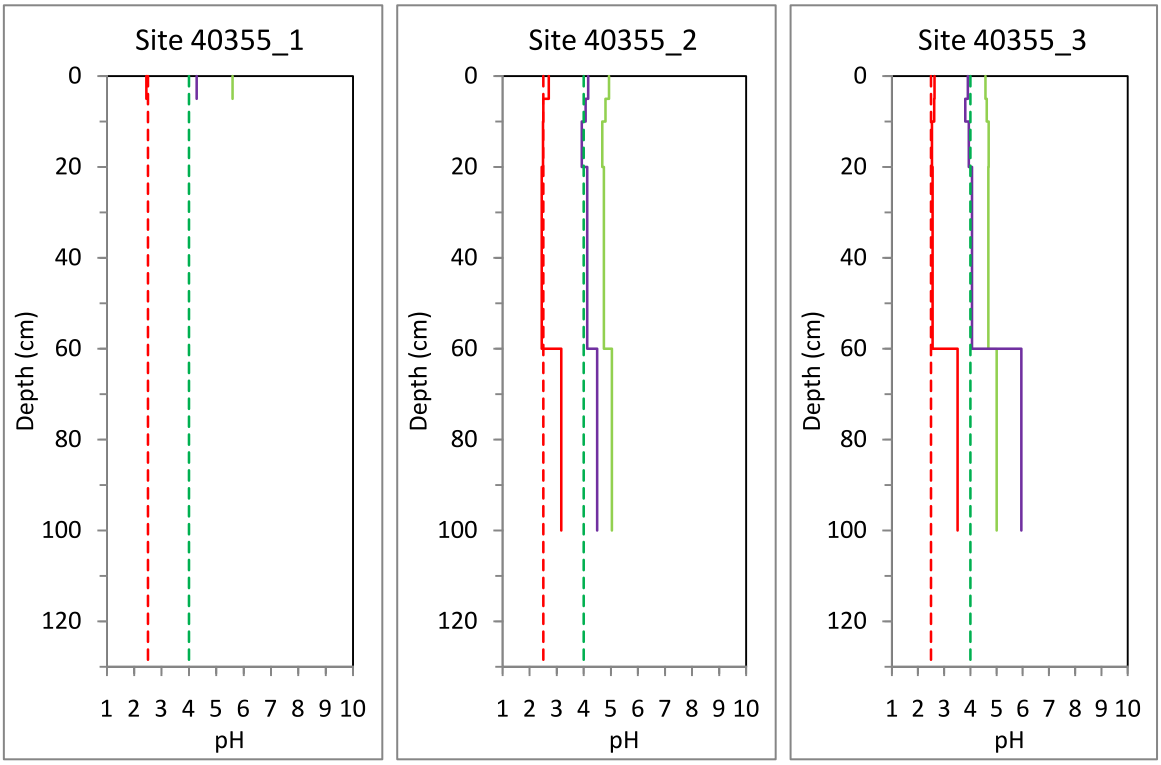


Figure 6 – Depth profiles of soil pH for Goulburn River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 7** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 11 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 38 – 55.2 mol H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic conditions with pH_w all less than 5.6.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 11 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01 (limit of detection) and 0.10 %S. The highest result (0.10%S) was located at the subaqueous site (40355_1). Five out of the eleven materials sampled indicated sulfidic conditions that were not distinguished between the shallow or upper soil layers in either profiles. All other sites within the mid to high points of the wetland indicated values at or below detection limits (<0.01 to 0.01%S).

1.3.5 Acid Volatile Sulfur (AVS)

One sample was analysed for S_{AV} from the subaqueous site (40355_1). The sample matrix was made up of highly decomposed organics with a value of 0.034 $\%S_{AV}$ dry weight.

1.3.6 Retained Acidity (RA)

Four out of the eleven samples had pH_{KCL} results below the threshold of 4.50 for retained acidity analysis. Of the four samples analysed for RA, only one sample from Site 2 had a detectable level of 1 mol H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

None of the samples were analysed for ANC as no samples had a pH higher than 6.5 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

Net acidity results for all sites and samples ranged between 38 to 125 mol H+/tonne. The highest net acidity result value was from the subaqueous sample that may contain MBO. The remainder ranged between 38 – 55 mol H+/tonne and were not vertically concentrated in the soil profile or specific, identifiable layers or materials.

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

All materials collected had a moderate net acidity with the exception of site 40355_1 which had a high net acidity value for bottom sediments of 125 mole H+/tonne.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 23 to 109 mg/L for surface soil samples collected (i.e. 0 – 10cm). Three surface soil samples were analysed for water soluble sulfate in total. The highest result (109 mg/L) was from the subaqueous sample that may contain MBO (40355_1) and exceeds the trigger criterion of 100 mg/L for MBO formation potential.

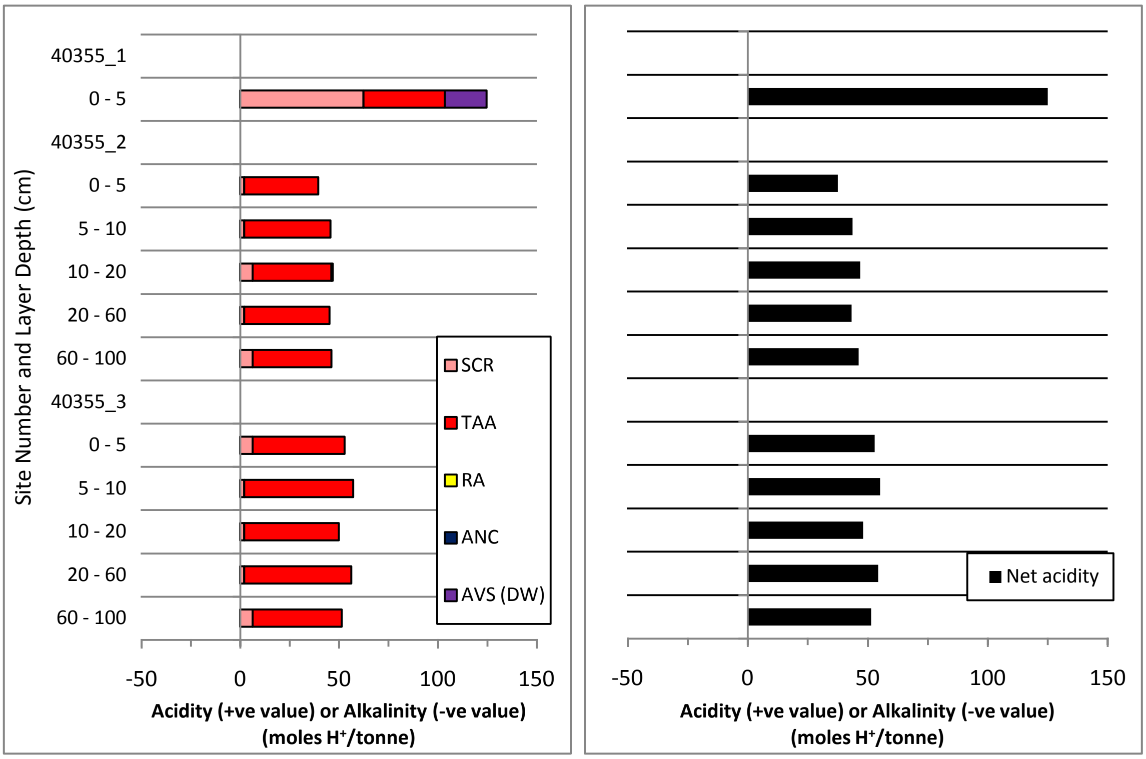


Figure 7 – Acid base accounting depth profiles for Goulburn River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two out of the three sites from Goulburn River. One measurement was from pit inflow waters and one from wetland surface waters. Pit inflow waters were not sufficient to collect a sample for laboratory analysis. One water sample was collected for laboratory analysis from wetland surface waters.

The wetland surface waters were neutral (pH 7.12) and pit inflow waters were slightly acidic (pH 6.54), within the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 – 8.0. All sites had high SEC values (>1,600µS/cm) which were within the Lowland River trigger values of 125 – 2,200µS/cm. Alkalinity (as HCO_3) was also high at all sites (240 HCO_3). The surface water site had oxidising conditions (113 Eh) with the wetland high point margin site having reducing conditions (-54) as pit inflow water. Wetland surface waters had a higher DO (4.48 mg/L) compared to the lower DO values (0.22 mg/L) for pit inflow waters as expected at the higher wetland margin site.

The surface water Aluminium concentration for the site was 60µg/L, above the trigger value of 55µg/L in freshwater with a pH greater than 6.5. Iron was also above the trigger value of 300µg/L for the site with a value of 670µg/L.

The water data indicates that the surface water has not been affected by acidification.

1.5 Discussion

Acid sulfate soil materials occurred at all three sites surveyed and sampled. Sulfidic sediments occurred as either subaqueous sediments that are monosulfidic (40355_1) or hypersulfidic within one subsoil (40355_2 10-20cm) and surface sample (40355_3 0-5cm). Sulfuric materials were not observed in this wetland.

The highest S_{CR} was 0.01%S for the two hypersulfidic classified subsoil and surface soil samples. The monosulfidic subaqueous sediment sample result was 0.10%S (using the S_{CR} test) and 0.034%S_{AV}. Both of the soil profiles (40355_2 and 40355_3) also contained hyposulfidic and other acidic materials throughout the profile. These results indicate that both soil profiles contain low oxdisable sulfide and minimal acidity would be produced from sulfidic sources.

The highest water soluble sulfate result (109 mg/L) was from the subaqueous sample that is classified as monosulfidic (40355_1). This value exceeds the trigger criterion of 100 mg/L for MBO formation potential. All materials collected had a moderate net acidity with the exception of site 40355_1 which had a high net acidity value for bottom sediments.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are three high priority sites based on the presence of monosulfidic and hypersulfidic materials and both sites contained hyposulfidic materials (S_{CR} < 0.10%) with a moderate priority. However, the remaining soil materials sampled are classified as "no further assessment".

Due to the low levels of sulfides present (all with the exception of subaqueous sediment equal to or less than 0.01%S) the requirement for Phase 2 laboratory analysis may not be warranted for all but monosulfidic samples (40355_1.1). In addition, the wetland area is very small (<1 ha) with a lower risk of significant oxidation and acidity generation except when the water level of the wetland is significantly reduced or dries out completely.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Goulburn River are:

- Acidification hazard: low to medium level of concern based on the moderate net acidities and sulfidic results (from S_{CR}) with 90% of samples equal to or below 0.01%S. The degree of acidification from sulfidic sources only appears to be low. There is a medium risk of acidification from monosulfides if the water level in the wetland reduced significantly.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results for currently subaqueous sediments exceeded the trigger value for monosulfide formation.

- Metal mobilisation: The low to medium acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation; however the lower pH_w results (pH 4.5-5.0) indicate that current soil pH is low and may be sufficient for mobilisation of aluminium, therefore a low to medium level of concern.

1.6 Summary of Key Findings for Goulburn River

The summary of key findings for Goulburn River is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Sulfidic materials identified included: o hypersulfidic (site 2 subsoil and site 3 surface). o monosulfidic (Site 1). o remainder either hyposulfidic (<0.10%S) or other acidic. • Net acidities ranged between 38 to 125 mol H+/tonne with the majority of acidity coming from titratable actual acidity (TAA). • The majority of materials had a moderate net acidity.
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Hydrosol – sandy or loamy occurring at water edge and wetland margin soils. • Site 3: Hydrosol – sandy or loamy occurring at wetland margin soils.
Hazard assessment:	• Acidification hazard – low to medium level of concern • De-oxygenation hazard – medium level of concern • Metal mobilisation hazard – low to medium level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Goulburn River.

Sample ID	Site ID	Upper depth (cm)	Lower depth (cm)	Wet weight (kg)	Dry weight (kg)	Moisture (%)	pH w	pH fox	pH incubation	Sulfate (mg/L)
40355_1.1	40355_1	0	5	0.0966	0.0371	62	5.59	2.45	4.28	109
40355_2.1	40355_2	0	5	0.1309	0.1045	20	4.93	2.70	4.16	25
40355_2.2	40355_2	5	10	0.1206	0.0931	23	4.80	2.50	4.07	-
40355_2.3	40355_2	10	20	0.1334	0.1023	23	4.68	2.49	3.93	-
40355_2.4	40355_2	20	60	0.1273	0.1006	21	4.74	2.44	4.12	-
40355_2.5	40355_2	60	100	0.1337	0.1072	20	5.04	3.17	4.49	-
40355_3.1	40355_3	0	5	0.1042	0.0869	17	4.58	2.63	3.90	23
40355_3.2	40355_3	5	10	0.0758	0.0627	17	4.62	2.62	3.80	-
40355_3.3	40355_3	10	20	0.0982	0.0772	21	4.70	2.53	3.94	-
40355_3.4	40355_3	20	60	0.1150	0.0903	21	4.69	2.56	4.06	-
40355_3.5	40355_3	60	100	0.1386	0.1108	20	5.00	3.51	5.95	-

Sample ID	Site ID	Upper depth (cm)	Lower depth (cm)	pH_{kcl}	TAA (mole H+ t-1)	RIS (S_{CR}) (%)	RA (mole H+ t-1)	ANC (%CaCO3)	Net acidity (mole H+ t-1)	AVS (DW) (%Sav DW)	ASS material type
40355_1.1	40355_1	0	5	5.26	41	0.10	0	-	125	0.034	Monosulfidic
40355_2.1	40355_2	0	5	4.50	38	<0.01	0	-	38	-	Other acidic
40355_2.2	40355_2	5	10	4.56	44	<0.01	0	-	44	-	Other acidic
40355_2.3	40355_2	10	20	4.41	40	0.01	1	-	47	-	Hypersulfidic
40355_2.4	40355_2	20	60	4.38	43	<0.01	0	-	43	-	Other acidic
40355_2.5	40355_2	60	100	4.63	40	0.01	0	-	46	-	Hyposulfidic
40355_3.1	40355_3	0	5	4.51	47	0.01	0	-	53	-	Hypersulfidic
40355_3.2	40355_3	5	10	4.54	55	<0.01	0	-	55	-	Other acidic
40355_3.3	40355_3	10	20	4.45	48	<0.01	0	-	48	-	Other acidic
40355_3.4	40355_3	20	60	4.43	54	<0.01	0	-	54	-	Other acidic
40355_3.5	40355_3	60	100	4.64	45	0.01	0	-	51	-	Hyposulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Goulburn River.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40355_1.W1	-
Site ID	(number)	-	-	40355_1	40355_3
Wetland ID	(code)	-	-	40355	40355
Site Number	(number)	-	-	1	1
Upper depth	cm	-	-	-30	80
Lower depth	cm	-	-	0	90
Temperature	(deg C)	-	-	13.5	19.3
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	1785	1997
Dissolved Oxygen	(%)	-	-	43.3	3.5
Dissolved Oxygen	(mg/l)	-	-	4.48	0.22
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	7.12	6.54
Redox potential	Eh	-	-	113	-54
Turbidity	(NTU)	*6 - 50*	*1 - 20*	31.5	1071
HCO_3	(mg/l)	-	-	240	240
Comment		-	-	SW	PW, no sample collected

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Goulburn River

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	14-04-10
Laboratory	(code)	-	Ecowise/ALS
Laboratory sample ID	number	-	2155288
Sample ID	(number)	-	40355_1.W1
Site ID	(number)	-	40355_1 (SW)
Wetland ID	(code)	-	40355
Site Number	(number)	-	1
Upper depth	cm	-	-30
Lower depth	cm	-	0
Na	mg l^{-1}	-	290
K	mg l^{-1}	-	7.9
Ca	mg l^{-1}	-	18
Mg	mg l^{-1}	-	34
Si	mg l^{-1}	-	1.8
Br	mg l^{-1}	-	<5
Cl	mg l^{-1}	-	390
NO_3	mg l^{-1}	0.7	0.02
NH_4-N[K]	mg l^{-1}	0.01	<0.1
PO_4-P[E]	mg l^{-1}	0.005	<0.01
SO_4	mg l^{-1}	-	70
Ag	µg l^{-1}	0.05	<1
Al[A]	µg l^{-1}	55	60
As[B]	µg l^{-1}	13	2
Cd	µg l^{-1}	0.2	<0.2
Co	µg l^{-1}	2.8	<1
Cr[C]	µg l^{-1}	1	<1
Cu[H]	µg l^{-1}	1.4	1
Fe	µg l^{-1}	300	670
Mn	µg l^{-1}	1700	170
Ni[H]	µg l^{-1}	11	2
Pb[H]	µg l^{-1}	3.4	<1
Se	µg l^{-1}	11	<1
Zn[H]	µg l^{-1}	8	4
DOC	mg l^{-1}	-	12

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]Trigger value for Aluminium in freshwater where pH > 6.5.

[B]Trigger value assumes As in solution as Arsenic (AsV).

[C]Trigger value for Chromium is applicable to Chromium (CrVI) only.

[E]Guideline is for filterable reactive phosphorous (FRP).

[H]Hardness affected (refer to Guidelines).

[K]Guideline for South-east Australia-Freshwater Lakes and reservoirs.

Table 6 - Site description data for acid sulfate soil assessment of Goulburn River.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40355_1	40355	1	14-04-10	55	343537	5949101
40355_2	40355	2	13-04-10	55	343486	5949068
40355_3	40355	3	13-04-10	55	343483	5949067

Depth to Water Table	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness	ASS Soil Classification	Comments
-120	water	water	low point, subaqueous	Subaqueous sediment samples	40	Subaqueous soil	-
-2	soft	low grass, reeds	Mid point	edge of water	10	Hydrosol - sandy or loamy	-
80	firm	low grass, reeds	High point	Dryer site above water	50	Hydrosol - sandy or loamy	-

Table 7 - Profile description data for acid sulfate soil assessment of Goulburn River.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40355_1.1	BA	0	5	GLEY12.510Y	Silty clay loam	Clayey	Wet	6.71	1:1
40355_2.1	SS	0	5	10YR44	Silty clay loam	Clayey	Moist	5.54	1:1
40355_2.2	SS	5	10	10YR44	Silty clay loam	Clayey	Moist	5.51	1:1
40355_2.3	SS	10	20	10YR44	Silty clay loam	Clayey	Moist	4.60	1:1
40355_2.4	SA	20	60	10YR44	Silty clay loam	Clayey	Moist	4.87	1:1
40355_2.5	SA	60	100	5Y31	Silty clay loam	Loamy	Moist	5.69	1:1
40355_3.1	SS	0	5	10YR44	Silty clay loam	Clayey	Moist	4.34	1:1
40355_3.2	SS	5	10	10YR44	Silty clay loam	Clayey	Moist	4.25	1:1
40355_3.3	SS	10	20	10YR44	Silty clay loam	Clayey	Moist	4.48	1:1
40355_3.4	SA	20	60	10YR44	Silty clay loam	Clayey	Moist	4.88	1:1
40355_3.5	SA	60	100	5Y31	Silty clay loam	Loamy	Moist	6.51	1:1

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40355_1.1	0	-	-	-	-	0	VS	buttery feel, organic materials, decomposed leaves
40355_2.1	10	FM	7.5YR46	MAT	-	0	VS	rootlets
40355_2.2	10	FM	7.5YR46	MAT	-	0	VS	minor plant roots
40355_2.3	10	FM	7.5YR46	MAT	-	0	VS	minor plant roots
40355_2.4	10	FM	7.5YR46	MAT	-	0	VS	-
40355_2.5	0	-	-	-	-	0	VS	-
40355_3.1	20	FM	7.5YR46	MAT	MA	1	VS	rootlets
40355_3.2	20	FM	7.5YR46	MAT	MA	1	VS	minor plant roots
40355_3.3	20	FM	7.5YR46	MAT	MA	1	W	minor plant roots
40355_3.4	20	FM	7.5YR46	MAT	MA	1	W	-
40355_3.5	0	-	-	-	-	-	VS	-

APPENDIX 3: LOCH GARY (40383) SUMMARY REPORT

APPENDIX 3:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40383
Wetland Name:	Loch Garry

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 LOCH GARRY 3

1.1 Location and Setting Description 3

1.2 Soil Profile Description and Distribution 3

1.3 Summary of Field and Laboratory Results 8

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 9

1.3.2 Acid Base Accounting 13

1.3.3 Titratable Actual Acidity (TAA) 13

1.3.4 Chromium Reducible Sulfur (S_{CR}) 13

1.3.5 Acid Volatile Sulfur (AVS) 13

1.3.6 Retained Acidity (RA) 13

1.3.7 Acid Neutralising Capacity (ANC) 13

1.3.8 Net Acidity 13

1.3.9 Water soluble SO_4 14

1.4 Hydrochemistry 15

1.5 Discussion 16

1.6 Summary of Key Findings for Loch Garry 17

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Loch Garry Sites. 4
Table 2 – Summary Of Key Findings. 17
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Loch Garry. 19
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Loch Garry. 23
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Loch Garry. 24
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Loch Garry. 25
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Loch Garry. 27

LIST OF FIGURES

Figure 1 – Loch Garry 40383 Site Plan.

Figure 2 – Loch Garry Conceptual Hydrotoposequence Cross Section – 40383.

Figure 3 - Photographs of site 40383_1, showing the mid stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 4 – Photographs of site 40383_2, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 5 – Photographs of site 40383_3, showing the stream channel surface condition, cracking surface and the shallow soil profile of reddish brown, strong, silty clay loam and clay.

Figure 6 – Photographs of site 40383_4, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 7 – Photographs of site 40383_5, showing the mid stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 8 – Photographs of site 40383_6, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 9 – Photographs of site 40383_7, showing the stream channel surface condition and the shallow soil profile reddish brown, strong, silty clay loam and clay.

Figure 10 – Photographs of site 40383_8, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 11 – Photographs of site 40383_9, showing the mid stream channel surface condition (water column of 33cm) and the shallow soil profile of light brownish grey, strong, wet, silty clay loam.

Figure 12 – Photographs of site 40383_10, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 13 – Photographs of site 40383_11, showing the stream channel surface condition and the shallow soil profile of reddish brown, strong, silty clay loam and clay.

Figure 14 – Photographs of site 40383_12, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 15 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 16 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 17 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 18 – Acid base accounting depth profiles for Loch Garry. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (AVS DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

Figure 19 – Acid base accounting depth profiles for Loch Garry. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (AVS DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 LOCH GARRY

1.1 Location and Setting Description

Loch Garry is situated approximately 20km North West of Shepparton and 2km West of Bunbartha VIC. The wetland is approximately 1km to the North East of the Goulburn River. The wetland is accessed from Loch Garry Road off the Barmah Shepparton Road and is a circular to horse shoe shaped oxbow channel, and approximately 2km wide by 2km in length, with a total area of 206 hectares.

The wetland is generally a dry stream channel with minor banks and low batters leading up onto the floodplain. At the time when the soil survey was conducted in April 2010, the wetland had no surface water within the channel with the exception of one small area (<10% of wetland) that contained shallow pooled water. The wetland is a typical oxbow which has a long curved stream channel but is closed to the Goulburn River.

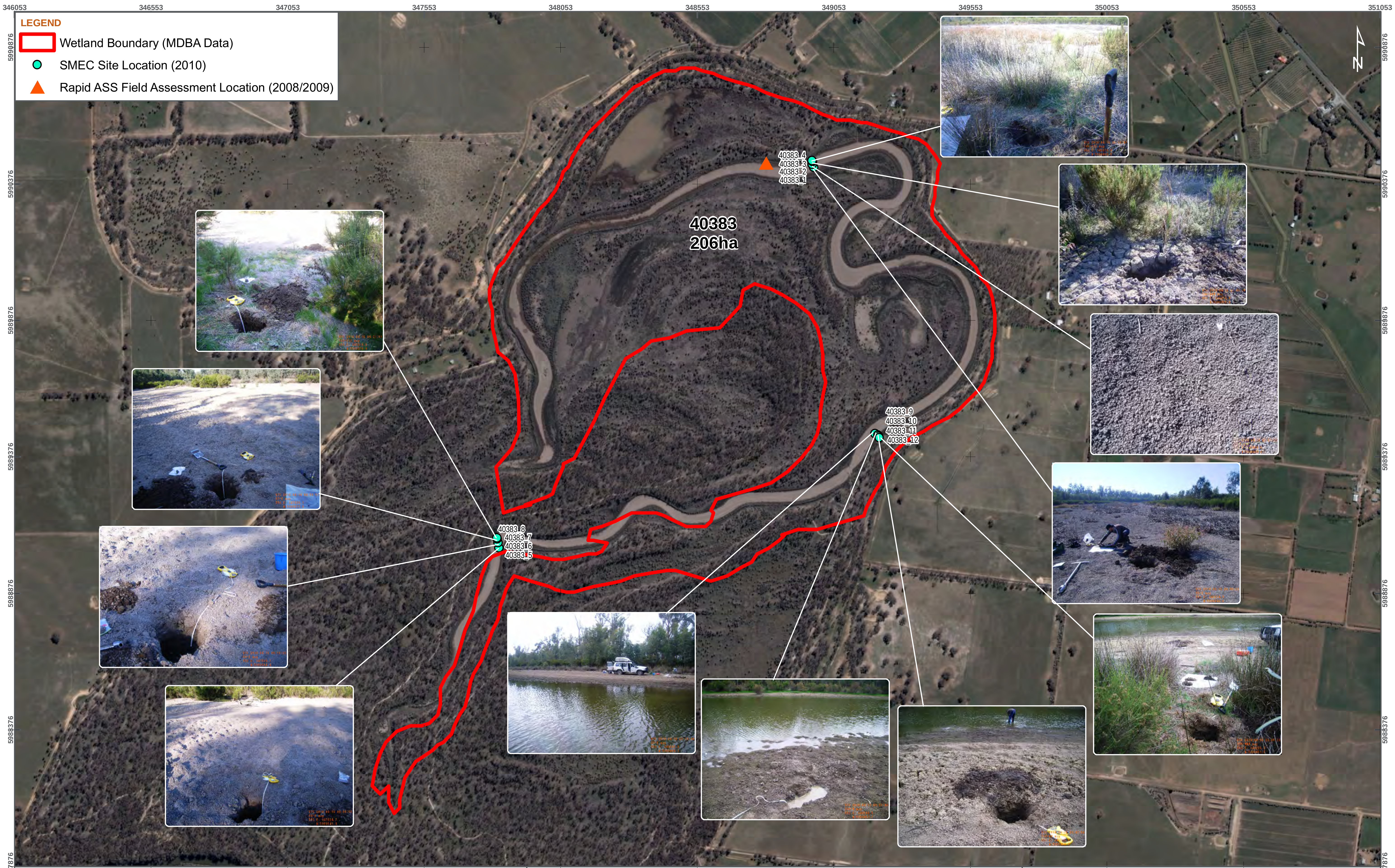
The small volume of surface water within the wetland was generally clear to slight brown and green and the bottom or lowest point could be seen visually through the shallow (33cm) water column. The channel was generally devoid of vegetation with the exception of some minor reeds and rushes in the most western portion of the wetland. The channel banks and upper floodplain contained low grasses, reeds, rushes, shrubs and medium to large trees. Twelve sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Twelve sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at the wetland for the twelve sites chosen and separated into four sites per transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 14** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

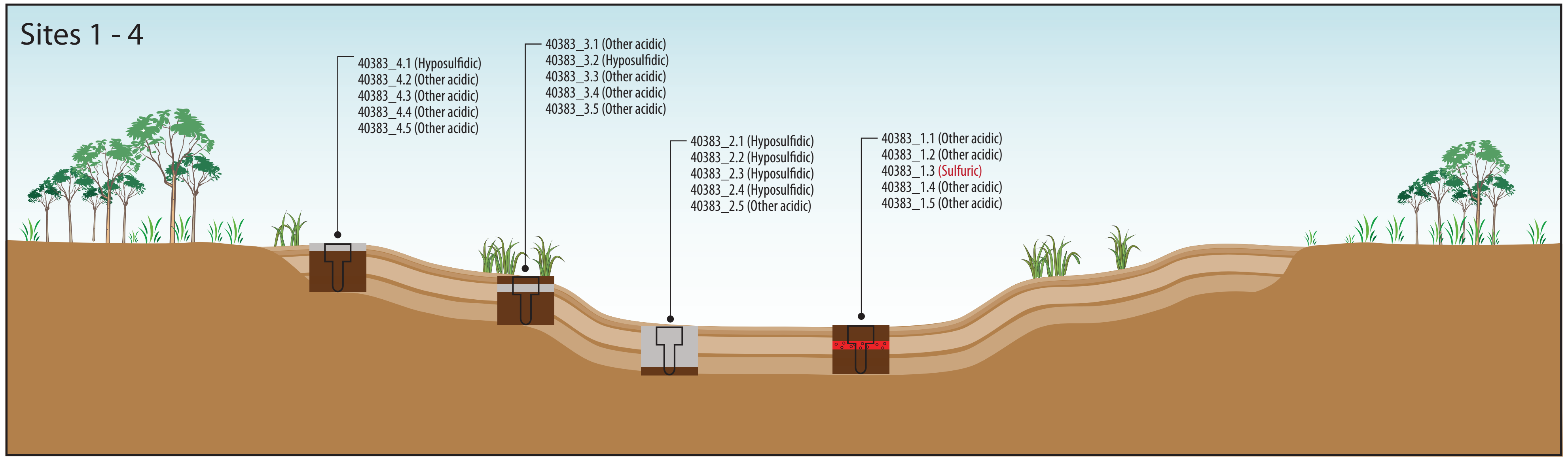
- 40383_1: loose, mainly bare with minor dead sedges, low point, mid stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_2: loose, mainly bare with minor dead sedges, mid point, stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_3: cracking, reeds and medium bushes, high point, stream channel; soil consisted of reddish brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_4: cracking, reeds and low grasses, high point, upper edge of stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_5: loose, bare, low point, mid stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.

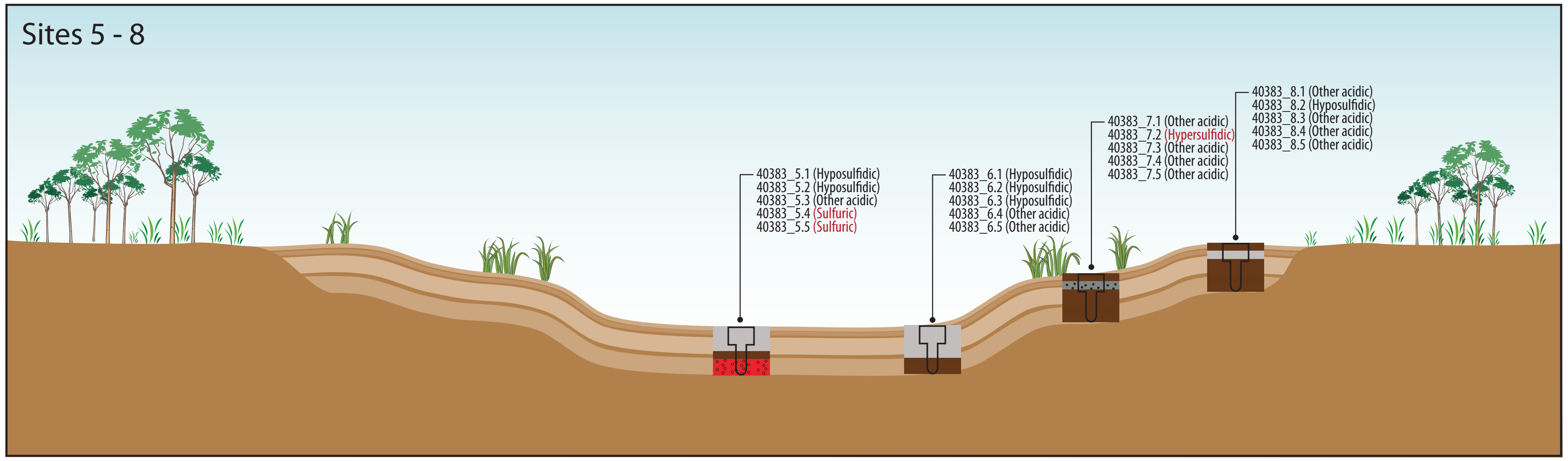


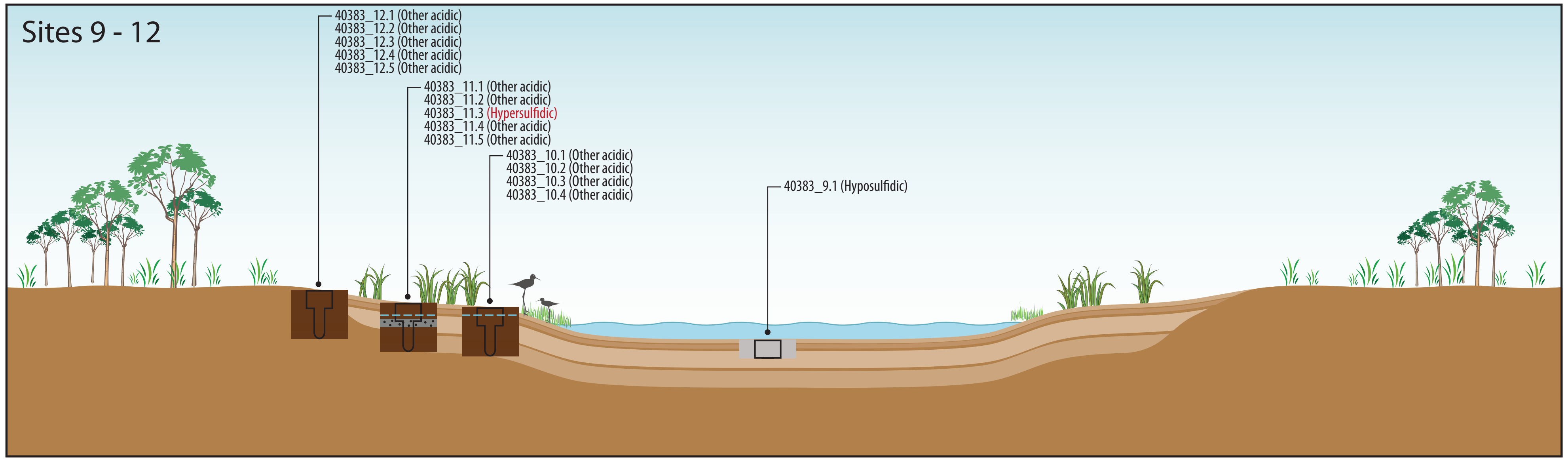
DATE 09/07/2010	SCALE 1:12,500 (0, 125, 250, 500 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 55	FIG NO. 1 — PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS			PROJECT NO. 3001801 — FIGURE TITLE Loch Garry 40383 - CMA: GBCMA

Note: Inset Photos show Surface Condition of Site

SMEC







LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2 **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Loch Garry 40383

SMEC · Australian Government · MURRAY–DARLING BASIN AUTHORITY

- 40383_6: loose, bare, mid point, stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_7: loose, bare, high point, stream channel; soil consisted of reddish brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_8: cracking, bushes and low grasses, high point, upper edge of stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_9: water surface, subaqueous sediments, bare, low point, mid stream channel; soil consisted of light brownish grey, strong, wet, silty clay loam.
- 40383_10: loose, minor low grasses and algae on ped surfaces, mid point, stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_11: cracking, bare, mid point, stream channel; soil consisted of reddish brown, strong, silty clay loam and clay overlying dark reddish grey, very firm, silty clay loam.
- 40383_12: cracking, reeds and low grasses, high point, upper edge of stream channel; soil consisted of very dark brown, strong, silty clay loam and clay overlying dark reddish grey and yellowish brown, very firm, silty clay loam.

Table 1 – Soil Identification, Subtype and General Location Description for Loch Garry Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40383_1	348980	5990436	Sulfuric cracking clay soil	Low point, mid stream channel, mainly bare with minor dead sedges.
40383_2	348974	5990448	Cracking clay soils	Mid point, stream channel, mainly bare with minor dead sedges.
40383_3	348974	5990457	Cracking clay soils	High point, stream channel, reeds and medium bushes.
40383_4	348972	5990461	Cracking clay soils	High point, upper edge of stream channel, reeds and low grasses.
40383_5	347826	5989043	Sulfuric cracking clay soil	Low point, mid stream channel, bare.
40383_6	347824	5989061	Cracking clay soils	Mid point, stream channel, bare.
40383_7	347821	5989076	Hypersulfidic cracking clay soils	High point, stream channel, bare.
40383_8	347819	5989079	Cracking clay soils	High point, upper edge of stream channel, bushes and low grasses.
40383_9	349204	5989461	Cracking clay soils	Low point, mid stream channel, subaqueous sediments, bare.
40383_10	349214	5989456	Cracking clay soils	Mid point, stream channel, minor low grasses and algae on ped surfaces.
40383_11	349217	5989452	Hypersulfidic cracking clay soils	Mid point, stream channel, bare.
40383_12	349220	5989447	Cracking clay soils	High point, upper edge of stream channel, reeds and low grasses.

Figure 3 - Photographs of site 40383_1, showing the mid stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 4 – Photographs of site 40383_2, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 5 – Photographs of site 40383_3, showing the stream channel surface condition, cracking surface and the shallow soil profile of reddish brown, strong, silty clay loam and clay.

Figure 6 – Photographs of site 40383_4, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 7 – Photographs of site 40383_5, showing the mid stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 8 – Photographs of site 40383_6, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 9 – Photographs of site 40383_7, showing the stream channel surface condition and the shallow soil profile reddish brown, strong, silty clay loam and clay.

Figure 10 – Photographs of site 40383_8, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 11 – Photographs of site 40383_9, showing the mid stream channel surface condition (water column of 33cm) and the shallow soil profile of light brownish grey, strong, wet, silty clay loam.

Figure 12 – Photographs of site 40383_10, showing the stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

Figure 13 – Photographs of site 40383_11, showing the stream channel surface condition and the shallow soil profile of reddish brown, strong, silty clay loam and clay.

Figure 14 – Photographs of site 40383_12, showing the upper edge of stream channel surface condition and the shallow soil profile of very dark brown, strong, silty clay loam and clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The following subheadings provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the two sites are presented in **Figures 15 to 17** on the following pages. Summary soil pH profile results indicate:

- 40383_1: all samples have pH_w < 5.0. Surface soils (0 - 30cm) have pH_w 4.45 – 4.84 with subsoils (30 – 110cm) ranging 3.94 – 4.07. Surface soils $pH_{incubation}$ ranged between 4.06 – 4.50 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged between 3.55 – 3.77 indicating sulfuric and other acidic conditions.
- 40383_2: all samples have pH_w < 5.0. Surface soils (0 - 40cm) have pH_w 4.48 – 4.91 with subsoils (40 – 100cm) ranging 4.22 – 4.44. Surface soils $pH_{incubation}$ ranged between 4.26 – 4.43 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.89 – 3.97 indicating hyposulfidic and other acidic conditions.
- 40383_3: all samples have pH_w < 5.0. Surface soils (0 - 20cm) have pH_w 4.69 – 4.98 with subsoils (20 – 100cm) ranging 4.31 – 4.47. Surface soils $pH_{incubation}$ ranged between 4.16 – 4.22 indicating other acidic and hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.86 – 3.97 indicating other acidic conditions.
- 40383_4: all samples have pH_w < 5.0. Surface soils (0 - 40cm) have pH_w 4.75 – 4.85 with subsoils (40 – 100cm) ranging 4.56 – 4.73. Surface soils $pH_{incubation}$ ranged between 4.05 – 4.14 indicating other acidic and hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.94 – 3.98 indicating other acidic conditions.
- 40383_5: all samples have pH_w < 5.0. Surface soils (0-30cm) have pH_w 4.32 – 5.32 with subsoils (30 – 100cm) ranging 3.81 – 4.10. Surface soils $pH_{incubation}$ ranged between 3.96 – 5.00 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.30 – 3.67 indicating sulfuric and other acidic conditions.
- 40383_6: all samples have pH_w < 5.0. Surface soils (0 – 30cm) have pH_w 4.72 – 4.88 with subsoils (30 – 110cm) ranging 4.02 – 4.08. Surface soils $pH_{incubation}$ ranged between 4.23 – 4.84 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.47 – 4.13 indicating hyposulfidic and other acidic conditions.
- 40383_7: all samples have pH_w < 5.5. Surface soils (0 - 15cm) have pH_w 4.59 – 5.28 with subsoils (20 – 130cm) ranging 4.30 – 4.36. Surface soils $pH_{incubation}$ ranged between 3.60 – 4.83 indicating other acidic and hypersulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.75 – 3.77 indicating other acidic conditions.
- 40383_8: all samples have pH_w < 5.1. Surface soils (0 - 40cm) have pH_w 4.53 – 5.04 with subsoils (40 – 100cm) ranging 4.57 – 4.73. Surface soils $pH_{incubation}$ ranged between 4.14 – 4.38 indicating other acidic and hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.94 – 3.96 indicating other acidic conditions.
- 40383_9: Only 1 subaqueous sample was collected (0 – 20cm) with pH_w 5.39 and $pH_{incubation}$ 4.73 indicating hyposulfidic conditions.
- 40383_10: all samples have pH_w < 6.0. Surface soils (0 - 15cm) have pH_w 4.94 – 5.73 with subsoils (15 – 100cm) ranging 4.30 – 5.30. Surface soils $pH_{incubation}$ ranged between 3.62 – 4.29 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged between 3.73 – 4.74 indicating other acidic conditions.
- 40383_11: all samples have pH_w < 6.0. Surface soils (0 - 15cm) have pH_w 5.13 – 5.57 with subsoils (15 – 100cm) ranging 4.50 – 5.58. Surface soils $pH_{incubation}$ ranged between 4.09 – 4.18 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged between 3.69 – 3.88 indicating hypersulfidic and other acidic conditions.
- 40383_12: all samples have pH_w < 5.0. Surface soils (0 - 40cm) have pH_w 4.79 – 4.82 with subsoils (40 – 100cm) ranging 4.82 – 4.89. Surface soils $pH_{incubation}$ ranged between 3.94 – 4.11 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged between 3.88 – 3.99 indicating other acidic conditions.

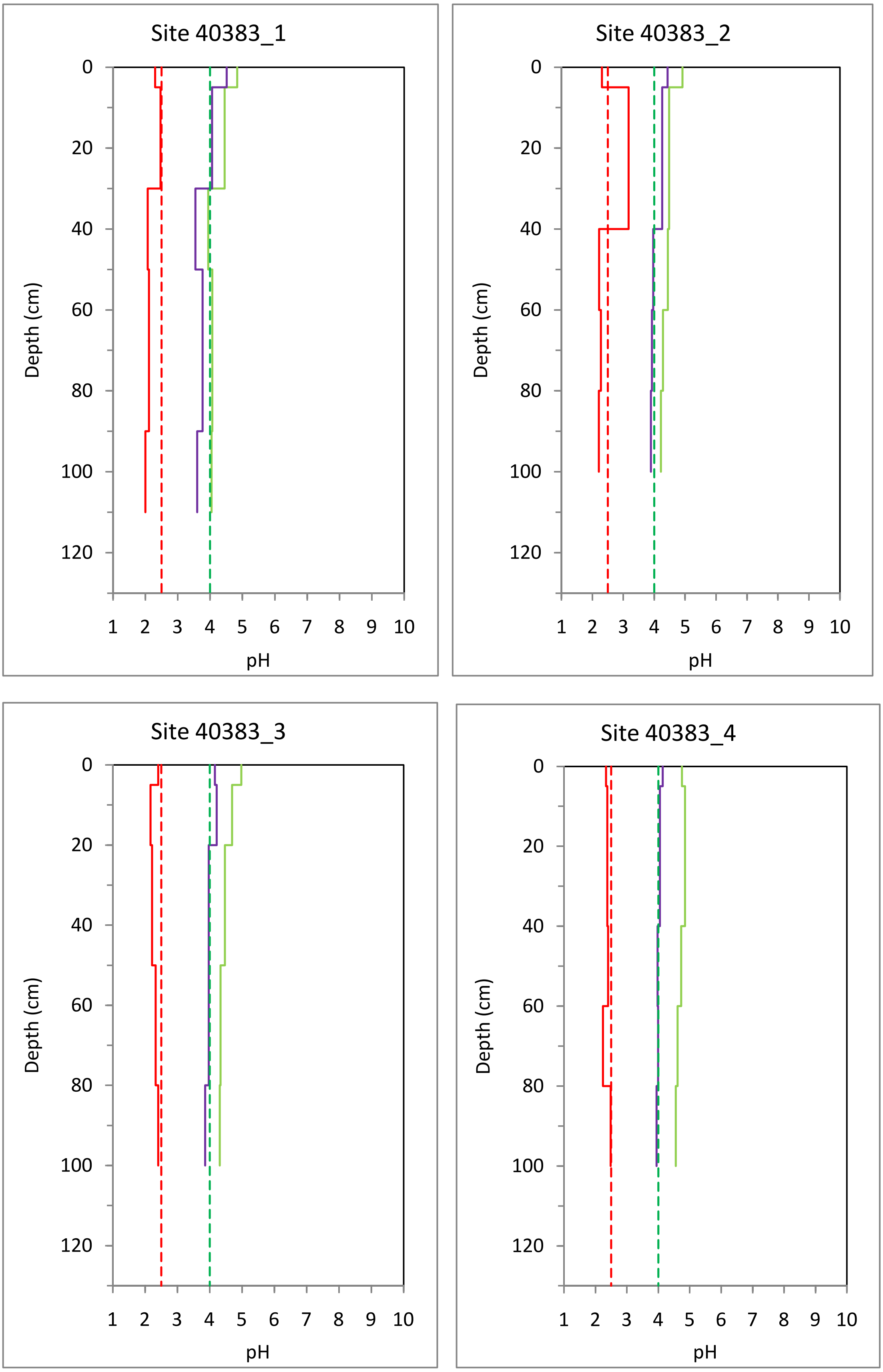


Figure 15 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

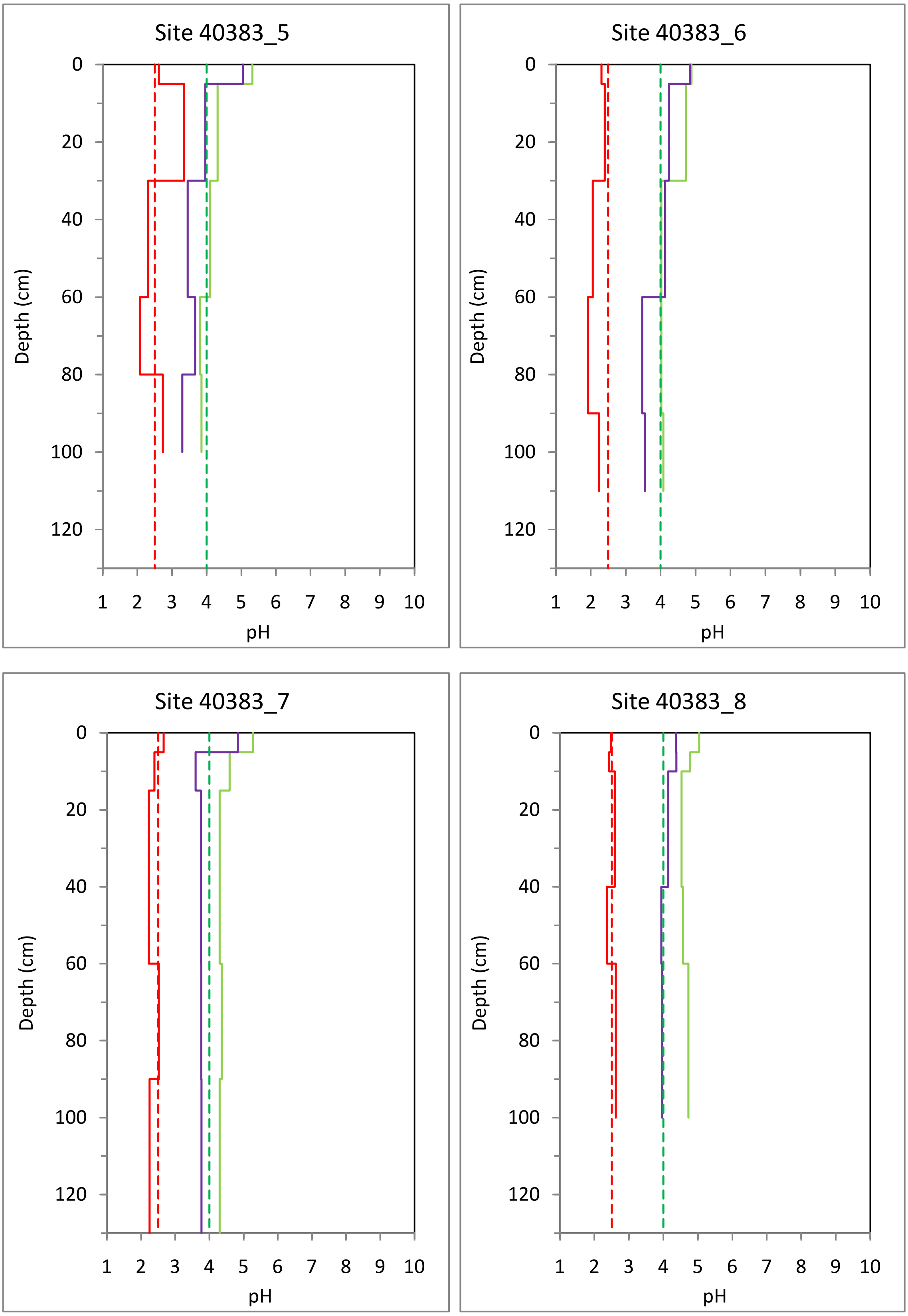


Figure 16 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

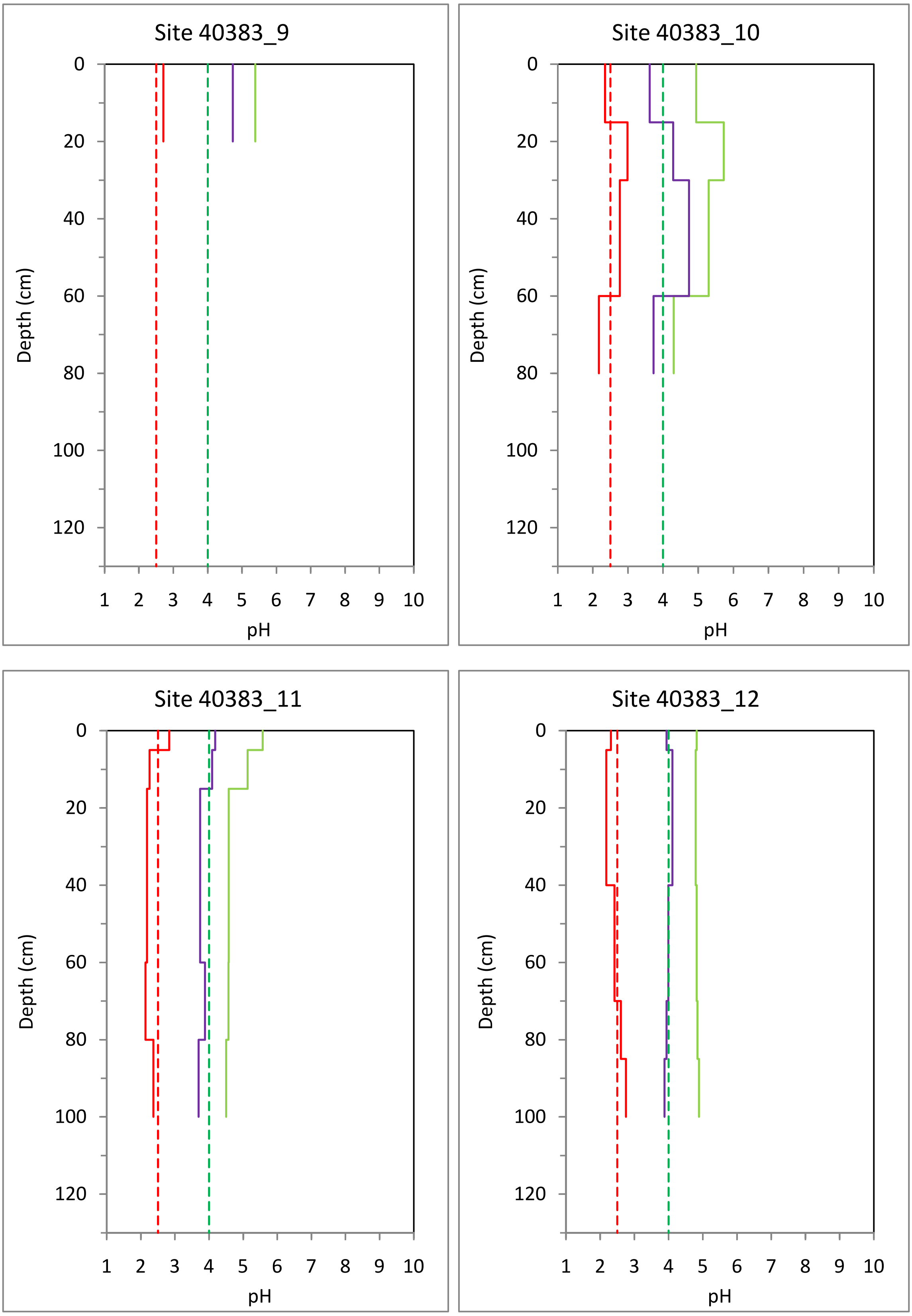


Figure 17 – Depth profiles of soil pH for Loch Garry, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The soil acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 18 and 19** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 55 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 6 – 145 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic in situ conditions. 46 out of the 55 samples collected (84%) had TAA > 50 mole H+/tonne.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 55 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where S_{CR} ≥ 0.01% S. Results ranged from <0.01 (limit of laboratory detection) to 0.01%S. 39 out of the 55 collected samples (71%) had S_{CR} <0.01%S.

Out of the 16 samples with 0.01% S, 11 were from sites 1, 2, 5, 6, 9 and 10 (low point to mid point within the stream channel). These account for 69% of results within the wetland containing sulfidic soil material. Typically for each site containing sulfidic materials, it was encountered within the upper surface soils.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Loch Garry.

1.3.6 Retained Acidity (RA)

Out of the 55 samples collected, 48 were analysed (87%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 0 – 6 mole H+/tonne. Typically, the highest results were from materials with high concentrations of iron mottling within the soil matrix and ped surfaces.

1.3.7 Acid Neutralising Capacity (ANC)

None of the samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 6 to 153 mol H+/tonne. The highest net acidity result values were from subsoils 50 – 100cm at all sites which were typically > 100 mole H+/tonne (high). Surface soils typically had lower net acidity values at all sites ranging between 19 – 100 mole H+/tonne (low to moderate). All samples with the exception of 40383_6.4 (6 mol H+/tonne) had net acidity values greater than the low value criterion of 19 mole H+/tonne.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 58 to 343 mg/L for surface soil samples collected (i.e. 0 – 10cm). Thirteen surface soil samples were analysed for water soluble sulfate in total. The highest result (343 mg/L) was from the subaqueous sample (40383_9.1). Twelve out of the thirteen samples (92%) analysed exceed the trigger criterion of 100 mg/L for MBO formation potential.

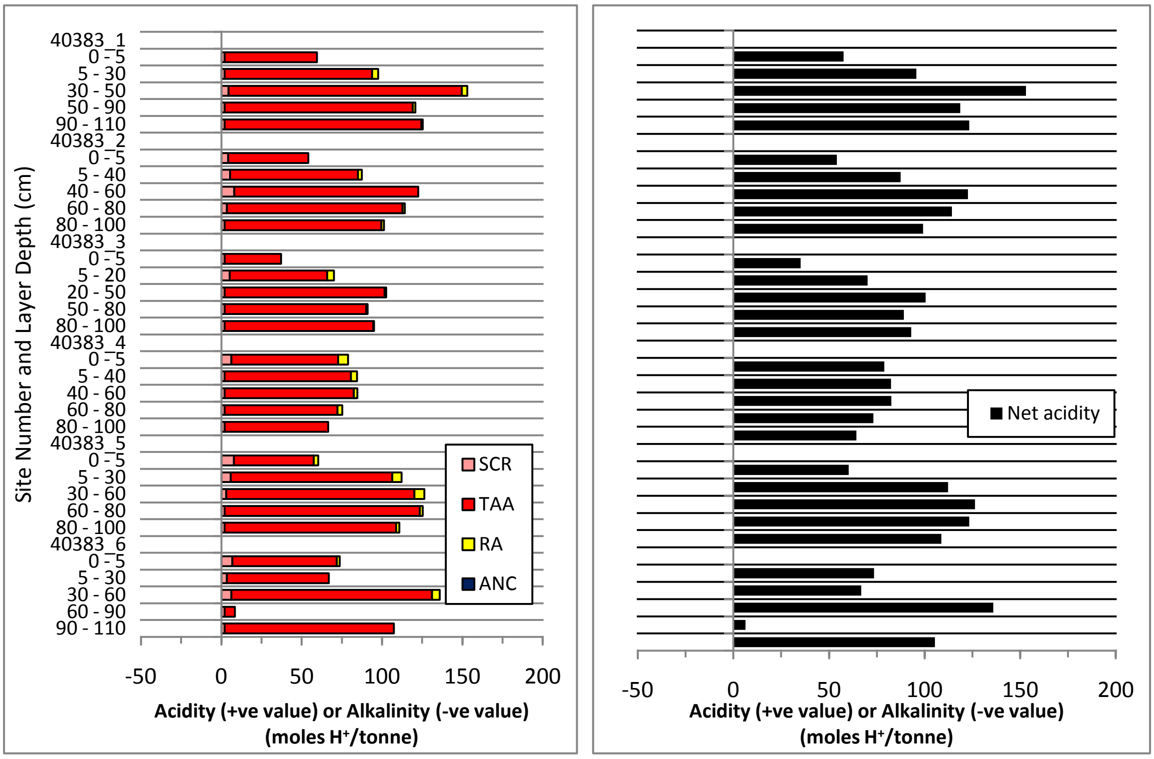


Figure 18 – Acid base accounting depth profiles for Loch Garry. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

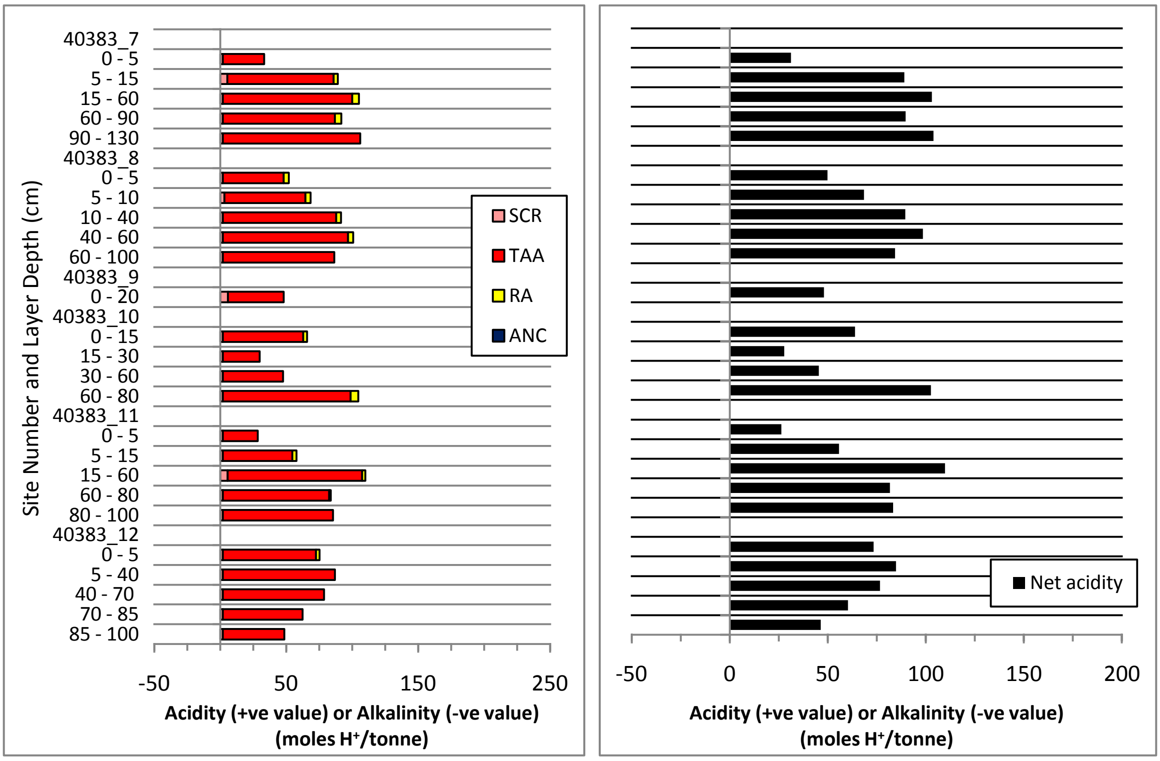


Figure 19 – Acid base accounting depth profiles for Loch Garry. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two sites from Loch Garry. One measurement was from pit inflow waters (40383_10) and one from wetland surface waters (40383_9). Two water samples were collected for laboratory analysis from the wetland.

The wetland pit inflow waters and surface waters were acidic (pH 5.00 – 5.46). Surface waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0.

Both sites had SEC values within the Lowland River criterion values of 125 – 2,200µS/cm but outside the criterion values for Freshwater Lakes (20 – 30µS/cm). SEC ranged between 974 – 949µS/cm with the higher value from the pit water sample (40383_10). Alkalinity (as HCO_3) was low <0 HCO_3. Both sites had oxidising conditions (212 to 245 Eh) with surface waters having a higher DO (11.36 mg/L) compared to the lower DO values (1.13 mg/L) for pit inflow waters.

The surface water site (40383_9) exceeded the trigger values for some nutrients (NO_3 15 mg/L, criterion of 0.7 mg/L, NH_4 34 mg/L, criterion of 0.01 mg/L, PO_4 0.02 mg/L, criterion of 0.005 mg/L) and some dissolved metals (Co - 15 µg/L, criterion of 2.8 µg/L, Mn – 2,700 µg/L, criterion of 1,700 µg/L, Ni – 13 µg/L, criterion of 11 µg/L and Zn – 72 µg/L, criterion of 8 µg/L).

The pit inflow water at site 40383_10 exceeded the trigger values for some nutrients (NO_3 12 mg/L, criterion of 0.7 mg/L, NH_4 41 mg/L, criterion of 0.01 mg/L, PO_4 0.03 mg/L, criterion of 0.005 mg/L) and some dissolved metals (Al – 210 µg/L, criterion of 55 µg/L, Cd – 0.3 µg/L, criterion of 0.2 µg/L, Co - 23 µg/L, criterion of 2.8 µg/L, Cu 4 µg/L, criterion of

1.4 µg/L, Fe 1,100 µg/L, criterion of 300 µg/L, Mn – 2,600 µg/L, criterion of 1,700 µg/L, Ni – 23 µg/L, criterion of 11 µg/L and Zn – 130 µg/L, criterion of 8 µg/L).

The water data indicates that the surface water and pit inflow water has been affected by acidification. There is low buffering capacity in surface and subsoils to counteract any significant sulfidic acidification if additional oxidation were to occur. Some dissolved metals results are quite high and may impact on the aquatic environment, especially Zinc results which are 10 times greater than the ANZECC 2000 trigger value for the surface water sample and 9 times greater for the pit inflow water sample.

1.5 Discussion

Acid sulfate soil materials occurred at all sites sampled with the exception of sites 40383_10 and 40383_12. Sulfuric material (pH_W <4.00) was encountered at two sites (40383_1 and 40383_5) which were both within the low point of the stream channel. The sulfuric material was encountered within subsoils.

Sulfidic soils occurred as both hypersulfidic and hyposulfidic materials with the latter being the predominant material type. Hypersulfidic materials were encountered at sites 40383_7 (surface soils) and 40383_11 (subsoils). Both sites indicated sulfidic conditions but with low S_{CR} values of 0.01% S. Hyposulfidic materials were encountered at sites 40383_2, 40383_3, 40383_4, 40383_5, 40383_6, 40383_8 and 40383_9. Typically, hyposulfidic materials were encountered in surface and subsoils within low to mid points of the stream channel and within surface soils only at high points of the stream channel edges.

No monosulfidic materials were encountered at the wetland. Twelve out of the thirteen surface samples (92%) analysed for water soluble sulfate collected from each site exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results for water soluble sulfate ranged between 58 to 343 mg/L and indicate that MBO could form under the right environmental conditions.

The highest net acidity result values were from subsoils 50 – 100cm at all sites which were typically > 100 mole H+/tonne (high). Surface soils typically had lower net acidity values at all sites ranging between 19 – 100 mole H+/tonne (low to moderate). All samples with the exception of 40383_6.4 (6 mol H+/tonne) had net acidity values greater than the low value criterion of 19 mole H+/tonne.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are three high priority samples based on the presence of sulfuric materials, two high priority samples based on the presence of hypersulfidic materials and twelve high priority samples based on the presence of water soluble sulfate results above the trigger criterion of 100 mg/L. This is a total of seventeen (17) samples with a high priority for Phase 2 laboratory analysis. There are a total of thirteen (13) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10%.

Due to the low level of sulfidic materials present (all S_{CR} analysis either <0.01 or 0.01% S) in surface and subsoils the requirement for Phase 2 laboratory analysis may not be warranted. However, the wetland area is large (206 ha) and 12 out of the 13 samples (92%) analysed exceed the trigger criterion of 100 mg/L for MBO formation potential. Therefore, Phase 2 analysis for the “Monosulfidic Formation Potential Method” may be suitable for selected surface samples. This would especially be the case if significant re flooding was going to be considered for the wetland. In addition, the wetland is currently acidic with dissolved metals such as Zinc quite high in the water samples analysed. If significant re flooding or wet and dry cycles were to occur dissolved metals may be released.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Loch Garry are:

- Acidification hazard: medium level of concern based on the high net acidities, low sulfidic results (from S_{CR}) and soil types present (i.e. clay based, fine grained). The degree of further acidification potential from sulfidic sources appears to be low to medium for surface soils and medium for subsoils that exhibit $pH_{incubation}$ results less than and near pH 4.00. The wetland is already considered to be acidic based on current soil and water pH results from this survey.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results exceeded the trigger value for monosulfide formation at the majority of sites. Currently however, no monosulfides were observed or formed during this survey with minimal surface water present in the wetland.

- Metal mobilisation: The medium acidification hazard indicates that future sulfidic sources of acidity may not be sufficient for further significant metals mobilisation than currently is the case. As the wetland soil and water is acidic currently, and hypersulfidic materials are not widespread, further significant decreases in pH may not occur in the near term. However, the lower $pH_{incubation}$ results for subsoils (<4.00) indicate that sub soil pH could oxidise further and generate acidity levels low enough for additional mobilisation of Nickel, Copper, Zinc and Manganese and other metals. Additionally, the wetland is currently dry and if significant re flooding or wet and dry cycles were to occur dissolved metals may be released. Therefore a medium level of concern.

1.6 Summary of Key Findings for Loch Garry

The summary of key findings for Loch Garry is detailed in Table 2.

Table 2 – Summary of Key Findings.

Soil materials:	• Acid sulfate soil materials occurred at all sites sampled with the exception of sites 40383_10 and 40383_12. • Sulfuric materials were observed at two sites within the low points of the dry stream channel. • Monosulfidic materials were not observed. • Water soluble sulfate results exceeded the trigger value for monosulfide formation at the majority of sites. • Sulfidic materials were identified at 9 out of the 12 sites. • Sulfidic soils occurred as both hypersulfidic and hyposulfidic materials with the latter being the predominant material type. • Hypersulfidic materials were encountered at sites 40383_7 (surface soils) and 40383_11 (subsoils). • Net acidities ranged between 6 to 153 mol H+/tonne with the majority of acidity coming from TAA (actual acidity). • Hyposulfidic materials were encountered at sites 40383_2, 40383_3, 40383_4, 40383_5, 40383_6, 40383_8 and 40383_9. • Typically, hyposulfidic materials were encountered in surface and subsoils within low to mid points of the stream channel and within surface soils only at high points of the stream channel edges.

Acid sulfate soil identification:	• Site 1: Sulfuric cracking clay soil occurring within the low point of the stream channel. • Site 2: Cracking clay soils occurring within the mid point of the stream channel. • Site 3: Cracking clay soils occurring within the mid point of the stream channel. • Site 4: Cracking clay soils occurring within the upper edge of the stream channel. • Site 5: Sulfuric cracking clay soil occurring within the low point of the stream channel. • Site 6: Cracking clay soils occurring within the mid point of the stream channel. • Site 7: Hypersulfidic cracking clay soils occurring within the mid point of the stream channel. • Site 8: Cracking clay soils occurring within the mid point of the stream channel. • Site 9: Cracking clay soils occurring within the low point of the stream channel. • Site 10: Cracking clay soils occurring within the mid point of the stream channel. • Site 11: Hypersulfidic cracking clay soils occurring within the mid point of the stream channel. • Site 12: Cracking clay soils occurring within the upper edge of the stream channel.
Hazard assessment:	• Acidification hazard – medium level of concern • De-oxygenation hazard – medium level of concern • Metal mobilisation hazard – medium level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Loch Garry.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40383_1.1	40383_1	0	5	0.0684	0.0635	7	4.84	2.30	4.51	261
40383_1.2	40383_1	5	30	0.0689	0.0515	25	4.45	2.47	4.06	-
40383_1.3	40383_1	30	50	0.0913	0.0630	31	3.94	2.07	3.55	-
40383_1.4	40383_1	50	90	0.1030	0.0670	35	4.07	2.11	3.77	-
40383_1.5	40383_1	90	110	0.1085	0.0660	39	4.05	2.00	3.60	-
40383_2.1	40383_2	0	5	0.0640	0.0583	9	4.91	2.31	4.43	226.5
40383_2.2	40383_2	5	40	0.0834	0.0626	25	4.48	3.17	4.26	-
40383_2.3	40383_2	40	60	0.0757	0.0472	38	4.44	2.22	3.97	-
40383_2.4	40383_2	60	80	0.0965	0.0613	36	4.28	2.28	3.93	-
40383_2.5	40383_2	80	100	0.0995	0.0657	34	4.22	2.21	3.89	-
40383_3.1	40383_3	0	5	0.0635	0.0577	9	4.98	2.41	4.16	232.5
40383_3.2	40383_3	5	20	0.0724	0.0621	14	4.69	2.17	4.22	-
40383_3.3	40383_3	20	50	0.0802	0.0567	29	4.47	2.22	3.97	-
40383_3.4	40383_3	50	80	0.0959	0.0672	30	4.34	2.33	3.97	-
40383_3.5	40383_3	80	100	0.1047	0.0723	31	4.31	2.41	3.86	-
40383_4.1	40383_4	0	5	0.0697	0.0581	17	4.75	2.34	4.14	184.5
40383_4.2	40383_4	5	40	0.0677	0.0567	16	4.85	2.38	4.05	-
40383_4.3	40383_4	40	60	0.0691	0.0557	19	4.73	2.40	3.98	-
40383_4.4	40383_4	60	80	0.0844	0.0698	17	4.61	2.24	3.99	-
40383_4.5	40383_4	80	100	0.0827	0.0697	16	4.56	2.48	3.94	-
40383_5.1	40383_5	0	5	0.0643	0.0621	3	5.32	2.62	5.05	129.75
40383_5.2	40383_5	5	30	0.0824	0.0590	28	4.32	3.35	3.96	-
40383_5.3	40383_5	30	60	0.0872	0.0644	26	4.10	2.31	3.45	-
40383_5.4	40383_5	60	80	0.1138	0.0831	27	3.81	2.07	3.67	-
40383_5.5	40383_5	80	100	0.1021	0.0788	23	3.85	2.74	3.30	-
40383_6.1	40383_6	0	5	0.0630	0.0603	4	4.88	2.31	4.84	243
40383_6.2	40383_6	5	30	0.0755	0.0631	16	4.72	2.40	4.23	-
40383_6.3	40383_6	30	60	0.0720	0.0511	29	4.02	2.06	4.13	-
40383_6.4	40383_6	60	90	0.0733	0.0497	32	4.02	1.92	3.47	-
40383_6.5	40383_6	90	110	0.0863	0.0632	27	4.08	2.24	3.55	-
40383_7.1	40383_7	0	5	0.0709	0.0677	5	5.28	2.66	4.83	198

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40383_7.2	40383_7	5	15	0.0752	0.0600	20	4.59	2.39	3.60	-
40383_7.3	40383_7	15	60	0.0933	0.0642	31	4.30	2.23	3.75	-
40383_7.4	40383_7	60	90	0.0952	0.0693	27	4.36	2.52	3.76	-
40383_7.5	40383_7	90	130	0.0902	0.0616	32	4.30	2.25	3.77	-
40383_8.1	40383_8	0	5	0.0796	0.0675	15	5.04	2.48	4.36	222
40383_8.2	40383_8	5	10	0.0797	0.0657	18	4.78	2.43	4.38	-
40383_8.3	40383_8	10	40	0.0600	0.0472	21	4.53	2.59	4.14	-
40383_8.4	40383_8	40	60	0.0722	0.0552	24	4.57	2.37	3.94	-
40383_8.5	40383_8	60	100	0.0772	0.0590	24	4.73	2.62	3.96	-
40383_9.1	40383_9	0	20	0.0751	0.0563	25	5.39	2.71	4.73	343.5
40383_10.1	40383_10	0	15	0.0991	0.0726	27	4.94	2.35	3.62	265.5
40383_10.2	40383_10	15	30	0.0968	0.0725	25	5.73	2.99	4.29	-
40383_10.3	40383_10	30	60	0.0781	0.0587	25	5.30	2.77	4.74	-
40383_10.4	40383_10	60	80	0.0979	0.0630	36	4.30	2.17	3.73	-
40383_11.1	40383_11	0	5	0.0694	0.0650	6	5.57	2.83	4.18	220.5
40383_11.2	40383_11	5	15	0.0761	0.0613	19	5.13	2.26	4.09	-
40383_11.3	40383_11	15	60	0.0819	0.0580	29	4.58	2.18	3.74	-
40383_11.4	40383_11	60	80	0.1048	0.0734	30	4.57	2.14	3.88	-
40383_11.5	40383_11	80	100	0.1023	0.0719	30	4.50	2.37	3.69	-
40383_12.1	40383_12	0	5	0.0770	0.0629	18	4.82	2.31	3.94	129.6
40383_12.2	40383_12	5	40	0.0903	0.0694	23	4.79	2.18	4.11	-
40383_12.3	40383_12	40	70	0.0839	0.0677	19	4.82	2.42	3.99	58.35
40383_12.4	40383_12	70	85	0.0815	0.0691	15	4.84	2.60	3.94	-
40383_12.5	40383_12	85	100	0.0985	0.0851	14	4.89	2.75	3.88	-

Table 3 (Continued) – Laboratory analytical data for acid sulfate soil assessment of Loch Garry.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
		cm	cm		mol H^+ t^{-1}	%	mol H^+ t^{-1}	%$CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40383_1.1	40383_1	0	5	4.35	58	<0.01	0	-	58	-	-
40383_1.2	40383_1	5	30	4.06	92	<0.01	4	-	96	-	-
40383_1.3	40383_1	30	50	3.71	145	0.01	3	-	153	-	-

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
		cm	cm		mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	$\%CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40383_1.4	40383_1	50	90	3.79	117	<0.01	2	-	119	-	-
40383_1.5	40383_1	90	110	3.76	122	<0.01	1	-	123	-	-
40383_2.1	40383_2	0	5	4.51	50	0.01	0	-	54	-	-
40383_2.2	40383_2	5	40	4.08	80	0.01	2	-	87	-	-
40383_2.3	40383_2	40	60	4.00	115	0.01	0	-	123	-	-
40383_2.4	40383_2	60	80	3.93	109	0.01	2	-	114	-	-
40383_2.5	40383_2	80	100	3.85	98	<0.01	2	-	99	-	-
40383_3.1	40383_3	0	5	4.59	35	<0.01	0	-	35	-	-
40383_3.2	40383_3	5	20	4.32	60	0.01	4	-	70	-	-
40383_3.3	40383_3	20	50	4.07	100	<0.01	1	-	101	-	-
40383_3.4	40383_3	50	80	3.91	88	<0.01	1	-	89	-	-
40383_3.5	40383_3	80	100	3.83	93	<0.01	0	-	93	-	-
40383_4.1	40383_4	0	5	4.25	66	0.01	6	-	79	-	-
40383_4.2	40383_4	5	40	4.22	79	<0.01	4	-	82	-	-
40383_4.3	40383_4	40	60	4.09	80	<0.01	2	-	83	-	-
40383_4.4	40383_4	60	80	4.06	70	<0.01	3	-	73	-	-
40383_4.5	40383_4	80	100	4.01	64	<0.01	0	-	64	-	-
40383_5.1	40383_5	0	5	4.47	50	0.01	3	-	60	-	-
40383_5.2	40383_5	5	30	4.01	100	0.01	6	-	112	-	-
40383_5.3	40383_5	30	60	3.84	117	0.00	6	-	126	-	-
40383_5.4	40383_5	60	80	3.67	121	<0.01	2	-	123	-	-
40383_5.5	40383_5	80	100	3.36	107	<0.01	2	-	109	-	-
40383_6.1	40383_6	0	5	4.26	65	0.01	2	-	74	-	-
40383_6.2	40383_6	5	30	4.29	63	0.01	0	-	67	-	-
40383_6.3	40383_6	30	60	3.81	125	0.01	5	-	136	-	-
40383_6.4	40383_6	60	90	6.37	6	<0.01	0	-	6	-	-
40383_6.5	40383_6	90	110	3.77	105	<0.01	0	-	105	-	-
40383_7.1	40383_7	0	5	4.83	31	<0.01	0	-	31	-	-
40383_7.2	40383_7	5	15	4.13	80	0.01	3	-	89	-	-
40383_7.3	40383_7	15	60	3.89	98	<0.01	5	-	103	-	-
40383_7.4	40383_7	60	90	3.89	85	<0.01	5	-	90	-	-
40383_7.5	40383_7	90	130	3.78	104	<0.01	0	-	104	-	-

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
		cm	cm		mol H^+ t^{-1}	%	mol H^+ t^{-1}	%$CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40383_8.1	40383_8	0	5	4.40	46	<0.01	4	-	50	-	-
40383_8.2	40383_8	5	10	4.24	61	0.01	4	-	68	-	-
40383_8.3	40383_8	10	40	4.08	86	<0.01	4	-	90	-	-
40383_8.4	40383_8	40	60	3.99	95	<0.01	4	-	99	-	-
40383_8.5	40383_8	60	100	3.98	84	<0.01	0	-	84	-	-
40383_9.1	40383_9	0	20	4.52	42	0.01	0	-	48	-	-
40383_10.1	40383_10	0	15	4.21	61	<0.01	3	-	64	-	-
40383_10.2	40383_10	15	30	4.91	28	<0.01	0	-	28	-	-
40383_10.3	40383_10	30	60	4.48	46	<0.01	0	-	46	-	-
40383_10.4	40383_10	60	80	3.91	97	<0.01	6	-	103	-	-
40383_11.1	40383_11	0	5	5.00	26	<0.01	0	-	26	-	-
40383_11.2	40383_11	5	15	4.36	53	<0.01	3	-	56	-	-
40383_11.3	40383_11	15	60	3.95	102	0.01	2	-	110	-	-
40383_11.4	40383_11	60	80	3.90	80	<0.01	1	-	82	-	-
40383_11.5	40383_11	80	100	3.92	83	<0.01	0	-	83	-	-
40383_12.1	40383_12	0	5	4.22	70	<0.01	3	-	73	-	-
40383_12.2	40383_12	5	40	4.05	85	<0.01	0	-	85	-	-
40383_12.3	40383_12	40	70	4.05	77	<0.01	0	-	77	-	-
40383_12.4	40383_12	70	85	4.05	60	<0.01	0	-	60	-	-
40383_12.5	40383_12	85	100	4.07	46	<0.01	0	-	46	-	-

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Loch Garry.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40383_10.W1	40383_9.W1
Site ID	(number)	-	-	40383_10	40383_9
Wetland ID	(code)	-	-	40383	40383
Site Number	(number)	-	-	10	9
Upper depth	cm	-	-	15	-33
Lower depth	cm	-	-	25	0
Temperature	(deg C)	-	-	17.6	22
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	974	949
Dissolved Oxygen	(%)	-	-	12.9	130.9
Dissolved Oxygen	(mg/l)	-	-	1.13	11.36
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	5.00	5.46
Redox potential	Eh	-	-	212	245
Turbidity	(NTU)	*6 - 50*	*1 - 20*	946	6.3
HCO_3	(mg/l)	-	-	0	0
Comment	-	-	-	PW	SW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Loch Garry.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	16-04-10	16-04-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2163094	2163093
Sample ID	(number)	-	40383_10.W1	40383_9.W1
Site ID	(number)	-	40383_10 (PW)	40383_9 (SW)
Wetland ID	(code)	-	40383	40383
Site Number	(number)	-	10	9
Upper depth	cm	-	15	-33
Lower depth	cm	-	25	0
Na	$mg\ l^{-1}$	-	40	40
K	$mg\ l^{-1}$	-	13	12
Ca	$mg\ l^{-1}$	-	26	27
Mg	$mg\ l^{-1}$	-	16	18
Si	$mg\ l^{-1}$	-	40	30
Br	$mg\ l^{-1}$	-	<5	<5
Cl	$mg\ l^{-1}$	-	47	41
NO_3	$mg\ l^{-1}$	0.7	12	15
NH_4-N[K]	$mg\ l^{-1}$	0.01	41	34
PO_4-P[E]	$mg\ l^{-1}$	0.005	0.03	0.02
SO_4	$mg\ l^{-1}$	-	250	230
Ag	$\mu g\ l^{-1}$	0.05	<1	<1
Al[A]	$\mu g\ l^{-1}$	55	210	30
As[B]	$\mu g\ l^{-1}$	13	2	1
Cd	$\mu g\ l^{-1}$	0.2	0.3	<0.2
Co	$\mu g\ l^{-1}$	2.8	23	15
Cr[C]	$\mu g\ l^{-1}$	1	1	<1
Cu[H]	$\mu g\ l^{-1}$	1.4	4	<1
Fe	$\mu g\ l^{-1}$	300	1100	40
Mn	$\mu g\ l^{-1}$	1700	2600	2700
Ni[H]	$\mu g\ l^{-1}$	11	23	13
Pb[H]	$\mu g\ l^{-1}$	3.4	<1	<1
Se	$\mu g\ l^{-1}$	11	1	<1
Zn[H]	$\mu g\ l^{-1}$	8	130	72
DOC	$mg\ l^{-1}$	-	78	63

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]*Trigger value for Aluminium in freshwater where pH > 6.5.*

[B]*Trigger value assumes As in solution as Arsenic (AsV).*

[C]*Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E]*Guideline is for filterable reactive phosphorous (FRP).*

[H]*Hardness affected (refer to Guidelines).*

[K]*Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Loch Garry.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	Easting	Northing
40383_1	40383	1	16-04-10	55	348980	5990436
40383_2	40383	2	16-04-10	55	348974	5990448
40383_3	40383	3	16-04-10	55	348974	5990457
40383_4	40383	4	16-04-10	55	348972	5990461
40383_5	40383	5	16-04-10	55	347826	5989043
40383_6	40383	6	16-04-10	55	347824	5989061
40383_7	40383	7	16-04-10	55	347821	5989076
40383_8	40383	8	16-04-10	55	347819	5989079
40383_9	40383	9	16-04-10	55	349204	5989461
40383_10	40383	10	16-04-10	55	349214	5989456
40383_11	40383	11	17-04-10	55	349217	5989452
40383_12	40383	12	17-04-10	55	349220	5989447

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40383_1	-	loose	mainly bare, dead sedges	low point	lowest point of dry channel	10	Sulfuric cracking clay soil	No water evident, channel surface doming/mounds of peds likely eroded from blocky structure due to rainfall
40383_2	-	loose	mainly bare, dead sedges	Mid point	mid point of channel hydro toposequence	8	Cracking clay soils	No water evident, channel surface doming/mounds of peds likely eroded from blocky structure due to rainfall
40383_3	-	cracking	reeds, medium bushes	High point	high point of channel hydro toposequence	8	Cracking clay soils	No water evident
40383_4	-	cracking	low grasses, reeds	High point	high point of channel bank	8	Cracking clay soils	No water evident

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40383_5	-	loose	bare	low point	lowest point of dry channel	9	Sulfuric cracking clay soil	No water evident, channel surface doming/mounds of peds likely eroded from blocky structure due to rainfall
40383_6	-	loose	bare	Mid point	mid point of channel hydro toposequence	8	Cracking clay soils	No water evident, channel surface doming/mounds of peds likely eroded from blocky structure due to rainfall
40383_7	-	loose	bare	High point	high point of channel hydro toposequence	8	Hypersulfidic cracking clay soils	No water evident
40383_8	-	cracking	low grasses, bushes	High point	high point of channel bank	8	Cracking clay soils	No water evident
40383_9	-33	water	bare	low point, subaqueo us	Subaqueous sediment samples	9	Cracking clay soils	Subaqueous sample collected from cracking clay surface below non permanent standing water, only surface water present at wetland, small turtles present
40383_10	15	loose	minor low grasses, algae on ped surfaces	Mid point, edge of water line, very wet to moist	edge of water	8	Cracking clay soils	-
40383_11	30	cracking	bare	Mid point	mid point of channel hydro toposequence	8	Hypersulfidic cracking clay soils	-
40383_12	-	cracking	low grasses, reeds	High point	high point of channel bank	8	Cracking clay soils	No water evident

Table 7 - Profile description data for acid sulfate soil assessment of Loch Garry.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40383_1.1	SS	0	5	2.5Y62	Silty clay loam	Clayey	Dry	6.15	1:1
40383_1.2	SS	5	30	10YR22	Clay	Clayey	Moderately	4.63	1:1
40383_1.3	SS	30	50	2.5YR31	Silty clay loam	Clayey	Moist	3.96	1:1
40383_1.4	SA	50	90	2.5YR31	Silty loam	Clayey	Moist	4.30	1:1
40383_1.5	SA	90	110	2.5YR31	Silty clay loam	Clayey	Moist	4.25	1:1
40383_2.1	SS	0	5	2.5Y62	Silty clay loam	Clayey	Dry	4.98	1:1
40383_2.2	SS	5	40	10YR22	Clay	Clayey	Moderately	4.62	1:1
40383_2.3	SS	40	60	2.5YR31	Silty clay loam	Clayey	Moist	4.53	1:1
40383_2.4	SA	60	80	2.5YR31	Silty loam	Clayey	Moist	4.63	1:1
40383_2.5	SA	80	100	2.5YR31	Silty clay loam	Clayey	Moist	4.55	1:1
40383_3.1	SS	0	5	2.5YR53	Silty clay loam	Clayey	Moderately	4.83	1:1
40383_3.2	SS	5	20	2.5YR43	Clay	Clayey	Moderately	5.04	1:1
40383_3.3	SS	20	50	2.5Y2.51	Silty clay loam	Clayey	Moist	4.45	1:1
40383_3.4	SA	50	80	2.5YR31	Silty loam	Clayey	Moist	4.34	1:1
40383_3.5	SA	80	100	2.5YR31	Silty clay loam	Clayey	Moist	4.62	1:1
40383_4.1	SS	0	5	2.5Y42	Silty clay loam	Clayey	Moderately	5.21	1:1
40383_4.2	SS	5	40	10YR22	Clay	Clayey	Moist	5.24	1:1
40383_4.3	SA	40	60	2.5YR31	Silty clay loam	Clayey	Moist	6.08	1:1
40383_4.4	SA	60	80	2.5YR31	Silty clay loam	Clayey	Moist	4.22	1:1
40383_4.5	SA	80	100	2.5YR31	Silty clay loam	Clayey	Moist	5.02	1:1
40383_5.1	SS	0	5	2.5Y62	Silty clay loam	Clayey	Dry	5.40	1:1
40383_5.2	SS	5	30	10YR22	Clay	Clayey	Moderately	4.65	1:1
40383_5.3	SS	30	60	2.5YR31	Silty clay loam	Clayey	Moist	3.92	1:1
40383_5.4	SA	60	80	2.5YR31	Silty clay loam	Clayey	Moist	4.02	1:1
40383_5.5	SA	80	100	10YR31	Silty clay loam	Clayey	Moist	3.83	1:1
40383_6.1	SS	0	5	2.5Y62	Silty clay loam	Clayey	Dry	5.51	1:1
40383_6.2	SS	5	30	10YR42	Clay	Clayey	Moderately	4.85	1:1
40383_6.3	SS	30	60	2.5YR31	Silty clay loam	Clayey	Moist	3.92	1:1
40383_6.4	PT	60	90	2.5YR31	Silty clay loam	Clayey	Moist	4.01	1:1
40383_6.5	PT	90	110	10YR31	Silty clay loam	Clayey	Moist	3.93	1:1
40383_7.1	SS	0	5	2.5YR53	Silty clay loam	Clayey	Moderately	5.37	1:1

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40383_7.2	SS	5	15	2.5YR43	Clay	Clayey	Moderately	5.01	1:1
40383_7.3	SS	15	60	2.5Y2.51	Silty clay loam	Clayey	Moist	4.14	1:1
40383_7.4	PT	60	90	2.5YR31	Silty loam	Clayey	Moist	4.68	1:1
40383_7.5	PT	90	130	2.5YR31	Silty clay loam	Clayey	Moist	4.39	1:1
40383_8.1	SS	0	5	2.5Y42	Silty clay loam	Clayey	Moderately	5.38	1:1
40383_8.2	SS	5	10	10YR22	Clay	Clayey	Moist	5.08	1:1
40383_8.3	SS	10	40	2.5YR31	Silty clay loam	Clayey	Moist	4.45	1:1
40383_8.4	SA	40	60	2.5YR31	Silty loam	Clayey	Moist	4.75	1:1
40383_8.5	SA	60	100	2.5YR31	Silty clay loam	Clayey	Moist	4.53	1:1
40383_9.1	SS	0	20	2.5Y62	Silty clay loam	Clayey	Wet	6.54	1:1
40383_10.1	SS	0	15	2.5Y62	Silty clay loam	Clayey	Moist	5.62	1:1
40383_10.2	SS	15	30	10YR22	Clay	Clayey	Wet	5.94	1:1
40383_10.3	SS	30	60	2.5YR31	Silty clay loam	Clayey	Wet	5.68	1:1
40383_10.4	SA	60	80	2.5YR31	Silty clay	Clayey	Wet	4.30	1:1
40383_11.1	SS	0	5	2.5YR53	Silty clay loam	Clayey	Moderately	6.05	1:1
40383_11.2	SS	5	15	2.5YR43	Clay	Clayey	Moderately	5.73	1:1
40383_11.3	SS	15	60	2.5Y2.51	Silty clay loam	Clayey	Moist	4.58	1:1
40383_11.4	SA	60	80	2.5YR31	Silty loam	Clayey	Moist	5.03	1:1
40383_11.5	SA	80	100	2.5YR31	Silty clay loam	Clayey	Moist	4.71	1:1
40383_12.1	SS	0	5	2.5Y42	Silty clay loam	Clayey	Moderately	4.95	1:1
40383_12.2	SS	5	40	10YR22	Clay	Clayey	Moist	4.88	1:1
40383_12.3	SS	40	70	2.5YR31	Silty clay loam	Clayey	Moist	5.21	1:1
40383_12.4	SA	70	85	2.5YR31	Silty clay loam	Clayey	Moist	5.07	1:1
40383_12.5	SA	85	100	10YR59	Silty clay loam	Clayey	Moist	5.65	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Loch Garry.

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40383_1.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_1.2	2	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, small pores
40383_1.3	5	FM	2.5YR36	MPF, SPO	CO	3	VF	charcoal fragments throughout matrix, decomposed organic fragments, small pores
40383_1.4	2	FM	2.5YR36	MAT	-	0	VF	
40383_1.5	2	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix, decomposed organic fragments
40383_2.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_2.2	2	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, small pores
40383_2.3	5	FM	2.5YR36	MPF, SPO	CO	3	VF	charcoal fragments throughout matrix, decomposed organic fragments, complete freshwater mussel shell, small pores
40383_2.4	2	FM	2.5YR36	MAT	-	0	VF	
40383_2.5	2	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix, decomposed organic fragments
40383_3.1	5	FM	5YR68	MPF, SPO	CO	3	S	moss on surface of large peds, difficult to bolus, small pores
40383_3.2	10	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, minor plant roots, small pores
40383_3.3	25	FM	2.5YR36	MPF, SPO	CO	3	VF	minor plant roots
40383_3.4	20	FM	2.5YR36	MAT	-	0	VF	
40383_3.5	20	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix
40383_4.1	5	FM	5YR68	MPF	MA	3	S	rootlets
40383_4.2	15	FM	5YR68	MPF	SB	3	S	rootlets, minor plant roots

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40383_4.3	2	FM	2.5YR36	MPF	SB	3	VF	rootlets, minor plant roots, charcoal fragments throughout matrix
40383_4.4	2	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix
40383_4.5	2	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix
40383_5.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_5.2	15	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, small pores
40383_5.3	25	FM	2.5YR36	MPF, SPO	CO	3	VF	charcoal fragments throughout matrix, decomposed organic fragments, small pores
40383_5.4	15	FM	2.5YR36	MAT	-	0	VF	
40383_5.5	15	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix, decomposed organic fragments
40383_6.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_6.2	15	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, small pores
40383_6.3	35	FM	2.5YR36	MPF, SPO	CO	3	VF	charcoal fragments throughout matrix, decomposed organic fragments, small pores
40383_6.4	15	FM	2.5YR36	MAT	-	0	VF	minor charcoal fragments throughout matrix, large decomposed organics
40383_6.5	15	FM	2.5YR36	MAT	--	0	VF	charcoal fragments throughout matrix
40383_7.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_7.2	15	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, minor plant roots, small pores
40383_7.3	20	FM	2.5YR36	MPF, SPO	CO	3	VF	charcoal fragments throughout matrix, decomposed organic fragments, small pores

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40383_7.4	10	FM	2.5YR36	MAT	-	0	VF	minor charcoal fragments throughout matrix, large decomposed organics
40383_7.5	10	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix
40383_8.1	5	FM	5YR68	MPF	SB	3	S	rootlets
40383_8.2	15	FM	5YR68	MPF	SB	3	S	rootlets, minor plant roots
40383_8.3	10	FM	2.5YR36	MPF	SB	3	VF	rootlets, minor plant roots, charcoal fragments throughout matrix
40383_8.4	15	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix
40383_8.5	20	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix
40383_9.1	10	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores, subaqueous
40383_10.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_10.2	10	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, small pores
40383_10.3	10	FM	2.5YR36	MPF, SPO	CO	3	S	decomposed organic fragments, small pores
40383_10.4	5	FM	2.5YR36	MAT	-	0	VF	minor charcoal fragments throughout matrix
40383_11.1	5	FM	5YR68	MPF, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40383_11.2	15	FM	5YR68	MPF, SPO	CO	3	S	difficult to bolus, minor plant roots, small pores
40383_11.3	20	FM	2.5YR36	MPF, SPO	CO	3	S	charcoal fragments throughout matrix, decomposed organic fragments, small pores
40383_11.4	5	FM	2.5YR36	MAT	-	0	VF	minor charcoal fragments throughout matrix, organics
40383_11.5	2	FM	2.5YR36	MAT	-	0	VF	charcoal fragments throughout matrix
40383_12.1	5	FM	5YR68	MPF	SB	3	S	rootlets

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40383_12.2	5	FM	5YR68	MPF	SB	3	S	rootlets, minor plant roots, sporadic darker organic inclusions, complete mussel shell
40383_12.3	15	FM	2.5YR36	MPF	SB	3	VF	rootlets, minor plant roots and charcoal fragments throughout matrix in lenses
40383_12.4	5	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix
40383_12.5	5	FM	2.5YR36	MAT	-	0	VF	minor plant roots, charcoal fragments throughout matrix

APPENDIX 4: TULLAROOP CREEK (40400) SUMMARY REPORT

APPENDIX 4:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40400
Wetland Name:	Tullaroop Creek

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 TULLAROOP CREEK 2

1.1 Location and Setting Description 2

1.2 Soil Profile Description and Distribution 2

1.3 Summary of Field and Laboratory Results 3

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 3

1.3.2 Acid Base Accounting 4

1.3.3 Titratable Actual Acidity (TAA) 4

1.3.4 Chromium Reducible Sulfur (S_{CR}) 4

1.3.5 Acid Volatile Sulfur (AVS) 4

1.3.6 Retained Acidity (RA) 4

1.3.7 Acid Neutralising Capacity (ANC) 5

1.3.8 Net Acidity 5

1.3.9 Water soluble SO_4 5

1.4 Hydrochemistry 6

1.5 Discussion 7

1.6 Summary of Key Findings for Tullaroop Creek 8

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Tullaroop Creek Sites. 2
Table 2 – Summary Of Key Findings 8
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Tullaroop Creek. 9
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Tullaroop Creek. 10
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Tullaroop Creek. 11
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Tullaroop Creek. 12
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Tullaroop Creek. 13

LIST OF FIGURES

Figure 1 – Tullaroop Creek 40400 Site Plan.

Figure 2 – Tullaroop Creek Conceptual Hydrotoposequence Cross Section – 40400.

Figure 3 – Photographs of site 40400_1, showing the water surface (water column of >1.5m), and the laid out soil profile of very soft, very dark greenish grey, wet, sand.

Figure 4 – Photographs of site 40400_2, showing the upper bank surface condition, and the laid out soft soil profile of dark yellowish brown, soft, clayey sand overlying very soft, greenish black sand.

Figure 5 – Depth profiles of soil pH for Tullaroop Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 6 – Acid base accounting depth profiles for Tullaroop Creek. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 TULLAROOP CREEK

1.1 Location and Setting Description

Tullaroop Creek is situated approximately 1km north of the town of Carisbrook and 7km to the east of the town of Maryborough VIC. The wetland is approximately 10km downstream of the Tullaroop Reservoir. Tullaroop Creek joins the Loddon River approximately 17km to the north which then drains into the Laanecoorie Reservoir. The wetland is accessed from Hood Street and is linear in shape, and approximately 50m wide by 330m in length, with a total area of <2 hectares.

The wetland is an incised channel form with minor banks and steep batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had surface water covering the majority of the wetland within the channel.

Water within the wetland was generally clear to slight brown and green and the bottom or lowest point could not be seen visually through the water column. The channel contained reeds where standing water occurred with large woody debris within the channel. Channel banks and upper floodplain contained low grasses and medium to large trees. Two sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Two sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at the wetland for the two sites chosen. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 4** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

- 40400_1: water surface, subaqueous sediments and the soil consisted of very soft, very dark greenish grey, wet, sand.
- 40400_2: loose with organic leaf and twig litter surface, upper edge of bank; soil consisted of dark yellowish brown, soft, clayey sand overlying very soft, greenish black sand.

Table 1 – Soil Identification, subtype and general location description for Tullaroop Creek Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40400_1	216379	5896218	Subaqueous soil	Low point, subaqueous sediments.
40400_2	216374	5896214	Hypersulfidic soil	Midpoint, upper edge of bank, low grass and some reeds and woody debris.

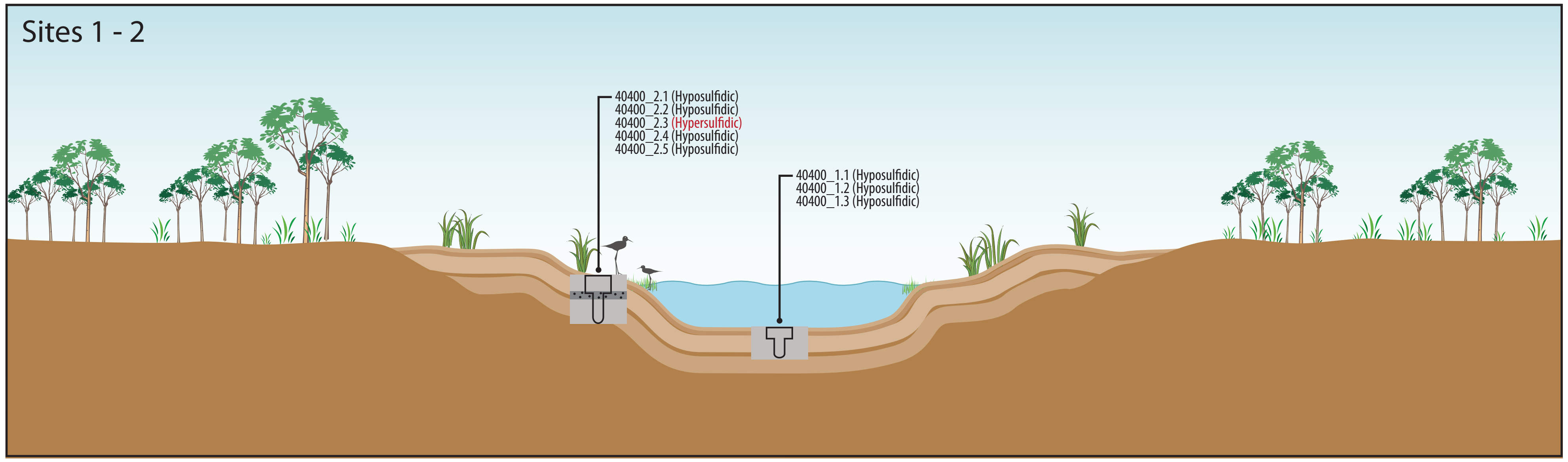
DATE 09/07/2010	SCALE 1:1,500 (0 12.5 25 50 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 54
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS		

FIG NO. 1 PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 FIGURE TITLE Tullaroop Creek 40400 - CMA: NCCMA

Note: Inset Photos show Surface Condition of Site

SMEC



LEGEND

Soil Types

Sulfuric	Hyposulfidic
Monosulfidic	Other acidic
Hypersulfidic	Other soils

40400_1

40400_2

DATE 15/07/2010	**SCALE** Not to Scale	**FIG NO.** 2	**PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS	**PROJECT NO.** 3001801	**FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Tullaroop Creek 40400

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

Figure 3 - Photographs of site 40400_1, showing the water surface (water column of >1.5m), and the laid out soil profile of very soft, very dark greenish grey, wet, sand.

Figure 4 – Photographs of site 40400_2, showing the upper bank surface condition, and the laid out soft soil profile of dark yellowish brown, soft, clayey sand overlying very soft, greenish black sand.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_{w}, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the two sites are presented in **Figure 5** below. Summary soil pH profile results indicate:

- 40400_1: all samples have pH_w > 5.5 and $pH_{incubation}$ between 4.18 – 6.36 indicating other acidic or hyposulfidic conditions. One sub soil layer (20 – 35cm) had a $pH_{incubation}$ of 4.18 indicating soils may become acidic.
- 40400_2: all samples have pH_w > 6.5 and $pH_{incubation}$ between 3.57 – 5.10 indicating other acidic, hyposulfidic or for the soil with pH <4.00, hypersulfidic conditions. The materials that had a $pH_{incubation}$ of 3.57 (15 -40cm) are likely to become or generate acidity.

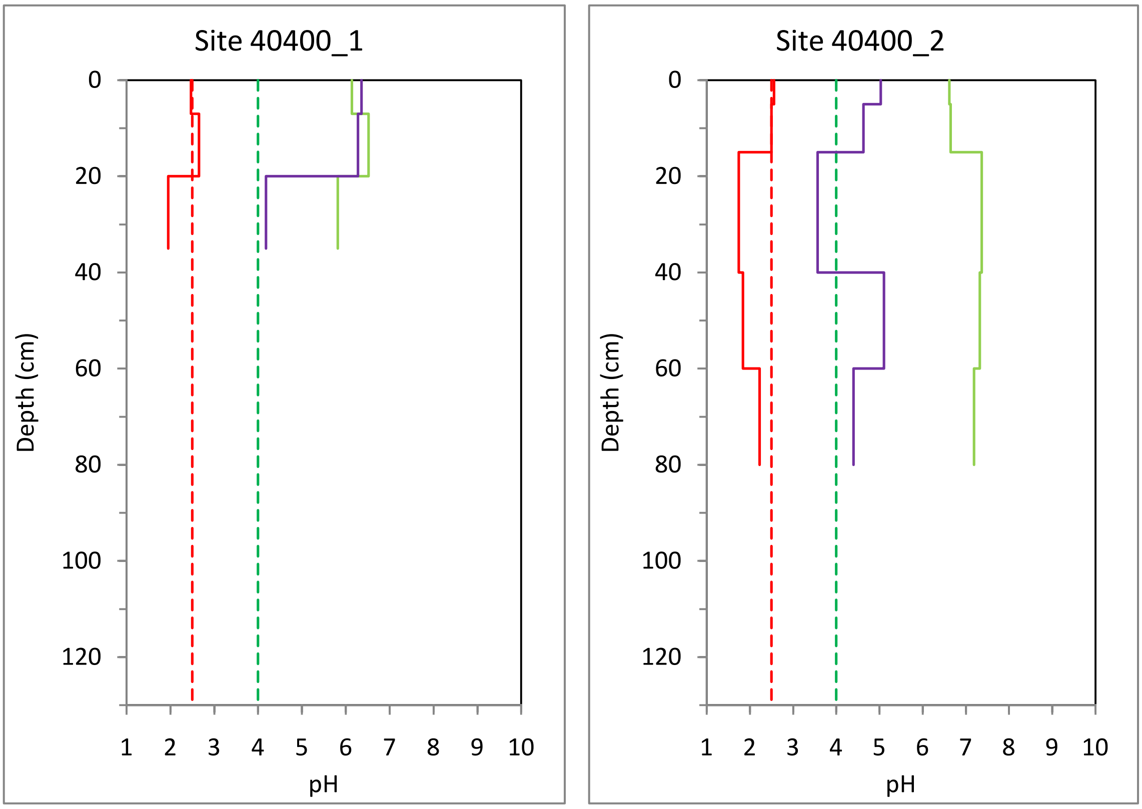


Figure 5 – Depth profiles of soil pH for Tullaroop Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 6** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 8 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 0 – 13 mol H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 8 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from 0.01 and 0.17 %S. Both sites indicated sulfidic conditions with the highest results (0.11 - 0.17%S) located within subsoils (15 – 60cm) at both sites and grey, sandy material.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Tullaroop Creek.

1.3.6 Retained Acidity (RA)

No pH_{KCL} results were below the threshold of 4.50 for retained acidity analysis. Therefore, no samples were analysed for Retained Acidity (RA).

1.3.7 Acid Neutralising Capacity (ANC)

Only 2 soil samples collected were analysed for Acid Neutralising Capacity (ANC) which has a trigger value pH_{KCL} >6.50. The two sub soil samples from 40400_1 (0 – 20cm) results ranged from 0.29 – 0.24 %$CaCO_3$ (equivalent to 58 – 48 mol H+/tonne). None of the remaining samples were analysed for ANC as no samples had a pH_{KCL} >6.50.

1.3.8 Net Acidity

Net acidity results for all sites and samples ranged between 6 to 82 mol H+/tonne. The highest net acidity result values were from subsoils 15 – 60cm at both sites, consisting of grey, sandy material. The remaining soil materials were <19 mol H+/tonne.

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Surface soil (0 – 20 cm) contained a low net acidity ranging between 6 – 18 mole H+/tonne. Sub soil (20 – 80 cm) contained a moderate net acidity ranging between 49 – 82 mole H+/tonne.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 283.5 to 1,048.5 mg/L for surface soil samples collected (i.e. 0 – 10cm). Two surface soil samples were analysed for water soluble sulfate in total. The highest result (1,048.5 mg/L) was from the subaqueous sample (40400_1) and exceeds the trigger criterion of 100 mg/L for MBO formation potential.

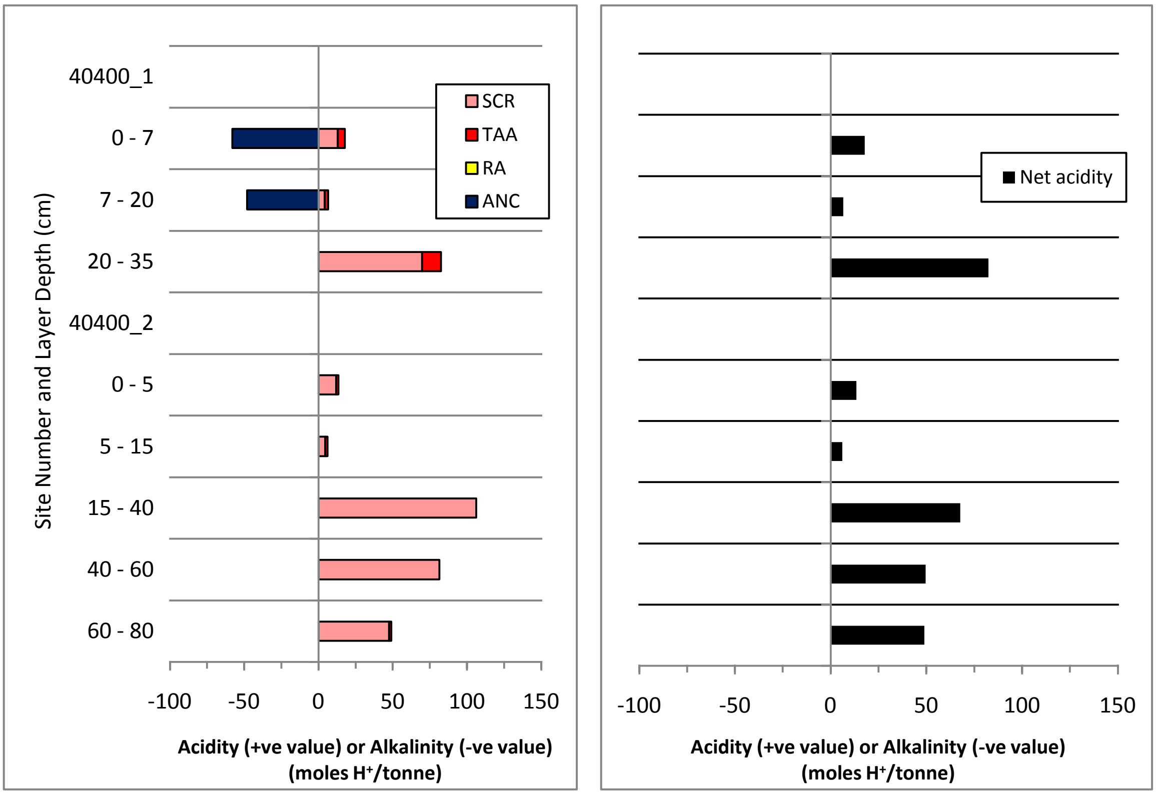


Figure 6 – Acid base accounting depth profiles for Tullaroop Creek. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two sites from Tullaroop Creek. One measurement was from pit inflow waters (40400_2) and one from wetland surface waters (40400_1). Two water samples were collected for laboratory analysis from the wetland.

The wetland surface waters were near neutral (pH 7.30) and pit inflow waters were slightly acidic (pH 6.38). Surface waters were within the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 – 8.0.

All sites had high SEC values greater than the Lowland River trigger values of 125 – 2,200µS/cm. SEC ranged between 3,950 – 5,610µS/cm with the higher value from the pit water sample (40400_2). Alkalinity (as HCO_3) ranged between 100 - >240 HCO_3 with the higher value from the pit water sample. Both sites had reducing conditions (-42 to -60Eh) with surface waters having a higher DO (10.0 mg/L) compared to the lower DO values (1.03 mg/L) for pit inflow waters.

The surface water site (40400_1) did not exceed any of the ANZECC 2000 trigger values for the analyses measured. The pit inflow water at site 40400_2 exceeded the trigger values for some nutrients (NH_4 0.8 mg/L, criterion of 0.01 mg/L) and some dissolved metals (Co - 15 µg/L, criterion of 2.8 µg/L), (Mn - 3,600 µg/L, criterion of 1,700 µg/L) and (Fe – 3,500 µg/L, criterion of 300 µg/L).

The water data indicates that the surface water has not been affected by acidification and pit inflow water has not been significantly affected by acidification. There is however only low buffering capacity in subsoils to counteract any significant sulfidic acidification if oxidation were to occur.

1.5 Discussion

Acid sulfate soil materials occurred at both sites (40400_1 and 40400_2) surveyed and sampled. Sulfidic sediments occurred as hyposulfidic materials in all samples analysed with the exception of 40400_2.3 which was hypersulfidic. Both sites indicated sulfidic conditions with the highest results (S_{CR} 0.11 - 0.17%S) located within subsoils (15 – 60cm) at both sites and grey, sandy material. Surface soils at both sites (0 – 20 cm) contained lower sulfidic materials with S_{CR} <0.02%S. No sulfuric (pH_W <4.00) or monosulfidic materials were encountered at the wetland.

Both water soluble sulfate surface samples collected from each site exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results for water soluble sulfate ranged between 283.5 to 1,048.5 mg/L and indicate that MBO could form under the right environmental conditions.

Surface soil (0 – 20 cm) contained a low net acidity with subsoils (20 – 80 cm) containing moderate net acidity.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are four high priority samples based on the presence of hyposulfidic materials with S_{CR} >0.10% and water soluble sulfate results above the trigger criterion of 100 mg/L. One sample with hypersulfuric materials is also a high priority (40400_2.3). There are five moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10%. Both sites are a high priority based on the priority ranking criteria.

Due to the low level of sulfidic materials present in surface soils the requirement for Phase 2 laboratory analysis may not be warranted. Subsoils do contain higher levels of sulfidic materials and Phase 2 laboratory analysis may be warranted. However, the wetland area is very small (<2 ha) with a lower risk of significant oxidation and acidity generation except when the water level of the wetland is significantly reduced or dries out completely. In addition, Tullaroop Creek is likely to receive regular seasonal flushing cycles that may prevent the build up of sulfidic materials.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Tullaroop Creek are:

- Acidification hazard: low to medium level of concern based on the moderate net acidities and sulfidic results (from S_{CR}). The degree of acidification potential from sulfidic sources appears to be low for surface soils and medium for subsoils that exhibit $pH_{incubation}$ results less than and near pH 4.00.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results exceeded the trigger value for monosulfide formation at both sites. Currently however, no monosulfides were observed or formed during this survey.

- Metal mobilisation: The low to medium acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation currently; however the lower $pH_{incubation}$ results (pH 3.57 – 4.50) indicate that currently neutral soil pH could oxidise and generate acidity levels low enough for the mobilisation of aluminium and other metals. Therefore a low to medium level of concern. Lowering of water levels significantly would likely be required for this to occur.

1.6 Summary of Key Findings for Tullaroop Creek

The summary of key findings for Tullaroop Creek is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Sulfidic materials were identified at each site and within all materials sampled and analysed. • All samples are hyposulfidic with the exception of 40400_2.3 which is hypersulfidic. • Net acidities ranged between 6 to 82 mol H+/tonne with the majority of acidity coming from S_{CR}. • Surface soils (0 – 20cm) had a low net acidity. • Subsoils (20 – 80cm) had a moderate net acidity.
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Hypersulfidic occurring within subsoils (15 – 40cm).
Hazard assessment:	• Acidification hazard – low to medium level of concern • De-oxygenation hazard – medium level of concern • Metal mobilisation hazard – low to medium level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Tullaroop Creek.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
		cm	cm	kg	kg	%	unit	unit	unit	mg/L
40400_1.1	40400_1	0	7	0.0736	0.0379	49	6.14	2.47	6.36	1048.5
40400_1.2	40400_1	7	20	0.1074	0.0754	30	6.52	2.65	6.28	-
40400_1.3	40400_1	20	35	0.1179	0.0748	37	5.82	1.95	4.18	-
40400_2.1	40400_2	0	5	0.1393	0.1122	19	6.62	2.56	5.03	-
40400_2.2	40400_2	5	15	0.1368	0.1090	20	6.65	2.50	4.63	-
40400_2.3	40400_2	15	40	0.1069	0.0774	28	7.37	1.74	3.57	283.5
40400_2.4	40400_2	40	60	0.1269	0.0919	28	7.32	1.84	5.10	-
40400_2.5	40400_2	60	80	0.1229	0.0981	20	7.19	2.22	4.40	-

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
		cm	cm		mol H^+ t^{-1}	%	mol H^+ t^{-1}	%$CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40400_1.1	40400_1	0	7	6.37	5	0.02	0	0.29	18	-	Hyposulfidic
40400_1.2	40400_1	7	20	6.35	2	0.01	0	0.24	6	-	Hyposulfidic
40400_1.3	40400_1	20	35	5.77	13	0.11	0	-	82	-	Hyposulfidic
40400_2.1	40400_2	0	5	6.29	1	0.02	0	-	13	-	Hyposulfidic
40400_2.2	40400_2	5	15	6.30	1	0.01	0	-	6	-	Hyposulfidic
40400_2.3	40400_2	15	40	6.68	0	0.17	0	-	68	-	Hypersulfidic
40400_2.4	40400_2	40	60	6.62	0	0.13	0	-	50	-	Hyposulfidic
40400_2.5	40400_2	60	80	6.21	1	0.08	0	-	49	-	Hyposulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Tullaroop Creek.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40400_1.W1	40400_2.W1
Site ID	(number)	-	-	40400_1	40400_2
Wetland ID	(code)	-	-	40400	40400
Site Number	(number)	-	-	1	2
Upper depth	cm	-	-	-40	25
Lower depth	cm	-	-	0	35
Temperature	(deg C)	-	-	9.5	13.2
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	3950	5610
Dissolved Oxygen	(%)	-	-	82.8	18.5
Dissolved Oxygen	(mg/l)	-	-	10	1.03
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	7.3	6.38
Redox potential	Eh	-	-	-42	-60
Turbidity	(NTU)	*6 - 50*	*1 - 20*	4.9	900
HCO_3	(mg/l)	-	-	100	>240
Comment		-	-	SW	PW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Tullaroop Creek.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	20-05-10	20-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201589	2201590
Sample ID	(number)	-	40400_1.W1	40400_2.W1
Site ID	(number)	-	40400_1	40400_2
Wetland ID	(code)	-	40400	40400
Site Number	(number)	-	1	2
Upper depth	cm	-	-40	25
Lower depth	cm	-	0	35
Na	$mg\ l^{-1}$	-	380	640
K	$mg\ l^{-1}$	-	11	12
Ca	$mg\ l^{-1}$	-	100	120
Mg	$mg\ l^{-1}$	-	200	260
Si	$mg\ l^{-1}$	-	1.5	19
Br	$mg\ l^{-1}$	-	<5	<5
Cl	$mg\ l^{-1}$	-	1000	1800
NO_3	$mg\ l^{-1}$	0.7	0.02	0.03
NH_4-N^K	$mg\ l^{-1}$	0.01	<0.1	0.8
PO_4-P^E	$mg\ l^{-1}$	0.005	<0.01	<0.05
SO_4	$mg\ l^{-1}$		180	61
Ag	$\mu g\ l^{-1}$	0.05	<1	<1
Al^A	$\mu g\ l^{-1}$	55	<10	<10
As^B	$\mu g\ l^{-1}$	13	9	6
Cd	$\mu g\ l^{-1}$	0.2	<0.2	<0.2
Co	$\mu g\ l^{-1}$	2.8	<1	15
Cr^C	$\mu g\ l^{-1}$	1	<1	<1
Cu^H	$\mu g\ l^{-1}$	1.4	<1	<1
Fe	$\mu g\ l^{-1}$	300	40	3500
Mn	$\mu g\ l^{-1}$	1700	8	3600
Ni^H	$\mu g\ l^{-1}$	11	3	5
Pb^H	$\mu g\ l^{-1}$	3.4	<1	<1
Se	$\mu g\ l^{-1}$	11	<1	<1
Zn^H	$\mu g\ l^{-1}$	8	1	3
DOC	$mg\ l^{-1}$	-	15	27

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]Trigger value for Aluminium in freshwater where pH > 6.5.

[B]Trigger value assumes As in solution as Arsenic (AsV).

[C]Trigger value for Chromium is applicable to Chromium (CrVI) only.

[E]Guideline is for filterable reactive phosphorous (FRP).

[H]Hardness affected (refer to Guidelines).

[K]Guideline for South-east Australia-Freshwater Lakes and reservoirs.

Table 6 - Site description data for acid sulfate soil assessment of Tullaroop Creek.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40400_1	40400	1	20-05-10	54	216379	5896218
40400_2	40400	2	20-05-10	54	216374	5896214

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40400_1	-40	water	water	low point, subaqueous	Subaqueous sediment samples	60	Subaqueous soil	-
40400_2	25	loose, organic leaf and twig litter	leaf and twig litter	High point	channel bank sediments	40	Hypersulfidic soil	-

Table 7 - Profile description data for acid sulfate soil assessment of Tullaroop Creek.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40400_1.1	SA	0	7	GLEY12.5N	Loamy sand	Sandy	Wet	7.75	1:1
40400_1.2	SA	7	20	GLEY13N	Sand	Sandy	Wet	7.61	1:1
40400_1.3	SA	20	35	GLEY13N	Sand	Sandy	Wet	7.37	1:1
40400_2.1	SS	0	5	10YR33	Clayey sand	Sandy	Moist	6.81	1:1
40400_2.2	SS	5	15	10YR46	Clayey sand	Sandy	Moist	7.02	1:1
40400_2.3	SS	15	40	GLEY12.5N	Sandy clay loam	Sandy	Wet	6.65	1:1
40400_2.4	SA	40	60	GLEY1510GY	Sand	Sandy	Wet	6.70	1:1
40400_2.5	SA	60	80	GLEY1510GY	Sand	Sandy	Wet	6.75	1:1

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40400_1.1	0	-	-	-	-	0	VS	organic odour, decomposed organics, fibrous roots
40400_1.2	0	-	-	-	-	0	VS	minor decomposed organics
40400_1.3	0	-	-	-	-	0	VS	minor decomposed organics
40400_2.1	0	-	-	-	GR	1	S	slightly decomposed organics, plant roots, leaf and twig litter
40400_2.2	0	-	-	-	GR	1	S	slightly decomposed organics, plant roots
40400_2.3	0	-	-	-	-	0	VS	organic odour, decomposed organics
40400_2.4	0	-	-	-	-	0	VS	minor organics
40400_2.5	0	-	-	-	-	0	VS	minor organics

APPENDIX 5: GEMMILLS SWAMP (40416) SUMMARY REPORT

APPENDIX 5:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40416
Wetland Name:	Gemmills Swamp

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 GEMMILLS SWAMP 3
1.1 Location and Setting Description 3
1.2 Soil Profile Description and Distribution 3
1.3 Summary of Field and Laboratory Results 7
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 7
1.3.2 Acid Base Accounting 11
1.3.3 Titratable Actual Acidity (TAA) 11
1.3.4 Chromium Reducible Sulfur (S_{CR}) 11
1.3.5 Acid Volatile Sulfur (AVS) 11
1.3.6 Retained Acidity (RA) 11
1.3.7 Acid Neutralising Capacity (ANC) 11
1.3.8 Net Acidity 11
1.3.9 Water soluble SO_4 11
1.4 Hydrochemistry 13
1.5 Discussion 13
1.6 Summary of Key Findings for Gemmills Swamp 14

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Gemmills Swamp Sites. 4
Table 2 – Summary Of Key Findings. 15
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Gemmills Swamp. 16
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Gemmills Swamp. 19
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Gemmills Swamp. 20
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Gemmills Swamp. 21
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Gemmills Swamp. 22

LIST OF FIGURES

Figure 1 – Gemmills Swamp 40416 Site Plan.

Figure 2 – Gemmills Swamp Conceptual Hydrotoposequence Cross Section – 40416.

Figure 3 – Photographs of site 40416_1, showing the water logged surface (water column of 5cm) and the laid out soil profile of dark grey, very soft, silty clay loam overlying very dark grey, very soft, clay.

Figure 4 – Photographs of site 40416_2, showing the water logged surface (water column of 15cm) and the laid out soil profile of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 5 – Photographs of site 40416_3, showing the water logged surface (water column of 2cm) and the laid out soil profile of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 6 – Photographs of site 40416_4, showing the surface condition and soil profile of dark greyish brown, soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 7 – Photographs of site 40416_5, showing the water logged surface (water column of 8cm) and the laid out soil profile of dark greyish brown, soft, loam overlying dark grey, very soft, clay.

Figure 8 – Photographs of site 40416_6, showing the surface condition and soil profile of dark greyish brown, soft, clay overlying dark greyish brown, very soft, clay.

Figure 9 – Photographs of site 40416_7, showing the surface condition and soil profile of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.

Figure 10 – Photographs of site 40416_8, showing the surface condition and soil profile of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.

Figure 11 – Depth profiles of soil pH for Gemmills Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 12 – Depth profiles of soil pH for Gemmills Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 13 – Acid base accounting depth profiles for Gemmills Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

Figure 14 – Acid base accounting depth profiles for Gemmills Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 GEMMILLS SWAMP

1.1 Location and Setting Description

Gemmills Swamp is situated approximately 4km West of Shepparton and 2km West of Mooroopna VIC. The wetland is approximately 2km to the West of the Goulburn River. The wetland is accessed from Echuca Mooroopna Road and McFarlane Road and is crescent in shape. The wetland is approximately 400m wide by 1,500m in length, with a total area of 68 hectares.

The wetland is wide and generally flat to slightly sloping inwards to the central low points. At the time when the soil survey was conducted in April 2010, the wetland had shallow surface water within the central lower points of the wetland covering approximately 70% of the wetland. The wetland generally became dryer moving to the North West upper sections.

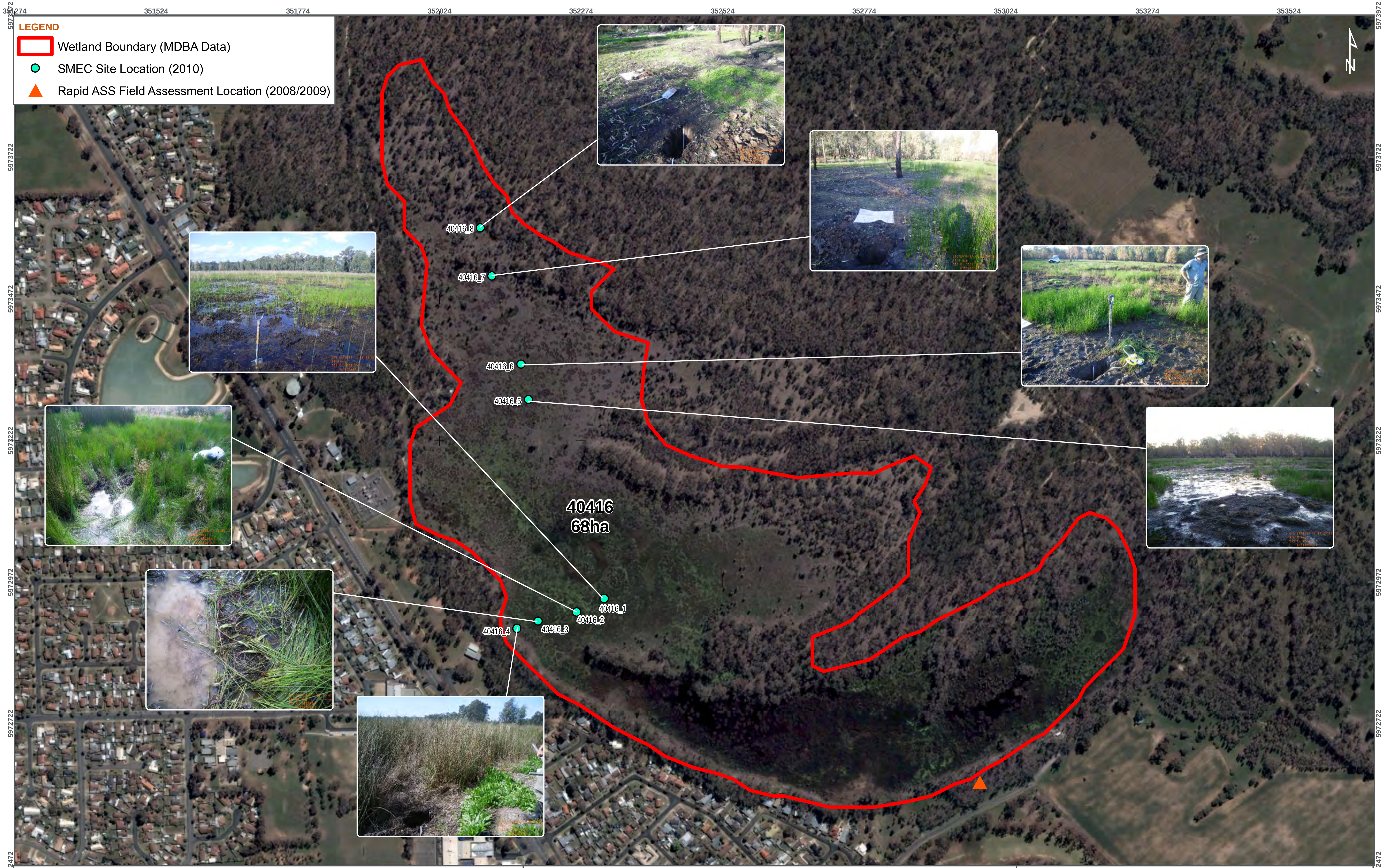
The wetland contained vegetation including grasses and reeds within the central portions of the wetland. Reeds were more prominent in the Eastern portion of the wetland and around the periphery of the wetland. Recent back burning was noted to have occurred within the past month on much of the periphery and central portions of the wetland containing burn organic residues and short stubble from grasses and reeds. The burning was observed within the central low points of the site indicating that these areas were dryer than the wet state noted for this survey. The wetland margins (above the surface water line) contained medium to large sized trees. Eight sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Eight sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at two different areas of the wetland with four sites chosen for each transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 10** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40416_1: water surface, burnt reeds and re - growth reeds, low point, water logged, soil consisted of dark grey, very soft, silty clay loam overlying very dark grey, very soft, clay.
- 40416_2: water surface, reeds and rushes, mid - point, water logged, soil consisted of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.
- 40416_3: water surface, reeds and rushes, mid - point, water logged, soil consisted of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.
- 40416_4: soft, reeds and rushes with twig litter, high point, soil consisted of dark greyish brown, soft, silty clay loam overlying dark greyish brown, very soft, clay.



DATE 09/07/2010	SCALE 1:6,000 (0 65 130 260 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 55
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS		

FIG NO. 1

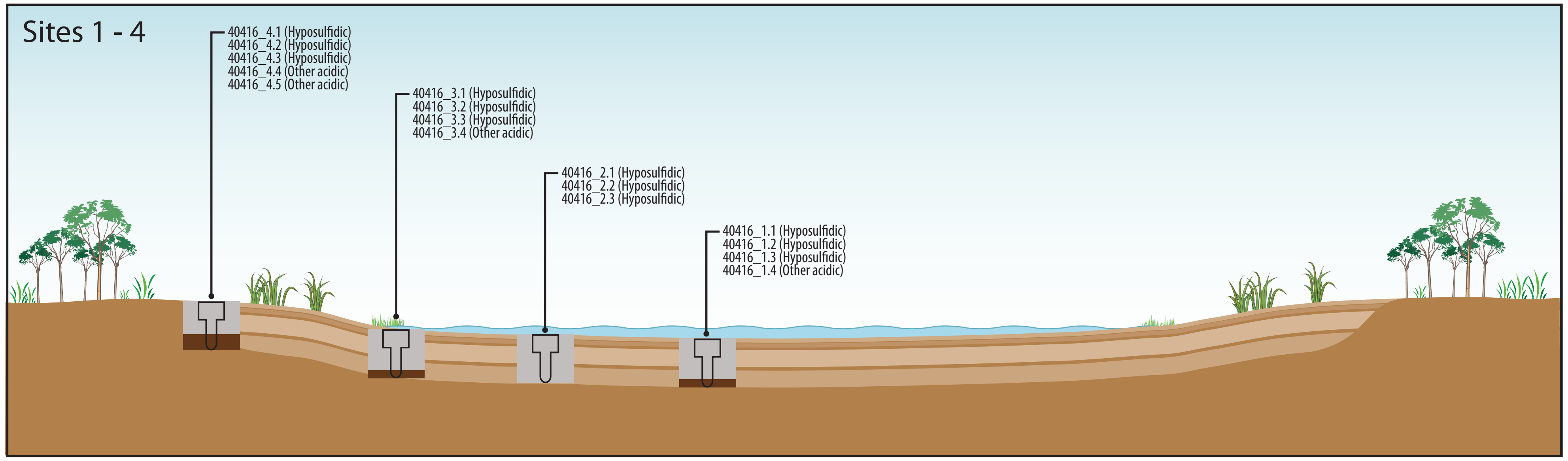
PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

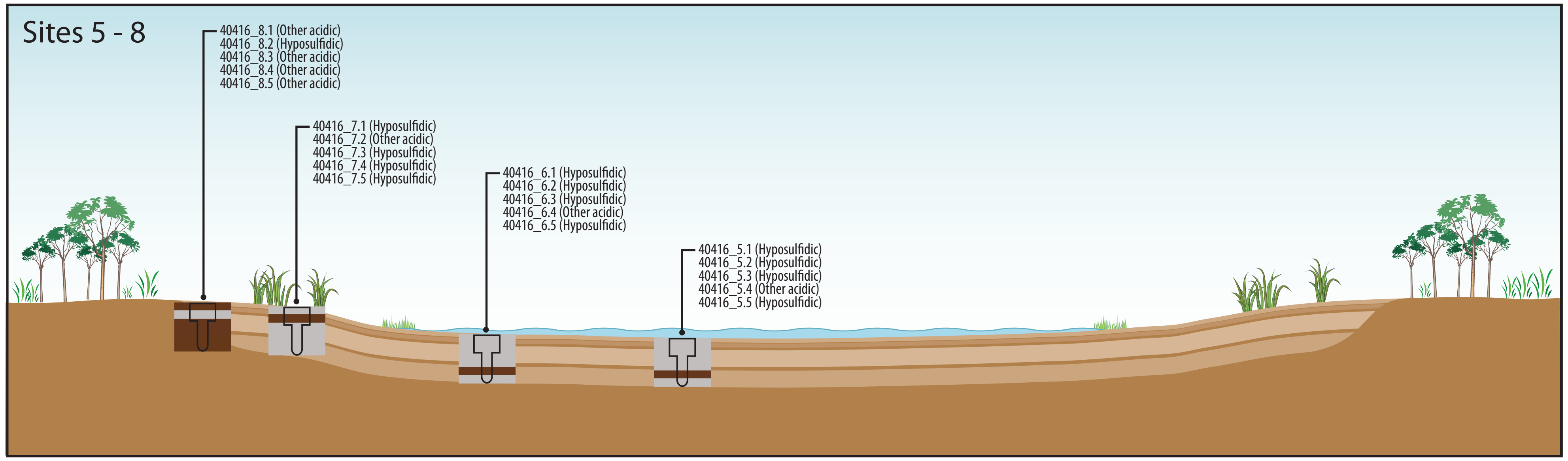
PROJECT NO. 3001801

FIGURE TITLE Gemmills Swamp 40416 - CMA: GBCMA

Note: Inset Photos show Surface Condition of Site

SMEC





LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils


40416_1


40416_2


40416_3


40416_4


40416_5


40416_6


40416_7


40416_8

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2 **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Gemmills Swamp 40416

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

SMEC

Australian Government

MURRAY–DARLING BASIN AUTHORITY

- 40416_5: water surface, burnt reeds and re - growth reeds, low point, water logged, soil consisted of dark greyish brown, soft, loam overlying dark grey, very soft, clay.
- 40416_6: soft, mainly bare, some reeds, mid - point, soil consisted of dark greyish brown, soft, clay overlying dark greyish brown, very soft, clay.
- 40416_7: loose, mainly bare, some reeds and medium trees, mid - point, soil consisted of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.
- 40416_8: loose, weeds and medium trees, high point, soil consisted of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.

Table 1 – Soil Identification, subtype and general location description for Gemmills Swamp Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40416_1	352316	5972943	Subaqueous soil	Low point, water logged, burnt reeds and re growth reeds.
40416_2	352267	5972919	Subaqueous soil	Mid point, water logged, reeds and rushes.
40416_3	352199	5972903	Subaqueous soil	Mid point, water logged, reeds, rushes and medium trees.
40416_4	352162	5972890	Hydrosol - sandy or loamy	High point, reeds and rushes with twig litter and medium trees.
40416_5	352182	5973294	Subaqueous soil	Low point, water logged, burnt reeds and re growth reeds.
40416_6	352169	5973356	Hydrosol - sandy or loamy	Mid point, mainly bare with reeds and rushes.
40416_7	352118	5973513	Hydrosol - sandy or loamy	Mid point, subaqueous, mainly bare with reeds, rushes and medium trees.
40416_8	352097	5973597	Hydrosol - sandy or loamy	High point, weeds and medium trees.

Figure 3 – Photographs of site 40416_1, showing the water logged surface (water column of 5cm) and the laid out soil profile of dark grey, very soft, silty clay loam overlying very dark grey, very soft, clay.

Figure 4 – Photographs of site 40416_2, showing the water logged surface (water column of 15cm) and the laid out soil profile of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 5 – Photographs of site 40416_3, showing the water logged surface (water column of 2cm) and the laid out soil profile of dark greyish brown, very soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 6 – Photographs of site 40416_4, showing the surface condition and soil profile of dark greyish brown, soft, silty clay loam overlying dark greyish brown, very soft, clay.

Figure 7 – Photographs of site 40416_5, showing the water logged surface (water column of 8cm) and the laid out soil profile of dark greyish brown, soft, loam overlying dark grey, very soft, clay.

Figure 8 – Photographs of site 40416_6, showing the surface condition and soil profile of dark greyish brown, soft, clay overlying dark greyish brown, very soft, clay.

Figure 9 – Photographs of site 40416_7, showing the surface condition and soil profile of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.

Figure 10 – Photographs of site 40416_8, showing the surface condition and soil profile of greyish brown, very weak, clay overlying dark greyish brown, weak, clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figures 11 and 12** on the following pages. Summary soil pH profile results indicate:

- 40416_1: all samples have pH_w < 5.7. Surface soils (0 - 40cm) have pH_w 4.49 – 4.56 with subsoils (40 – 90cm) ranging 5.48 – 5.63. Surface soils $pH_{incubation}$ ranged between 4.43 – 5.29 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 4.44 – 4.63 indicating hyposulfidic and other acidic conditions.
- 40416_2: all samples have pH_w < 5.5. Surface soils (0 - 30cm) have pH_w 4.00 – 5.04 with subsoils (30 – 50cm) 5.02. Surface soils $pH_{incubation}$ ranged between 4.39 – 4.66 indicating hyposulfidic conditions. Sub soil $pH_{incubation}$ was 4.39 indicating hyposulfidic conditions.
- 40416_3: all samples have pH_w < 5.5. Surface soils (0 - 10cm) have pH_w 4.83 – 4.81 with subsoils (10 – 75cm) ranging 4.91 – 5.26. Surface soils $pH_{incubation}$ ranged between 4.47 – 5.17 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 4.47 – 4.77 indicating hyposulfidic and other acidic conditions.
- 40416_4: all samples have pH_w < 5.5. Surface soils (0 - 10cm) have pH_w 4.77 – 5.13 with subsoils (10 – 100cm) ranging 5.30 – 5.44. Surface soils $pH_{incubation}$ ranged between 4.35 – 4.71 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 4.55 – 4.73 indicating hyposulfidic and other acidic conditions.
- 40416_5: all samples have pH_w < 6.0. Surface soils (0 - 15cm) have pH_w 4.70 – 5.91 with subsoils (15 – 100cm) ranging 5.05 – 5.65. Surface soils $pH_{incubation}$ ranged between 4.31 – 6.54 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 4.52 – 5.31 indicating hyposulfidic and other acidic conditions.
- 40416_6: all samples have pH_w < 6.0. Surface soils (0 - 30cm) have pH_w 5.03 – 5.06 with subsoils (30 – 90cm) ranging 5.11 – 5.57. Surface soils $pH_{incubation}$

ranged between 4.35 – 4.68 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 4.59 – 4.73 indicating hyposulfidic and other acidic conditions.

- 40416_7: all samples have $pH_w < 6.0$. Surface soils (0 - 30cm) have pH_w 4.22 – 4.95 with subsoils (30 – 110cm) ranging 5.39 – 5.57. Surface soils $pH_{incubation}$ ranged between 4.09 – 4.90 indicating hyposulfidic and other acidic conditions. Subsoils $pH_{incubation}$ ranged between 4.32 – 5.38 indicating hyposulfidic conditions.
- 40416_8: all samples have $pH_w < 6.0$. Surface soils (0 - 45cm) have pH_w 4.78 – 5.41 with subsoils (45 – 110cm) ranging 5.53 – 5.65. Surface soils $pH_{incubation}$ ranged between 4.38 – 4.63 indicating hyposulfidic and other acidic conditions. Subsoils $pH_{incubation}$ ranged between 4.83 – 4.91 indicating other acidic conditions.

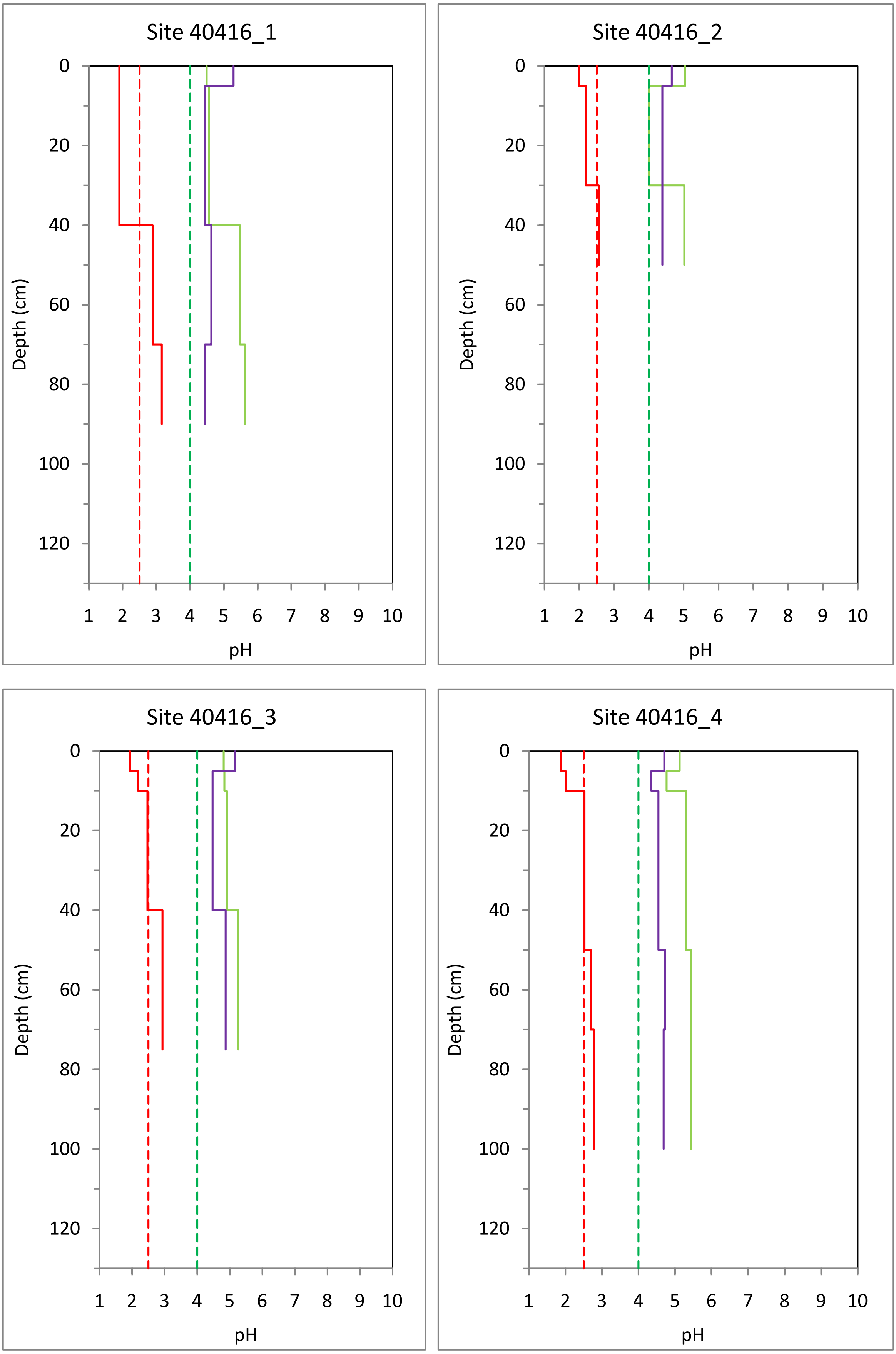


Figure 11 – Depth profiles of soil pH for Gemmills Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

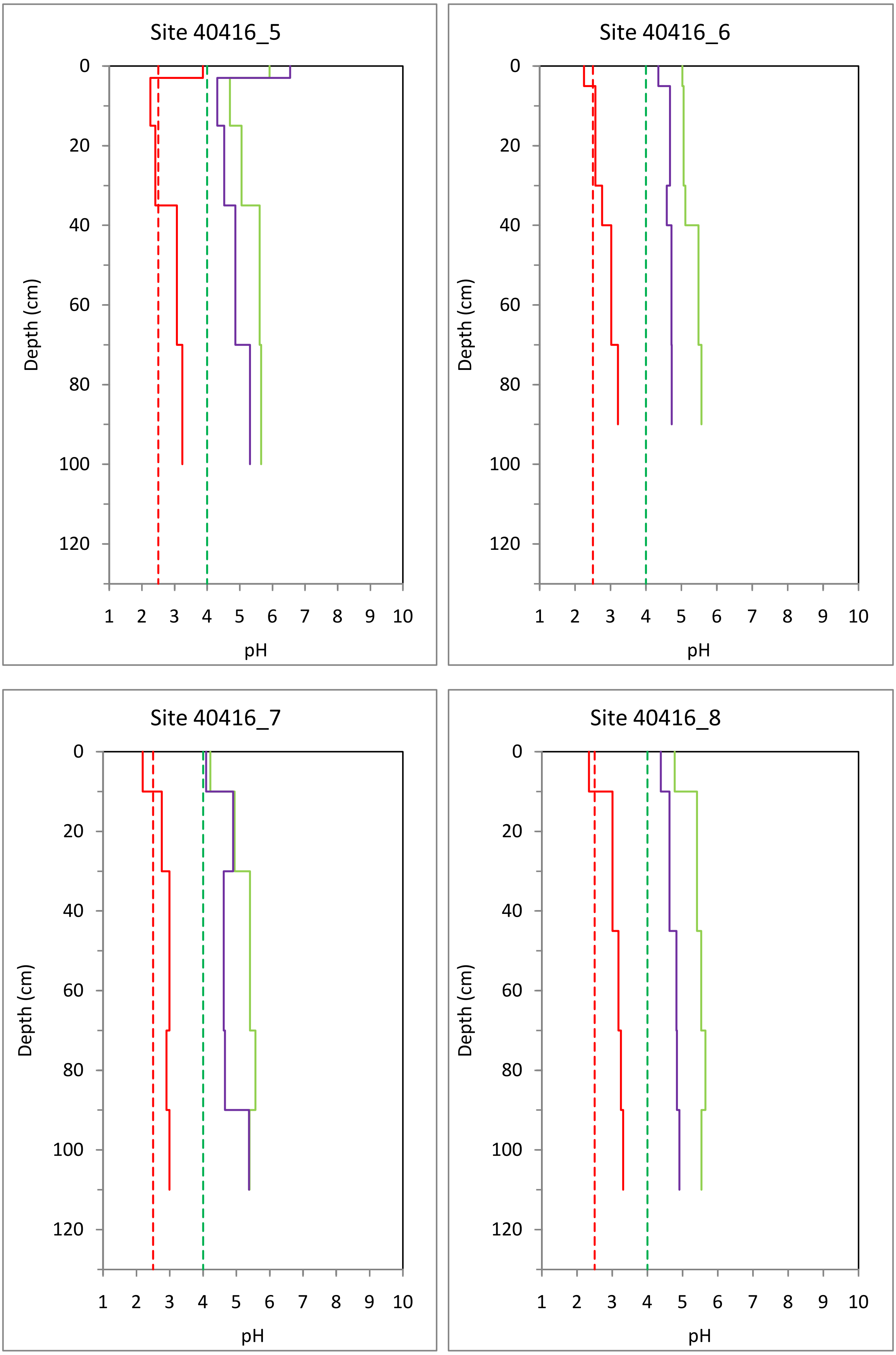


Figure 12 – Depth profiles of soil pH for Gemmills Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 13 and 14** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 36 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 27 – 122 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic in situ conditions within the surface soil profile with acidity decreasing slightly with depth.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 36 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where S_{CR} ≥ 0.01% S. Results ranged from <0.01 (limit of laboratory detection) to 0.02% S. 11 out of the 36 collected samples (31%) had S_{CR} <0.01% S with 18 out of the 36 samples (50%) having S_{CR} 0.01% S. The majority of sites had a decreasing S_{CR} concentration trend with increasing depth of sample.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Gemmills Swamp.

1.3.6 Retained Acidity (RA)

Out of the 36 samples collected, 30 were analysed (83%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 0 – 6 mole H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

None of the 36 samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 29 to 136 mol H+/tonne. Results were high for surface samples for site 40416_1 (> 100 mole H+/tonne). All remaining samples from each site were moderate net acidity (19 - 100 mole H+/tonne). Surface soils (0 – 30cm) typically had the highest net acidity values with TAA the major contributor. Net acidity values decreased at every site with increasing sample depths.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 53 – 126 mg/L for surface soil samples collected (i.e. 0 – 10cm). Ten surface soil samples were analysed for water soluble sulfate in total. Four samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential from sites 40416_1, 40416_4, 40416_6 and 40416_7.

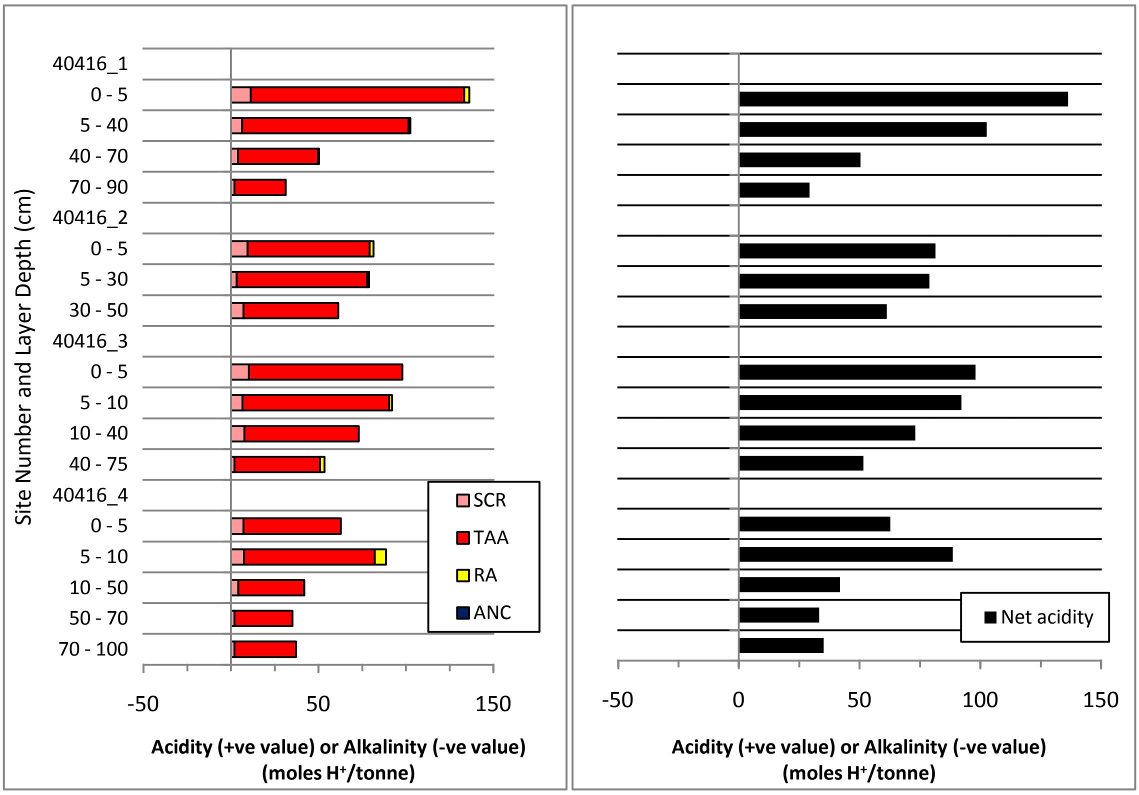


Figure 13 – Acid base accounting depth profiles for Gemmills Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

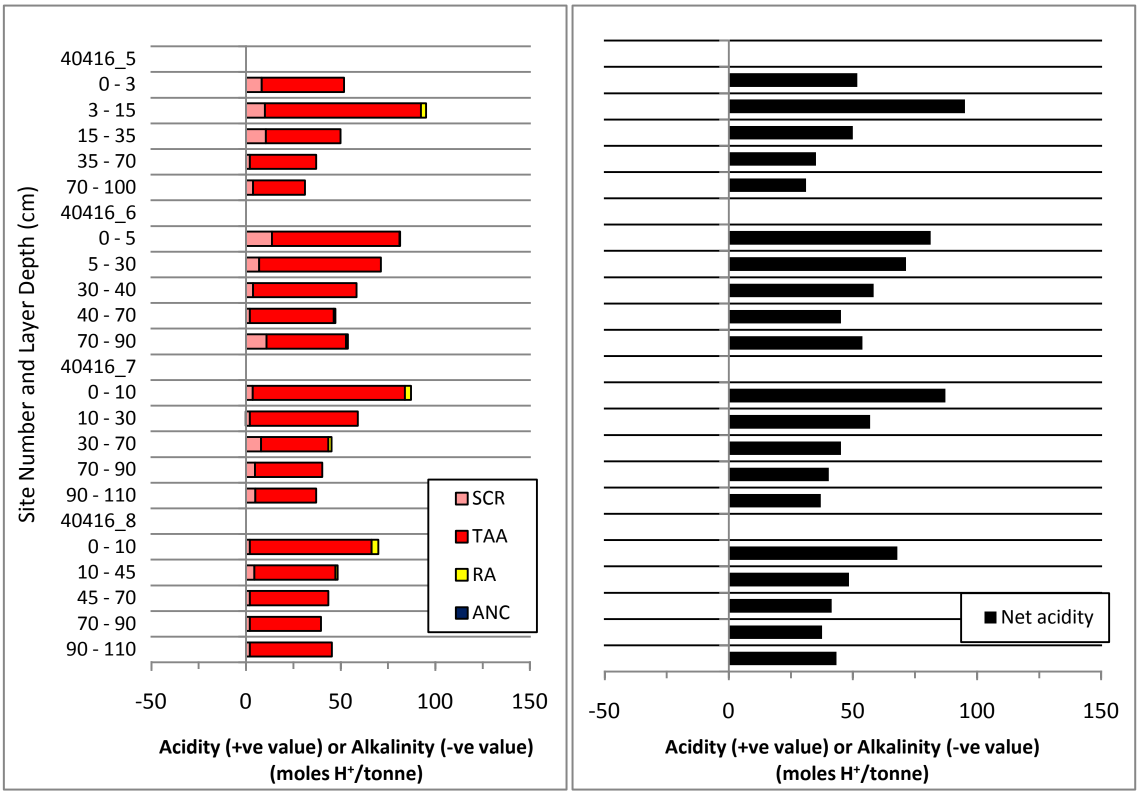


Figure 14 – Acid base accounting depth profiles for Gemmills Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at five out of the eight sites from Gemmills Swamp. Two measurements were from pit inflow waters and three from wetland surface waters. Three water samples were collected for laboratory analysis including one from pit inflow waters and two from wetland surface waters.

The wetland pit inflow waters were typically acidic (pH 5.64 – 5.74). The wetland surface waters were typically acidic to slightly acidic (pH 5.91 – 6.78). Surface waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0 at sites 40416_1 and 40416_2 and within the range for site 40416_3.

Wetland sites 40416_1, 40416_4 and 40416_6 had SEC values within the Lowland River criterion values of 125 – 2,200µS/cm and outside the lower range of 125µS/cm for sites 40416_2 and 40416_3 (72.7 – 85.1µS/cm). All sites measured and sampled were outside the criterion values for Freshwater Lakes (20 – 30µS/cm). SEC ranged between 72.7 – 552µS/cm with the highest values from the pit water inflow sites.

Alkalinity (as HCO_3) was low <0 - 40 HCO_3 at all sites measured. All sites had oxidising conditions (64 to 221 Eh) with surface waters having a higher DO (2.14 – 9.00mg/L) compared to the lower DO values (0.44 – 0.85mg/L) for pit water inflows.

All surface water sites (40416_1 and 40416_2) and the pit water inflow site (40416_6) exceeded the ANZECC 2000 trigger values for nutrients (NH_4 and PO_4). All sites exceeded the ANZECC 2000 trigger values for some dissolved metals (Al, Cr, Cu, Fe, Mn and Zn) with Ni exceeding the trigger values for sites 40416_2 and 40416_6.

The water data indicates that the surface water and pit inflow water may have been affected by acidification to a degree. The acidification however is only slight for surface waters and may be from natural organic acids within the wetland system (pH 5.5 – 6.5). Alkalinity is low and soils indicate a lack of buffering capacity.

1.5 Discussion

Acid sulfate soil materials occurred at all sites as hyposulfidic materials with other acidic materials typically at the base of sites in subsoils. Hyposulfidic materials were typically encountered in surface and subsoils within the low points and water logged soils. Both sites (40416_4 and 40416_8) at the higher edge of the wetland contained less hyposulfidic materials at each site within the soil profile compared to low point sites.

No monosulfidic or sulfuric materials were encountered at the wetland. Water soluble sulfate values ranged between 53 – 126 mg/L for surface soil samples collected (i.e. 0 – 10cm). Four samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential and indicate that MBO could form under the right environmental conditions.

Chromium Reducible Sulfur (S_{CR}) results ranged from <0.01 (limit of laboratory detection) to 0.02% S. The majority of sites had a decreasing S_{CR} concentration trend with increasing depth of sample.

Results for net acidity were high for surface samples for site 40416_1 (> 100 mole H+/tonne). All remaining samples from each site were moderate net acidity (19 - 100 mole H+/tonne). Surface soils (0 – 30cm) typically had the highest net acidity values with TAA the major contributor. Net acidity values decreased at every site with sample depths.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are four (4) high priority samples based on the presence of water soluble sulfate results above the trigger criterion of 100 mg/L. There are a total of twenty five (25) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10%.

Due to the low level of sulfidic materials present (all S_{CR} analysis either <0.01 or 0.01 – 0.02% S) in surface and subsoils the requirement for Phase 2 laboratory analysis may not be warranted. However, 4 out of the 10 samples (40%) analysed exceed the trigger criterion of 100 mg/L for MBO formation potential. Therefore, Phase 2 analysis for the “Monosulfidic Formation Potential Method” may be suitable for selected surface samples. The lack of MBO formation observed during this survey however indicates that conditions may not be suitable for the formation of MBO currently.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Gemmills Swamp are:

- Acidification hazard: low level of concern based on the low sulfidic results (from S_{CR}). The degree of further acidification potential from sulfidic sources appears to be low for surface soils and subsoils. The wetland is already considered to be slightly acidic based on current soil and water pH results from this survey. This acidity however may come from organic acidity not related to sulfide oxidation from sulfidic materials.

- De-oxygenation hazard: low level of concern as water soluble sulfate results exceeded the trigger value for monosulfide formation at four sites out of ten. Currently however, no monosulfides were observed or formed during this survey with surface water present within the majority (70%) of the wetland. The lack of MBO formation observed during this survey however indicates that conditions may not be suitable for the formation of MBO currently.

- Metal mobilisation: The low acidification hazard indicates that sources of acidity may not be sufficient or in situ for metals mobilisation from sulfidic sources. As the wetland soil and water is slightly acidic currently, and hypersulfidic materials were not encountered, further significant decreases in pH may not occur in the medium term. However, the lower $pH_{incubation}$ results for surface and subsoils (4.00 – 5.50) indicate that pH could oxidise further and generate acidity levels low enough for mobilisation of some dissolved metals such as Aluminium if a drying event were to occur and then a re wetting event. There is a low to medium level of concern.

1.6 Summary of Key Findings for Gemmills Swamp

The summary of key findings for Gemmills Swamp is detailed in Table 2 on the following page.

Table 2 – Summary of Key Findings.

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Hypersulfidic materials were not observed. • Sulfidic materials identified included hyposulfidic materials at all sites. • Hyposulfidic materials were typically encountered in surface and subsoils within the low points and water logged soils. • Other acidic materials were typically encountered at the base or near the base of all sites in subsoils. • Net acidities ranged between 29 to 136 mol H+/tonne mol H+/tonne with the majority of acidity coming from TAA (actual acidity).
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Subaqueous soil occurring under current standing water level in the wetland. • Site 3: Subaqueous soil occurring under current standing water level in the wetland. • Site 4: Hydrosol – sandy or loamy occurring at high point of transect at edge of wetland water. • Site 5: Subaqueous soil occurring under current standing water level in the wetland. • Site 6: Hydrosol – sandy or loamy occurring at mid point of wetland hydrotoposequence. • Site 7: Hydrosol – sandy or loamy occurring at mid point of wetland hydrotoposequence. • Site 8: Hydrosol – sandy or loamy occurring at mid point of wetland hydrotoposequence.
Hazard assessment:	• Acidification hazard – low level of concern. • De-oxygenation hazard – low level of concern. • Metal mobilisation hazard – low to medium level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Gemmills Swamp.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40416_1.1	40416_1	0	5	0.1003	0.0612	39	4.49	1.90	5.29	101.85
40416_1.2	40416_1	5	40	0.1064	0.0748	30	4.56	1.90	4.43	-
40416_1.3	40416_1	40	70	0.1375	0.1074	22	5.48	2.89	4.63	-
40416_1.4	40416_1	70	90	0.1436	0.1107	23	5.63	3.16	4.44	-
40416_2.1	40416_2	0	5	0.1007	0.0623	38	5.04	1.99	4.66	72.6
40416_2.2	40416_2	5	30	0.1079	0.0761	29	4.00	2.18	4.39	-
40416_2.3	40416_2	30	50	0.1251	0.0954	24	5.02	2.56	4.39	-
40416_3.1	40416_3	0	5	0.1012	0.0630	38	4.81	1.93	5.17	85.5
40416_3.2	40416_3	5	10	0.1181	0.0799	32	4.83	2.18	4.47	-
40416_3.3	40416_3	10	40	0.1190	0.0870	27	4.91	2.47	4.47	-
40416_3.4	40416_3	40	75	0.1146	0.0847	26	5.26	2.93	4.87	-
40416_4.1	40416_4	0	5	0.1064	0.0671	37	5.13	1.88	4.71	126.6
40416_4.2	40416_4	5	10	0.1131	0.0782	31	4.77	2.01	4.35	-
40416_4.3	40416_4	10	50	0.1244	0.0942	24	5.30	2.52	4.55	-
40416_4.4	40416_4	50	70	0.1175	0.0924	21	5.44	2.69	4.73	-
40416_4.5	40416_4	70	100	0.1088	0.0890	18	5.44	2.78	4.69	-
40416_5.1	40416_5	0	3	0.0989	0.0476	52	5.91	3.87	6.54	98.4
40416_5.2	40416_5	3	15	0.1114	0.0793	29	4.70	2.26	4.31	-
40416_5.3	40416_5	15	35	0.1122	0.0822	27	5.05	2.41	4.52	-
40416_5.4	40416_5	35	70	0.1236	0.0928	25	5.61	3.07	4.86	-
40416_5.5	40416_5	70	100	0.1258	0.0968	23	5.65	3.24	5.31	-
40416_6.1	40416_6	0	5	0.1111	0.0729	34	5.03	2.25	4.35	114.75
40416_6.2	40416_6	5	30	0.1239	0.0904	27	5.06	2.57	4.68	-
40416_6.3	40416_6	30	40	0.1262	0.0935	26	5.11	2.76	4.59	-
40416_6.4	40416_6	40	70	0.1259	0.0965	23	5.48	3.02	4.72	-
40416_6.5	40416_6	70	90	0.1246	0.0959	23	5.57	3.21	4.73	-
40416_7.1	40416_7	0	10	0.1111	0.0819	26	4.22	2.19	4.09	114.15
40416_7.2	40416_7	10	30	0.1181	0.0966	18	4.95	2.76	4.90	69.45
40416_7.3	40416_7	30	70	0.1314	0.1085	17	5.41	2.99	4.62	-
40416_7.4	40416_7	70	90	0.1175	0.0960	18	5.57	2.90	4.66	-
40416_7.5	40416_7	90	110	0.1311	0.1070	18	5.39	2.99	5.38	-

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40416_8.1	40416_8	0	10	0.0946	0.0763	19	4.78	2.34	4.38	94.65
40416_8.2	40416_8	10	45	0.1192	0.0956	20	5.41	3.01	4.63	52.8
40416_8.3	40416_8	45	70	0.1183	0.0915	23	5.53	3.18	4.83	-
40416_8.4	40416_8	70	90	0.1297	0.1008	22	5.65	3.25	4.84	-
40416_8.5	40416_8	90	110	0.1118	0.0896	20	5.54	3.31	4.91	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Gemmills Swamp

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40416_1.1	40416_1	0	5	3.88	122	0.02	3	-	136	-	Hyposulfidic
40416_1.2	40416_1	5	40	3.96	95	0.01	1	-	103	-	Hyposulfidic
40416_1.3	40416_1	40	70	4.26	46	0.01	1	-	50	-	Hyposulfidic
40416_1.4	40416_1	70	90	4.59	29	<0.01	0	-	29	-	Other acidic
40416_2.1	40416_2	0	5	4.35	70	0.02	2	-	81	-	Hyposulfidic
40416_2.2	40416_2	5	30	4.15	75	0.01	1	-	79	-	Hyposulfidic
40416_2.3	40416_2	30	50	4.15	54	0.01	0	-	61	-	Hyposulfidic
40416_3.1	40416_3	0	5	4.26	88	0.02	0	-	98	-	Hyposulfidic
40416_3.2	40416_3	5	10	4.07	84	0.01	2	-	92	-	Hyposulfidic
40416_3.3	40416_3	10	40	4.19	65	0.01	0	-	73	-	Hyposulfidic
40416_3.4	40416_3	40	75	4.27	49	<0.01	3	-	51	-	Other acidic
40416_4.1	40416_4	0	5	4.48	56	0.01	0	-	63	-	Hyposulfidic
40416_4.2	40416_4	5	10	4.16	75	0.01	6	-	89	-	Hyposulfidic
40416_4.3	40416_4	10	50	4.40	38	0.01	0	-	42	-	Hyposulfidic
40416_4.4	40416_4	50	70	4.52	33	<0.01	0	-	33	-	Other acidic
40416_4.5	40416_4	70	100	4.42	35	<0.01	0	-	35	-	Other acidic
40416_5.1	40416_5	0	3	5.07	43	0.01	0	-	52	-	Hyposulfidic
40416_5.2	40416_5	3	15	4.05	82	0.02	3	-	95	-	Hyposulfidic
40416_5.3	40416_5	15	35	4.82	40	0.02	0	-	50	-	Hyposulfidic
40416_5.4	40416_5	35	70	4.60	35	<0.01	0	-	35	-	Other acidic
40416_5.5	40416_5	70	100	4.67	27	0.01	0	-	31	-	Hyposulfidic

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40416_6.1	40416_6	0	5	4.29	67	0.02	0	-	81	-	Hyposulfidic
40416_6.2	40416_6	5	30	4.19	64	0.01	0	-	71	-	Hyposulfidic
40416_6.3	40416_6	30	40	4.20	55	0.01	0	-	58	-	Hyposulfidic
40416_6.4	40416_6	40	70	4.27	44	<0.01	1	-	45	-	Other acidic
40416_6.5	40416_6	70	90	4.29	42	0.02	1	-	54	-	Hyposulfidic
40416_7.1	40416_7	0	10	4.10	80	0.01	3	-	87	-	Hyposulfidic
40416_7.2	40416_7	10	30	4.13	57	<0.01	0	-	57	-	Other acidic
40416_7.3	40416_7	30	70	4.39	36	0.01	2	-	45	-	Hyposulfidic
40416_7.4	40416_7	70	90	4.35	36	0.01	0	-	40	-	Hyposulfidic
40416_7.5	40416_7	90	110	4.33	32	0.01	0	-	37	-	Hyposulfidic
40416_8.1	40416_8	0	10	4.14	64	<0.01	4	-	68	-	Other acidic
40416_8.2	40416_8	10	45	4.33	43	0.01	1	-	48	-	Hyposulfidic
40416_8.3	40416_8	45	70	4.34	41	<0.01	0	-	41	-	Other acidic
40416_8.4	40416_8	70	90	4.31	38	<0.01	0	-	38	-	Other acidic
40416_8.5	40416_8	90	110	4.23	43	<0.01	0	-	43	-	Other acidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Gemmills Swamp.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40416_1.W1	40416_2.W1	-	-	40416_6.W1
Site ID	(number)	-	-	40416_1	40416_2	40416_3	40416_4	40416_6
Wetland ID	(code)	-	-	40416	40416	40416	40416	40416
Site Number	(number)	-	-	1	2	3	4	6
Upper depth	cm	-	-	-5	-15	-10	25	30
Lower depth	cm	-	-	0	0	0	35	40
Temperature	(deg C)	-	-	26.3	18.8	18.2	17.7	20.3
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	182.8	85.1	72.7	271	552
Dissolved Oxygen	(%)	-	-	106.9	20.4	16	4.8	15.3
Dissolved Oxygen	(mg/l)	-	-	9	1.88	2.14	0.44	0.85
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	5.91	6.24	6.78	5.64	5.74
Redox potential	Eh	-	-	221	193	146	64	137
Turbidity	(NTU)	*6 - 50*	*1 - 20*	40	58.5	982	79.3	36.3
HCO_3	(mg/l)	-	-	0	40	0	40	0
Comment	-	-	-	SW	SW	SW, no sample collected	PW, no sample collected	PW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Gemmills Swamp.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	17-04-10	17-04-10	17-04-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2163096	2163095	2163092
Sample ID	(number)	-	40416_1.W1 (SW)	40416_2.W1 (SW)	40416_6.W1 (PW)
Site ID	(number)	-	40416_1	40416_2	40416_6
Wetland ID	(code)	-	40416	40416	40416
Site Number	(number)	-	1	2	6
Upper depth	cm	-	-5	-15	30
Lower depth	cm	-	0	0	40
Na	$mg\ l^{-1}$	-	12	5	48
K	$mg\ l^{-1}$	-	25	3	4
Ca	$mg\ l^{-1}$	-	8	4	16
Mg	$mg\ l^{-1}$	-	5	3	13
Si	$mg\ l^{-1}$	-	7.7	20	44
Br	$mg\ l^{-1}$	-	<5	<5	<5
Cl	$mg\ l^{-1}$	-	5	24	110
NO_3	$mg\ l^{-1}$	0.7	0.02	0.03	0.25
NH_4-N[K]	$mg\ l^{-1}$	0.01	0.2	0.2	0.5
PO_4-P[E]	$mg\ l^{-1}$	0.005	0.21	0.32	0.01
SO_4	$mg\ l^{-1}$	-	<1	<1	47
Ag	$\mu g\ l^{-1}$	0.05	<1	<1	<1
Al[A]	$\mu g\ l^{-1}$	55	280	250	170
As[B]	$\mu g\ l^{-1}$	13	2	6	3
Cd	$\mu g\ l^{-1}$	0.2	<0.2	<0.2	<0.2
Co	$\mu g\ l^{-1}$	2.8	1	1	16
Cr[C]	$\mu g\ l^{-1}$	1	2	4	2
Cu[H]	$\mu g\ l^{-1}$	1.4	3	4	12
Fe	$\mu g\ l^{-1}$	300	2700	8000	360
Mn	$\mu g\ l^{-1}$	1700	88	40	580
Ni[H]	$\mu g\ l^{-1}$	11	6	20	36
Pb[H]	$\mu g\ l^{-1}$	3.4	<1	2	1
Se	$\mu g\ l^{-1}$	11	<1	<1	2
Zn[H]	$\mu g\ l^{-1}$	8	14	17	39
DOC	$mg\ l^{-1}$	-	30	100	78

Notes:
The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]*Trigger value for Aluminium in freshwater where pH > 6.5.*

[B]*Trigger value assumes As in solution as Arsenic (AsV).*

[C]*Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E]*Guideline is for filterable reactive phosphorous (FRP).*

[H]*Hardness affected (refer to Guidelines).*

[K]*Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Gemmills Swamp.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40416_1	40416	1	17-04-10	55	352316	5972943
40416_2	40416	2	17-04-10	55	352267	5972919
40416_3	40416	3	17-04-10	55	352199	5972903
40416_4	40416	4	17-04-10	55	352162	5972890
40416_5	40416	5	17-04-10	55	352182	5973294
40416_6	40416	6	17-04-10	55	352169	5973356
40416_7	40416	7	17-04-10	55	352118	5973513
40416_8	40416	8	17-04-10	55	352097	5973597

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40416_1	-5	water	Burnt reeds, reeds	low point, subaqueous	Subaqueous sediment samples	30	Subaqueous soil	recently burnt surface
40416_2	-15	water	reeds, rushes	mid point	Change in vegetation	10	Subaqueous soil	-
40416_3	-2	soft	reeds, rushes	mid point	high point of wetland hydro toposequence	5	Subaqueous soil	-
40416_4	25	soft	leaf and twig litter, reeds, rushes	high point	high point of wetland edge	5	Hydrosol - sandy or loamy	-
40416_5	-8	water	Burnt reeds, reeds	low point, subaqueous	Subaqueous sediment samples	30	Subaqueous soil	recently burnt surface
40416_6	30	soft	mainly bare, some reeds	mid point	Dryer site in hydro toposequence	10	Hydrosol - sandy or loamy	recently burnt surface
40416_7	-	loose	mainly bare, some rushes	mid point	Dryer site in hydro toposequence	5	Hydrosol - sandy or loamy	No water evident, recently burnt surface
40416_8	-	loose	weeds	high point	high point of wetland edge	5	Hydrosol - sandy or loamy	No water evident, recently burnt surface

Table 7 - Profile description data for acid sulfate soil assessment of Gemmills Swamp.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40416_1.1	SS	0	5	10YR41	Silty clay loam	Loamy	Wet	5.31	1:1
40416_1.2	SS	5	40	10YR41	Silty clay loam	Loamy	Wet	5.02	1:1
40416_1.3	PT	40	70	10YR41	Clay	Clayey	Wet	5.32	1:1
40416_1.4	PT	70	90	10YR31	Clay	Clayey	Wet	6.18	1:1
40416_2.1	SS	0	5	10YR42	Silty clay loam	Loamy	Wet	6.08	1:1
40416_2.2	SS	5	30	10YR42	Silty clay loam	Loamy	Wet	5.48	1:1
40416_2.3	SA	30	50	10YR42	Clay	Clayey	Wet	5.58	1:1
40416_3.1	SS	0	5	10YR42	Silty clay loam	Loamy	Wet	5.56	1:1
40416_3.2	SS	5	10	10YR42	Silty clay loam	Loamy	Wet	5.87	1:1
40416_3.3	SS	10	40	10YR42	Clay	Clayey	Wet	6.16	1:1
40416_3.4	SA	40	75	10YR42	Clay	Clayey	Wet	6.08	1:1
40416_4.1	SS	0	5	10YR31	Silty clay loam	Loamy	Moist	5.49	1:1
40416_4.2	SS	5	10	10YR42	Silty clay loam	Loamy	Moist	5.83	1:1
40416_4.3	SS	10	50	10YR42	Clay	Clayey	Wet	5.94	1:1
40416_4.4	PT	50	70	10YR42	Clay	Clayey	Wet	6.03	1:1
40416_4.5	PT	70	100	10YR42	Clay	Clayey	Wet	6.44	1:1
40416_5.1	SS	0	3	10YR21	Loam	Loamy	Wet	6.41	1:1
40416_5.2	SS	3	15	10YR42	Loam	Loamy	Wet	6.53	1:1
40416_5.3	PT	15	35	10YR42	Clay	Clayey	Wet	5.56	1:1
40416_5.4	PT	35	70	10YR31	Clay	Clayey	Wet	6.28	1:1
40416_5.5	PT	70	100	10YR41	Clay	Clayey	Wet	6.59	1:1
40416_6.1	SS	0	5	10YR42	Loam	Loamy	Wet	5.86	1:1
40416_6.2	SS	5	30	10YR42	Clay	Clayey	Wet	6.24	1:1
40416_6.3	SS	30	40	10YR42	Clay	Clayey	Wet	6.31	1:1
40416_6.4	SA	40	70	10YR42	Clay	Clayey	Wet	6.31	1:1
40416_6.5	SA	70	90	10YR42	Clay	Clayey	Wet	6.34	1:1
40416_7.1	SS	0	10	10YR32	Clay	Clayey	Moist	4.90	1:1
40416_7.2	SS	10	30	10YR52	Clay	Clayey	Moist	5.91	1:1
40416_7.3	SS	30	70	10YR42	Clay	Clayey	Moist	6.30	1:1
40416_7.4	SA	70	90	10YR42	Clay	Clayey	Moist	6.27	1:1
40416_7.5	SA	90	110	10YR42	Clay	Clayey	Moist	6.33	1:1

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40416_8.1	SS	0	10	10YR42	Clay	Clayey	Moist	5.83	1:1
40416_8.2	SS	10	45	10YR52	Clay	Clayey	Moist	6.19	1:1
40416_8.3	SS	45	70	10YR42	Clay	Clayey	Moist	6.33	1:1
40416_8.4	SA	70	90	10YR42	Clay	Clayey	Moist	6.44	1:1
40416_8.5	SA	90	110	10YR42	Clay	Clayey	Moist	6.36	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Gemmills Swamp

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40416_1.1	0	-	-	-	-	0	VS	organics, rootlets, difficult to bolus
40416_1.2	0	-	-	-	-	0	VS	rootlets
40416_1.3	20	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets
40416_1.4	10	FM	5YR58	MAT, RPO	-	0	VS	-
40416_2.1	0	-	-	-	-	0	VS	organics, rootlets, difficult to bolus
40416_2.2	0	-	-	-	-	0	VS	rootlets
40416_2.3	5	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets
40416_3.1	0	-	-	-	-	0	VS	organics, rootlets, difficult to bolus
40416_3.2	0	-	-	-	-	0	VS	rootlets
40416_3.3	15	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets
40416_3.4	15	FM	5YR58	MAT, RPO	-	0	VS	minor organics
40416_4.1	0	-	-	-	MA	1	S	organics, rootlets, difficult to bolus
40416_4.2	0	-	-	-	MA	1	S	organics, rootlets, charcoal fragments throughout matrix
40416_4.3	15	FM	5YR58	MAT, RPO	MA	1	S	organics, rootlets, charcoal fragments throughout matrix
40416_4.4	15	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets, charcoal fragments throughout matrix
40416_4.5	5	FM	5YR58	MAT, RPO	-	0	VS	minor charcoal fragments throughout matrix
40416_5.1	0	-	-	-	MA	1	S	strongly organic, rootlets, difficult to bolus, ash debris on surface from recent fire

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40416_5.2	0	-	-	-	MA	1	S	minor rootlets, charcoal fragments throughout matrix
40416_5.3	2	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets, charcoal fragments throughout matrix
40416_5.4	15	FM	5YR58	MAT, RPO	-	0	VS	minor rootlets, charcoal fragments throughout matrix
40416_5.5	2	FM	5YR58	MAT, RPO	-	0	VS	
40416_6.1	2	FM	5YR58	MAT, RPO	MA	1	S	organics, rootlets, difficult to bolus
40416_6.2	10	FM	5YR58	MAT, RPO	MA	1	S	organics, rootlets, charcoal fragments throughout matrix
40416_6.3	10	FM	5YR58	MAT, RPO	-	0	VS	organics, rootlets
40416_6.4	5	FM	5YR58	MAT, RPO	-	0	VS	organics, rootlets
40416_6.5	2	FM	5YR58	MAT, RPO	-	0	VS	organics, charcoal fragments throughout matrix
40416_7.1	0	-	-	-	MA	1	S	organics, rootlets, ash debris on surface from recent fire
40416_7.2	20	FM	5YR58	MAT, RPO	MA	1	VW	organics, rootlets, charcoal fragments throughout matrix
40416_7.3	15	FM	5YR58	MAT, RPO	MA	1	W	rootlets, charcoal fragments throughout matrix
40416_7.4	10	FM	5YR58	MAT, RPO	-	0	W	rootlets, charcoal fragments throughout matrix
40416_7.5	10	FM	5YR58	MAT, RPO	-	0	W	charcoal fragments throughout matrix
40416_8.1	10	FM	5YR58	MAT, RPO	MA	1	S	organics, rootlets
40416_8.2	15	FM	5YR58	MAT, RPO	MA	1	VW	rootlets, charcoal fragments throughout matrix
40416_8.3	10	FM	5YR58	MAT, RPO	MA	1	W	rootlets, charcoal fragments throughout matrix
40416_8.4	5	FM	5YR58	MAT, RPO	-	0	W	rootlets, charcoal fragments throughout matrix
40416_8.5	5	FM	5YR58	MAT, RPO	-	0	W	rootlets

APPENDIX 6: GUNBOWER CREEK (40486) SUMMARY REPORT

APPENDIX 6:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40486

Wetland Name: Gunbower Creek

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 GUNBOWER CREEK 2
1.1 Location and Setting Description 2
1.2 Soil Profile Description and Distribution 2
1.3 Summary of Field and Laboratory Results 4
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 5
1.3.2 Acid Base Accounting 7
1.3.3 Titratable Actual Acidity (TAA) 7
1.3.4 Chromium Reducible Sulfur (S_{CR}) 7
1.3.5 Acid Volatile Sulfur (AVS) 7
1.3.6 Retained Acidity (RA) 7
1.3.7 Acid Neutralising Capacity (ANC) 7
1.3.8 Net Acidity 7
1.3.9 Water soluble SO_4 8
1.4 Hydrochemistry 8
1.5 Discussion 9
1.6 Summary of Key Findings for Gunbower Creek 10

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Gunbower Creek Sites. 3
Table 2 – Summary Of Key Findings 10
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Gunbower Creek. 11
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Gunbower Creek. 13
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Gunbower Creek. 14
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Gunbower Creek. 15
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Gunbower Creek. 16

LIST OF FIGURES

Figure 1 – Gunbower Creek 40486 Site Plan.

Figure 2 – Gunbower Creek Conceptual Hydrotoposequence Cross Section – 40486.

Figure 3 – Photographs of site 40486_1, showing the surface condition and the soil profile of weak, very dark greyish brown clay overlying very firm, dark greenish grey clay.

Figure 4 – Photographs of site 40486_2, showing the surface condition and the soil profile of weak, dark greyish brown clay loam overlying very firm, dark greyish brown clay.

Figure 5 – Photographs of site 40486_3, showing the surface condition and the soil profile of loose salt crust on surface, then weak, brown clay loam overlying very firm, dark grey clay.

Figure 6 – Photographs of site 40486_4, showing the surface condition and the soil profile of weak, brown and dark brown clay loam overlying very firm, dark greyish brown clay loam sandy.

Figure 7 – Depth profiles of soil pH for Gunbower Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 8 – Acid base accounting depth profiles for Gunbower Creek. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

1 GUNBOWER CREEK

1.1 Location and Setting Description

Gunbower Creek is situated on the southern side of the River Murray, approximately 40km North West of the township of Echuca VIC. The wetland is accessed from O'Brien Road and Walkers Road off the Murray Valley Highway. The wetland is horse shoe in shape (curved) with a longer linear section connecting to Gunbower Creek to the North via a small cut channel. During this survey the wetland was not connected to Gunbower Creek and the small cut channel contained fill. The Murray River is approximately 7km to the North of the wetland. The wetland is approximately 100m wide by 1,400m in linear curved length, with a total area of 13 hectares.

The wetland is a cut off stream channel (oxbow) with minor banks and low to moderately sloping batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had minimal ponded surface water within the channel of the wetland. The wetland is a typical oxbow which has a long curved stream channel but is closed to Gunbower Creek.

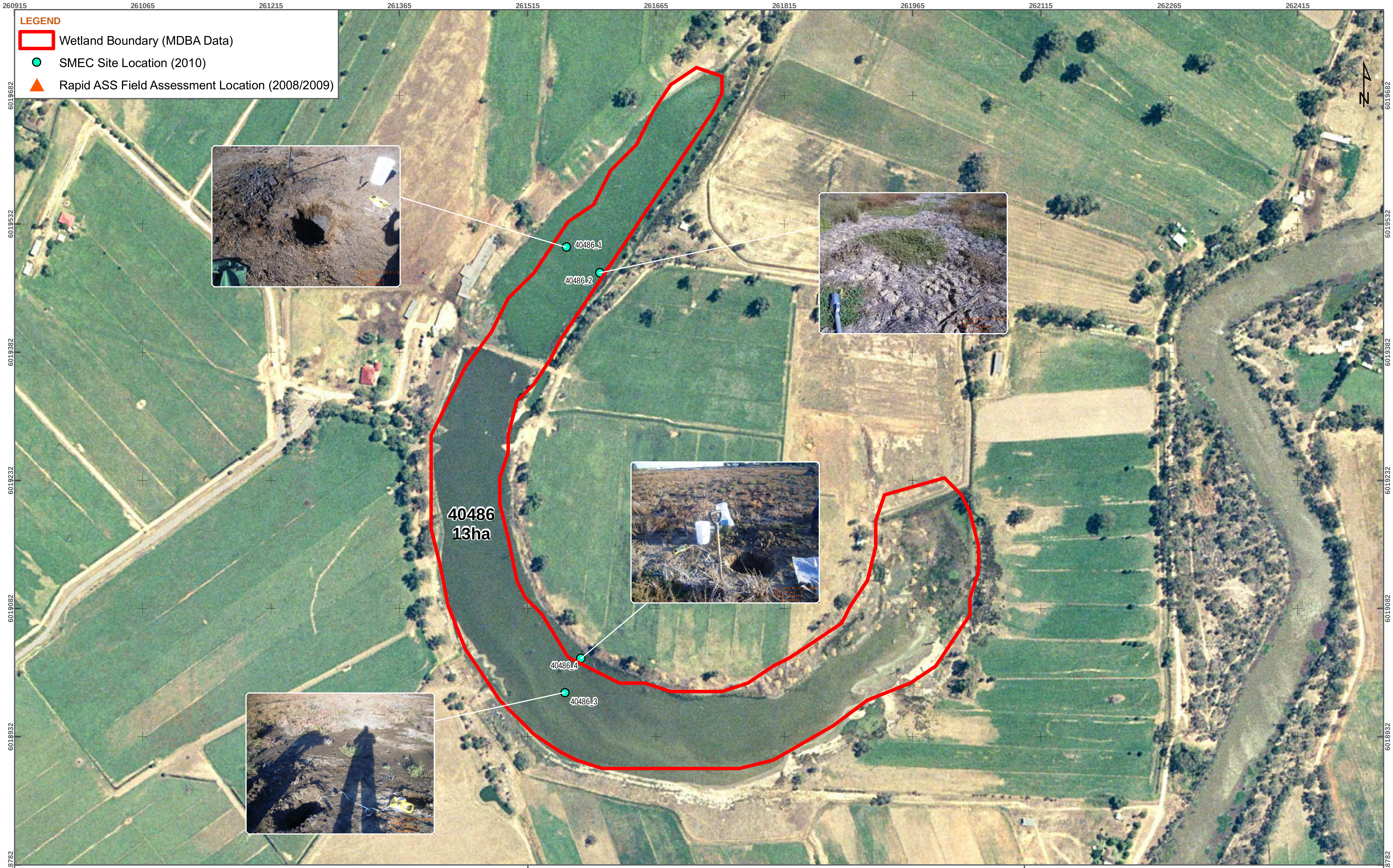
The surface water within the wetland was generally clear to brown and shallow (<30cm) and related primarily to adjacent farming activities (ponds) and in deeper ruts within the soil from tyre tracks. The wetland had salt bush, weeds and reeds within the stream channel with the channel edges containing low grasses, reeds and some medium sized trees. The upper channel banks and upper floodplain contained low grasses, shrubs and medium to large trees. Two sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Four sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at two different areas of the wetland with two sites chosen for each transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 6** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

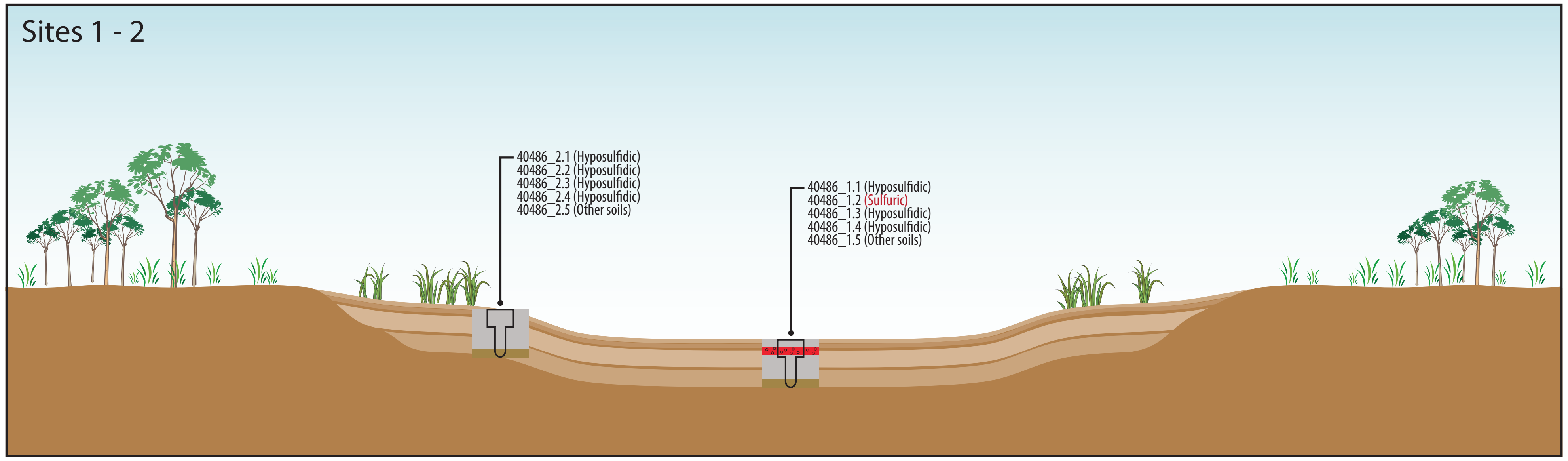
- 40486_1: loose, bare, low point, mid stream channel; soil consisted of weak, very dark greyish brown clay overlying very firm, dark greenish grey clay.
- 40486_2: cracking, weeds and salt bush, high point, edge of stream channel; soil consisted of weak, dark greyish brown clay loam overlying very firm, dark greyish brown clay.
- 40486_3: saline, mainly bare with salt bush, low point, mid stream channel; soil consisted of loose salt crust on surface, then weak, brown clay loam overlying very firm, dark grey clay.
- 40486_4: loose, weeds and salt bush, high point, edge of stream channel; soil consisted of weak, brown and dark brown clay loam overlying very firm, dark greyish brown clay loam sandy.

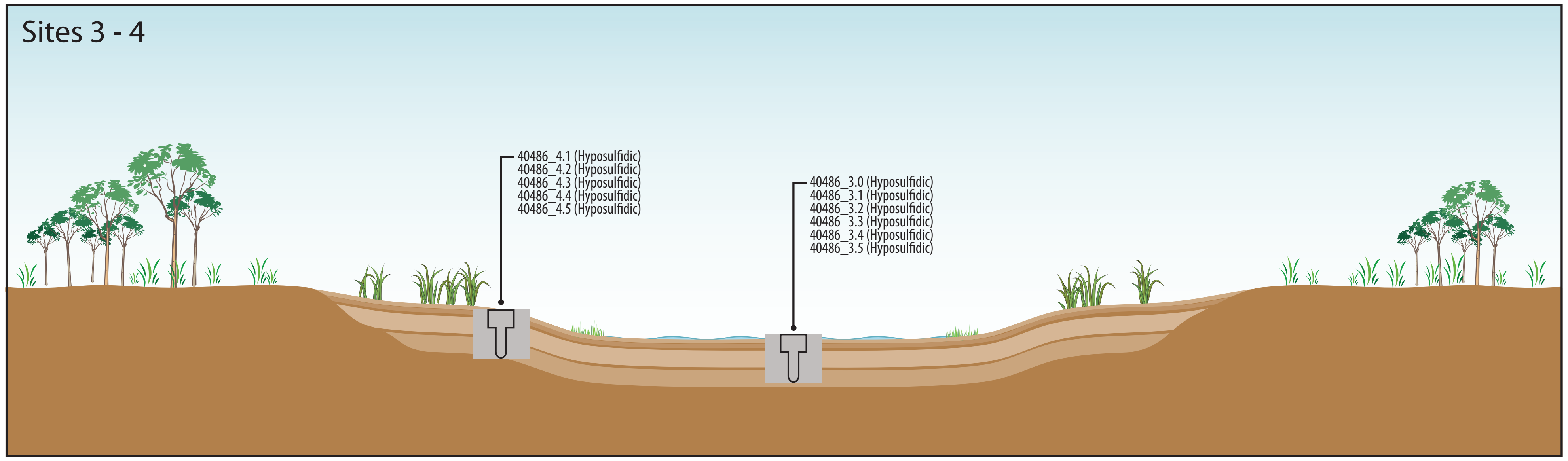


DATE 09/07/2010	SCALE 1:4,000	0 37.5 75 150 Meters	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 55	FIG NO. 1 — PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewartr	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\ 009DATA\GIS				PROJECT NO. 3001801 — FIGURE TITLE Gunbower Creek 40486 - CMA:NCCMA

Note: Inset Photos show Surface Condition of Site

SMEC



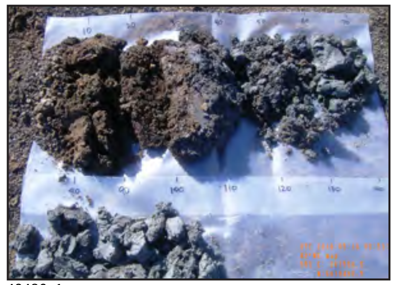


LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

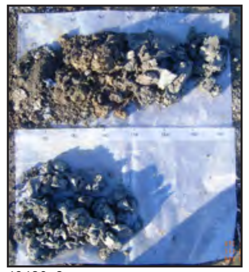

40486_1


40486_1

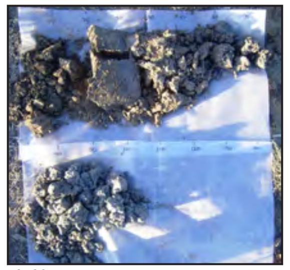

40486_2


40486_2


40486_3


40486_3


40486_4


40486_4

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2 **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Gunbower Creek 40486

Table 1 – Soil Identification, subtype and general location description for Gunbower Creek Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40486_1	261561	6019504	Sulfuric soil	Low point, mid stream channel, bare.
40486_2	261600	6019475	Cracking clay soils	High point, edge of stream channel, weeds and salt bush.
40486_3	261559	6018983	Cracking clay soils	Low point, mid stream channel, bare, salt on surface.
40486_4	261578	6019023	Hypersulfidic soil	High point, edge of stream channel, weeds and salt bush.

Figure 3 – Photographs of site 40486_1, showing the surface condition and the soil profile of weak, very dark greyish brown clay overlying very firm, dark greenish grey clay.

Figure 4 – Photographs of site 40486_2, showing the surface condition and the soil profile of weak, dark greyish brown clay loam overlying very firm, dark greyish brown clay.

Figure 5 – Photographs of site 40486_3, showing the surface condition, surface salt crust and the soil profile of loose salt crust on surface, then weak, brown clay loam overlying very firm, dark grey clay.

Figure 6 – Photographs of site 40486_4, showing the surface condition and the soil profile of weak, brown and dark brown clay loam overlying very firm, dark greyish brown clay loam sandy.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The following subheadings provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figure 7** on the following page. Summary soil pH profile results indicate:

- 40486_1: all samples have $pH_w < 8.0$. Surface soils (0 - 35cm) have pH_w 3.93 – 5.59 with subsoils (35 – 100cm) ranging 6.67 – 7.56. Surface soils $pH_{incubation}$ ranged 3.95 – 5.08 indicating hyposulfidic and sulfuric conditions. Subsoils $pH_{incubation}$ ranged 5.16 – 6.90 indicating hyposulfidic and other acidic conditions.
- 40486_2: all samples have $pH_w < 6.5$. Surface soils (0 - 25cm) have pH_w 4.83 – 4.89 with subsoils (25 – 100cm) ranging 6.01 – 6.30. Surface soils $pH_{incubation}$ ranged 4.38 – 4.71 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.25 – 5.73 indicating hyposulfidic and other acidic conditions.
- 40486_3: all samples have $pH_w < 8.0$. Surface soils (0 - 15cm) have pH_w 6.41 – 7.07 with subsoils (15 – 110cm) ranging 4.31 – 7.57. Surface soils $pH_{incubation}$ ranged 5.92 – 7.06 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.08 – 7.06 indicating hyposulfidic conditions.
- 40486_4: all samples have $pH_w < 8.0$. Surface soils (0 - 30cm) have pH_w 4.61 – 5.17 with subsoils (30 – 100cm) ranging 5.17 – 7.93. Surface soils $pH_{incubation}$ ranged 3.50 – 4.29 indicating hyposulfidic and hypersulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.12 – 7.27 indicating hyposulfidic conditions.

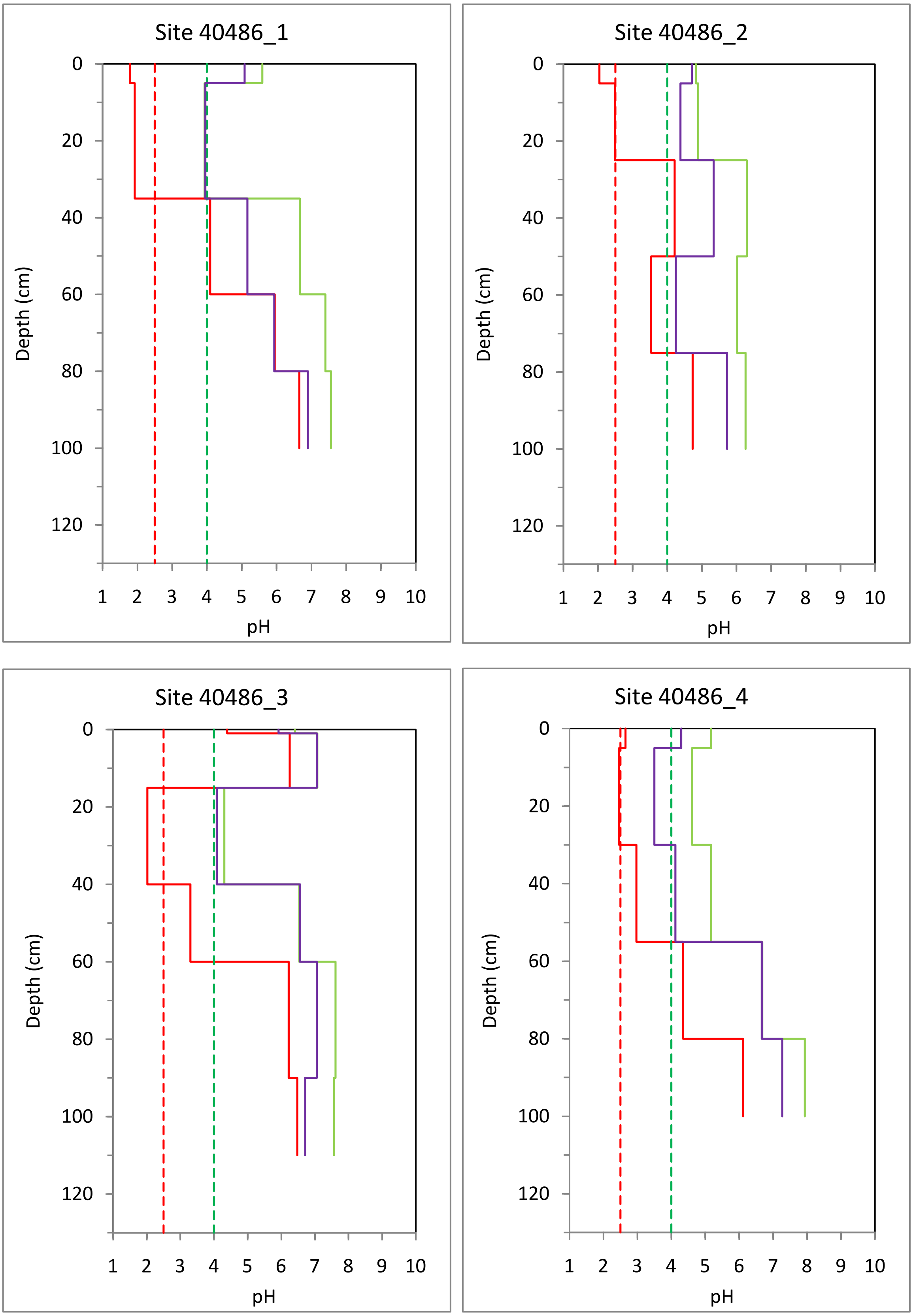


Figure 7 – Depth profiles of soil pH for Gunbower Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 8** on the following page.

1.3.3 Titratable Actual Acidity (TAA)

All 21 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 0 – 109 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic and near neutral in situ conditions moving vertically down the soil profile.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 21 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where S_{CR} ≥ 0.01% S. Results ranged from <0.01 (limit of laboratory detection) to 0.95%S. 5 out of the 21 collected samples (24%) had S_{CR} >0.10% S with all 5 samples from the upper surface soils and within the mid stream channel sample points (40846_1 and 40846_3). All sites had a decreasing S_{CR} concentration trend with increasing depths.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Gunbower Creek.

1.3.6 Retained Acidity (RA)

Out of the 21 samples collected, 5 were analysed (24%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 0 – 244 mole H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

Out of the 21 samples collected, 2 were analysed (10%) for ANC. Results ranged from 2 – 4 %$CaCO_3$ and both samples were from 40486_3 (salt crust and surface soils). None of the remaining samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between -542 to 610 mol H+/tonne. With the exception of 40846_3, all sites had a decreasing net acidity value trend with increasing depths. Site 40846_3 where a thin salt crust was present on the surface, had negative net acidity values for the surface materials (-584 to -284 mole H+/tonne) with low net acidity for subsoils.

Surface soils (0 – 30cm) typically had high net acidity values with the exception of site 40486_3. Subsoils (30 – 100cm) typically had low to moderate net acidity values at all sites.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 2,250 to 131,550 mg/L for surface soil samples collected (i.e. 0 – 10cm). Five surface soil samples were analysed for water soluble sulfate in total. All samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results were extremely high with no sample less than 20 times the trigger criterion indicating that this wetland has an extremely high risk for the formation of MBO under the right environmental conditions.

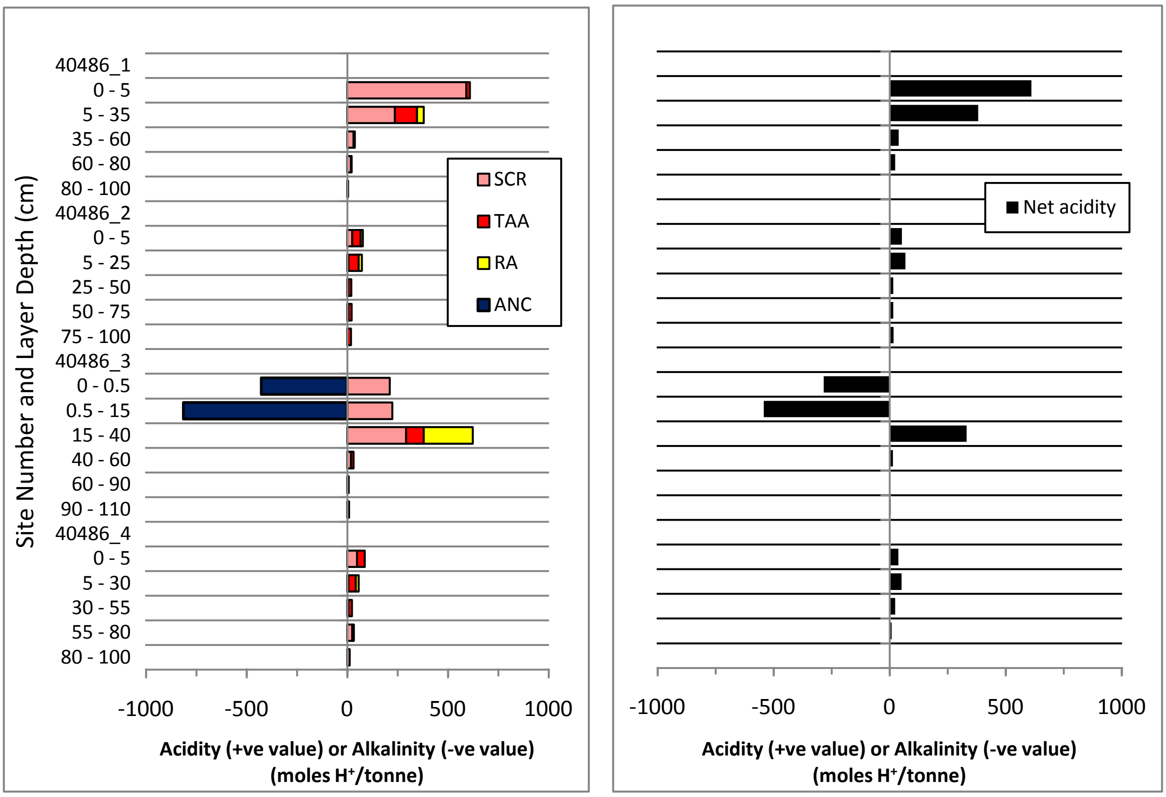


Figure 8 – Acid base accounting depth profiles for Gunbower Creek. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at one out of the four sites from Gunbower Creek. The one field measurement and sampling was from site 40486_3 near the sample point where vehicle track ruts contained shallow pooled surface water.

The surface waters were slightly acidic (pH 6.55) and within the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0. SEC values were outside the Lowland River criterion values of 125 – 2,200µS/cm and outside the criterion values for Freshwater Lakes (20 – 30µS/cm) with a concentration of 2,530 µS/cm. Alkalinity (as HCO_3) was 150 mg/L and the site surface water had oxidising conditions (272 Eh).

The surface water site exceeded the trigger values for some nutrients (NH_4 0.2 mg/L, criterion of 0.01 mg/L and PO_4 1.2 mg/L, criterion of 0.005 mg/L) and some dissolved metals (Cu 5 µg/L, criterion of 1.4 µg/L).

The limited water data indicates that the surface water has not been significantly affected by acidification. The surface soil salinity observed within the wetland may provide some buffering capacity to potential acidification.

1.5 Discussion

Acid sulfate soils within Gunbower Creek occurred as areas of hyposulfidic and sulfuric soil material within the stream channel. Hyposulfidic soil was typically encountered within surface and subsoils at both the low points (mid channel) and high points (edge of the channel). Sulfuric material was encountered at site 40486_1 within surface soils (5 – 35cm). 5 out of the 21 collected samples (24%) had S_{CR} >0.10% S with all 5 samples from the upper surface soils and within the mid stream channel sample points (40846_1 and 40846_3). All sites had a decreasing S_{CR} concentration trend with increasing depths.

No monosulfidic materials were encountered at the wetland. Water soluble sulfate values ranged between 2,250 to 131,550 mg/L. All samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results were extremely high with no sample less than 20 times the trigger criterion.

Net acidity results for all sites and samples ranged between -542 to 610 mol H+/tonne. With the exception of 40846_3, all sites had a decreasing net acidity value trend with increasing sample depths. Surface soils (0 – 30cm) typically had high net acidity values with the exception of site 40486_3. Subsoils (30 – 100cm) typically had low to moderate net acidity values at all sites.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are a total of five (5) high priority samples based on the presence of water soluble sulfate values that exceed the trigger criterion of 100 mg/L for MBO formation potential, one (1) high priority sample with sulfuric materials and four (4) high priority samples with hyposulfidic materials S_{CR} >0.10%. There are thirteen (13) samples with moderate priority with hyposulfidic materials S_{CR} <0.10%.

Due to the high concentration of sulfidic materials present (24% of samples had S_{CR} >0.10% S from the upper surface soils) the requirement for Phase 2 laboratory analysis may be warranted for selected surface samples. Sulfuric soils were encountered at site 40486_1 and all surface soils samples exceeded the trigger criterion of 100 mg/L for MBO formation potential significantly. Therefore, Phase 2 analysis for the “Monosulfidic Formation Potential Method” may be suitable for selected surface samples. This would especially be the case if significant re flooding is considered for the wetland.

The wetland currently has some sulfuric materials with currently low pH values (below 4.00 and within 4.00 – 5.00) within surface soils throughout the wetland. If re - flooding were to occur metals such as Aluminium, Iron and Zinc may be liberated and dissolved metals would be released if pH values were to decrease further. Without pit inflow water (shallow groundwater) data this risk is difficult to quantify. The wetland however is medium in size (13 ha) with some buffering capacity present in surface soils from saline soils and surface salt crusts.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Gunbower Creek are:

- Acidification hazard: medium level of concern based on the high net acidities and sulfidic results (from S_{CR}) with 24% of samples >0.10% S. Sulfuric materials were observed within surface soils and acidic pH values <5.00. The degree of acidification potential from sulfidic sources appears to be high for surface soils (0 – 30cm) and medium to low for subsoils (30 – 100cm). However, the wetland has some alkalinity and buffering capacity that may act to buffer acidity from sulfidic sources if oxidation occurred, along with highly saline surface soils. Therefore, a medium level of concern.

- De-oxygenation hazard: medium to high level of concern as water soluble sulfate results for all surface soil materials significantly exceeded the trigger value for monosulfide formation, although no MBO materials were observed in areas that were sampled.

- Metal mobilisation: The medium acidification hazard indicates that sulfidic sources of acidity may be sufficient for metals mobilisation. The wetland has some alkalinity and salinity that may provide buffering capacity. The saline surface soils may reduce the risk of metals being liberated from sulfidic sources by keeping pH higher along with other environmental factors. Therefore, a medium level of concern.

1.6 Summary of Key Findings for Gunbower Creek

The summary of key findings for Gunbower Creek is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Acid sulfate soils within Gunbower Creek occurred as areas of hyposulfidic and sulfuric soil material within the stream channel. • Sulfuric materials were observed at site 40486_1, surface soils. • Water soluble sulfate results exceeded the trigger value for monosulfide formation at all sites within surface soils. • Monosulfidic materials were not observed. • Hyposulfidic soil was typically encountered within surface and subsoils at both the low points (mid channel) and high points (edge of the channel). • All sites had a decreasing S_{CR} concentration trend with increasing depths. • With the exception of 40846_3, all sites had a decreasing net acidity value trend with increasing sample depths. • Surface soils (0 – 30cm) typically had high net acidity values with the exception of site 40486_3. • Subsoils (30 – 100cm) typically had low to moderate net acidity values at all sites.
Acid sulfate soil identification:	• Site 1: Sulfuric soil occurring within the low point of the channel in the wetland. • Site 2: Cracking clay soil occurring at the channel edge water of the wetland. • Site 3: Cracking clay soil occurring within the low point of the channel in the wetland. • Site 4: Hypersulfidic soil occurring at the channel edge water of the wetland.
Hazard assessment:	• Acidification hazard – medium level of concern. • De-oxygenation hazard – medium to high level of concern. • Metal mobilisation hazard – medium level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Gunbower Creek.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40486_1.1	40486_1	0	5	0.0646	0.0577	11	5.59	1.79	5.08	15600
40486_1.2	40486_1	5	35	0.1054	0.0608	42	3.93	1.92	3.95	-
40486_1.3	40486_1	35	60	0.1103	0.0864	22	6.67	4.09	5.16	-
40486_1.4	40486_1	60	80	0.1216	0.0954	22	7.40	5.95	5.93	-
40486_1.5	40486_1	80	100	0.1190	0.0927	22	7.56	6.65	6.90	-
40486_2.1	40486_2	0	5	0.0613	0.0595	3	4.83	2.04	4.71	2250
40486_2.2	40486_2	5	25	0.1044	0.0876	16	4.89	2.49	4.38	-
40486_2.3	40486_2	25	50	0.1025	0.0875	15	6.30	4.21	5.34	-
40486_2.4	40486_2	50	75	0.1003	0.0834	17	6.01	3.53	4.25	-
40486_2.5	40486_2	75	100	0.1174	0.0941	20	6.26	4.73	5.73	-
40486_3.0	40486_3	0	1	0.0670	0.0591	12	6.41	4.39	5.92	131550
40486_3.1	40486_3	1	15	0.0752	0.0600	20	7.07	6.25	7.06	21600
40486_3.2	40486_3	15	40	0.0857	0.0534	38	4.31	2.02	4.08	-
40486_3.3	40486_3	40	60	0.1240	0.0944	24	6.54	3.30	6.56	-
40486_3.4	40486_3	60	90	0.1301	0.0997	23	7.61	6.22	7.06	-
40486_3.5	40486_3	90	110	0.1129	0.0896	21	7.57	6.48	6.71	-
40486_4.1	40486_4	0	5	0.0715	0.0502	30	5.17	2.65	4.29	13965
40486_4.2	40486_4	5	30	0.0998	0.0858	14	4.61	2.46	3.50	-
40486_4.3	40486_4	30	55	0.0932	0.0786	16	5.17	2.97	4.12	-
40486_4.4	40486_4	55	80	0.0819	0.0677	17	6.68	4.34	6.66	-
40486_4.5	40486_4	80	100	0.1108	0.0932	16	7.93	6.11	7.27	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Gunbower Creek.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40486_1.1	40486_1	0	5	5.77	18	0.95	0	-	610	-	Hyposulfidic
40486_1.2	40486_1	5	35	3.80	109	0.38	34	-	381	-	Sulfuric
40486_1.3	40486_1	35	60	5.97	7	0.05	0	-	38	-	Hyposulfidic
40486_1.4	40486_1	60	80	6.29	4	0.03	0	-	23	-	Hyposulfidic
40486_1.5	40486_1	80	100	6.36	3	<0.01	0	-	3	-	Other soil
40486_2.1	40486_2	0	5	4.44	43	0.04	10	-	53	-	Hyposulfidic
40486_2.2	40486_2	5	25	4.37	51	0.01	16	-	67	-	Hyposulfidic
40486_2.3	40486_2	25	50	5.48	15	0.01	0	-	15	-	Hyposulfidic
40486_2.4	40486_2	50	75	5.25	16	0.01	0	-	16	-	Hyposulfidic
40486_2.5	40486_2	75	100	5.25	17	<0.01	0	-	17	-	Other soil
40486_3.0	40486_3	0	1	6.71	0	0.34	0	2	-284	-	Hyposulfidic
40486_3.1	40486_3	1	15	7.21	0	0.36	0	4	-542	-	Hyposulfidic
40486_3.2	40486_3	15	40	4.21	87	0.47	244	-	332	-	Hyposulfidic
40486_3.3	40486_3	40	60	5.86	13	0.03	0	-	13	-	Hyposulfidic
40486_3.4	40486_3	60	90	6.49	1	0.01	0	-	1	-	Hyposulfidic
40486_3.5	40486_3	90	110	6.26	4	0.01	0	-	4	-	Hyposulfidic
40486_4.1	40486_4	0	5	5.27	37	0.08	0	-	37	-	Hyposulfidic
40486_4.2	40486_4	5	30	4.42	38	0.01	14	-	51	-	Hypersulfidic
40486_4.3	40486_4	30	55	4.75	18	0.01	0	-	24	-	Hyposulfidic
40486_4.4	40486_4	55	80	6.03	8	0.04	0	-	8	-	Hyposulfidic
40486_4.5	40486_4	80	100	6.60	0	0.02	0	-	0	-	Hyposulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Gunbower Creek.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40486_3.W1
Site ID	(number)	-	-	40486_3
Wetland ID	(code)	-	-	40486
Site Number	(number)	-	-	3
Upper depth	cm	-	-	-35
Lower depth	cm	-	-	0
Temperature	(deg C)	-	-	14.7
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	2530
Dissolved Oxygen	(%)	-	-	108.5
Dissolved Oxygen	(mg/l)	-	-	11.54
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	6.55
Redox potential	Eh	-	-	272
Turbidity	(NTU)	*6 - 50*	*1 - 20*	85.3
HCO_3	(mg/l)	-	-	150
Comment	-	-	-	SW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Gunbower Creek.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	18-05-10
Laboratory	(code)	-	Ecowise/ALS
Laboratory sample ID	number	-	2194049
Sample ID	(number)	-	40486_3.W1 (SW)
Site ID	(number)	-	40486_3
Wetland ID	(code)	-	40486
Site Number	(number)	-	3
Upper depth	cm	-	-35
Lower depth	cm	-	0
Na	$mg\ l^{-1}$	-	210
K	$mg\ l^{-1}$	-	30
Ca	$mg\ l^{-1}$	-	170
Mg	$mg\ l^{-1}$	-	88
Si	$mg\ l^{-1}$	-	0.6
Br	$mg\ l^{-1}$	-	<5
Cl	$mg\ l^{-1}$	-	400
NO_3	$mg\ l^{-1}$	0.7	0.04
NH_4-N[K]	$mg\ l^{-1}$	0.01	0.2
PO_4-P[E]	$mg\ l^{-1}$	0.005	1.2
SO_4	$mg\ l^{-1}$	-	530
Ag	$\mu g\ l^{-1}$	0.05	<1
Al[A]	$\mu g\ l^{-1}$	55	20
As[B]	$\mu g\ l^{-1}$	13	3
Cd	$\mu g\ l^{-1}$	0.2	<0.2
Co	$\mu g\ l^{-1}$	2.8	1
Cr[C]	$\mu g\ l^{-1}$	1	<1
Cu[H]	$\mu g\ l^{-1}$	1.4	5
Fe	$\mu g\ l^{-1}$	300	100
Mn	$\mu g\ l^{-1}$	1700	1100
Ni[H]	$\mu g\ l^{-1}$	11	6
Pb[H]	$\mu g\ l^{-1}$	3.4	<1
Se	$\mu g\ l^{-1}$	11	<1
Zn[H]	$\mu g\ l^{-1}$	8	5
DOC	$mg\ l^{-1}$	-	22

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]Trigger value for Aluminium in freshwater where pH > 6.5.

[B]Trigger value assumes As in solution as Arsenic (AsV).

[C]Trigger value for Chromium is applicable to Chromium (CrVI) only.

[E]Guideline is for filterable reactive phosphorous (FRP).

[H]Hardness affected (refer to Guidelines).

[K]Guideline for South-east Australia-Freshwater Lakes and reservoirs.

Table 6 - Site description data for acid sulfate soil assessment of Gunbower Creek.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40486_1	40486	1	18-05-10	55	261561	6019504
40486_2	40486	2	18-05-10	55	261600	6019475
40486_3	40486	3	18-05-10	55	261559	6018983
40486_4	40486	4	18-05-10	55	261578	6019023

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40486_1	-	loose	bare	low point	iron staining on surface peds	30	Sulfuric soil	No water evident, likely manure spreading on surface in recent past, possibly lime application along fence lines with remnant lime on surface
40486_2	-	cracking	weeds, salt bush	high point	cracking surface clays	20	Cracking clay soils	No water evident
40486_3	-	saline	mainly bare, some salt bush	low point	saline surface, wettest point of transect	30	Cracking clay soils	Water sample collected from nearby surface channel from vehicle wheel ruts, salt on surface in sporadic patchy wet and drying areas
40486_4	-	loose	reeds, salt bush	high point	edge of channel, high point of hydro toposequence	20	Hypersulfidic soil	No water evident

Table 7 - Profile description data for acid sulfate soil assessment of Gunbower Creek.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40486_1.1	SS	0	5	7.5YR31	Clayey sand	Sandy	Moderately	6.09	1:1
40486_1.2	SS	5	35	10YR32	Clay	Clayey	Moist	3.41	1:1
40486_1.3	SS	35	60	10YR41	Clay	Clayey	Moist	6.70	1:1
40486_1.4	SA	60	80	GLEY1410Y	Clay	Clayey	Moist	7.01	1:1
40486_1.5	SA	80	100	GLEY1410Y	Clay	Clayey	Moist	7.30	1:1
40486_2.1	SS	0	5	10YR51	Clay loam sandy	Sandy	Moderately	4.19	1:1
40486_2.2	SS	5	25	10YR42	Clay loam	Loamy	Moderately	4.24	1:1
40486_2.3	SS	25	50	7.5YR41	Clay	Clayey	Moist	5.56	1:1
40486_2.4	SA	50	75	10YR42	Clay	Clayey	Moist	5.52	1:1
40486_2.5	SA	75	100	10YR42	Clay	Clayey	Moist	5.52	1:1
40486_3.0	BC	0	1	10YR42	Salt	Salty	Dry	4.31	1:1
40486_3.1	SS	1	15	10YR31	Clay loam	Loamy	Moderately	5.93	1:1
40486_3.2	SS	15	40	10YR43	Clay loam	Loamy	Moist	4.23	1:1
40486_3.3	SS	40	60	10YR41	Clay	Clayey	Moist	7.04	1:1
40486_3.4	SA	60	90	10YR41	Clay	Clayey	Moist	7.88	1:1
40486_3.5	SA	90	110	10YR41	Clay	Clayey	Moist	7.43	1:1
40486_4.1	SS	0	5	10YR43	Loam	Loamy	Moist	5.30	1:1
40486_4.2	SS	5	30	10YR33	Clay loam	Loamy	Moist	3.90	1:1
40486_4.3	SS	30	55	10YR42	Clay loam sandy	Clayey	Moist	3.73	1:1
40486_4.4	SA	55	80	10YR42	Clay loam sandy	Clayey	Moist	6.05	1:1
40486_4.5	SA	80	100	10YR41	Clay loam sandy	Clayey	Moist	7.44	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Gunbower Creek.

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40486_1.1	5	FM	2.5RY56	MAT, RPO	MA	1	W	dry manure on surface, hard to bolus, some salts
40486_1.2	10	FM	2.5RY56	MAT, RPO	MA	1	W	some salts, rootlets, plant materials
40486_1.3	5	FM	2.5RY56	MAT, RPO	MA	1	W	rootlets, likely redox boundary in profile
40486_1.4	0	-	-	-	-	0	VF	minor plant materials
40486_1.5	0	-	-	-	-	0	VF	minor plant materials
40486_2.1	5	FM	5YR58	MAT, RPO	MA	1	W	rootlets
40486_2.2	15	FM	5YR58	MAT, RPO	MA	1	W	minor plant materials, rootlets
40486_2.3	20	FM	5YR58	MAT, RPO	MA	1	VF	rootlets
40486_2.4	10	FM	5YR58	MAT, RPO	-	0	VF	rootlets
40486_2.5	10	FM	5YR58	MAT, RPO	-	0	VF	-
40486_3.0	0	SALT	-	-	SG	1	L	alt crust, white, sporadic patches on surface
40486_3.1	0	-	-	-	MA	1	W	minor plant materials
40486_3.2	10	FM	5YR58	MAT, RPO	MA	1	W	minor plant materials
40486_3.3	0	-	-	-	MA	1	W	-
40486_3.4	0	-	-	-	-	0	VF	-
40486_3.5	0	-	-	-	-	0	VF	-
40486_4.1	0	-	-	-	MA	1	W	rootlets, minor plant materials
40486_4.2	5	FM	5YR58	MAT, RPO	MA	1	W	rootlets, some salt crystals in matrix, charcoal fragments throughout matrix
40486_4.3	5	FM	5YR58	MAT, RPO	MA	1	W	rootlets, some salt crystals in matrix
40486_4.4	5	FM	5YR58	MAT, RPO	-	0	VF	rootlets, some salt crystals in matrix, blue to grey mottles
40486_4.5	2	FM	GLEY145G	MAT	-	0	VF	-

APPENDIX 7: HEPPELS LAGOON (40553) SUMMARY REPORT

APPENDIX 7:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40553
Wetland Name:	Heppels Lagoon

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 HEPPELS LAGOON 2
1.1 Location and Setting Description 2
1.2 Soil Profile Description and Distribution 2
1.3 Summary of Field and Laboratory Results 3
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 3
1.3.2 Acid Base Accounting 4
1.3.3 Titratable Actual Acidity (TAA) 4
1.3.4 Chromium Reducible Sulfur (S_{CR}) 4
1.3.5 Acid Volatile Sulfur (AVS) 4
1.3.6 Retained Acidity (RA) 5
1.3.7 Acid Neutralising Capacity (ANC) 5
1.3.8 Net Acidity 5
1.3.9 Water soluble SO_4 5
1.4 Hydrochemistry 6
1.5 Discussion 6
1.6 Summary of Key Findings for Heppels Lagoon 7

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Heppels Lagoon Sites. 2
Table 2 – Summary Of Key Findings. 7
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Heppels Lagoon. 8
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Heppels Lagoon. 9
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Heppels Lagoon. 10
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Heppels Lagoon. 11
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Heppels Lagoon. 12

LIST OF FIGURES

Figure 1 – Heppels Lagoon 40553 Site Plan.

Figure 2 – Heppels Lagoon Conceptual Hydrotoposequence Cross Section – 40553.

Figure 3 – Photographs of site 40553_1, showing the water surface (water column of 1.80m), and the chip tray soil profile of dark grey, very soft, wet, clay.

Figure 4 – Photographs of site 40553_2, showing the edge of water surface condition and the chip tray soil profile of brown, very soft, clay loam overlying dark yellowish brown, very soft clay.

Figure 5 – Depth profiles of soil pH for Heppels Lagoon, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 6 – Acid base accounting depth profiles for Heppels Lagoon. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 HEPPELS LAGOON

1.1 Location and Setting Description

Heppels Lagoon is situated on the southern side of the River Murray, approximately 27km North West of the township of Echuca VIC. The wetland is accessed from Heppell Road off the Murray Valley Highway. The wetland is horse shoe in shape with a linear section connecting to an irrigation channel to the North via a culvert. The wetland is approximately 200m wide by 500m in length, with a total area of 4 hectares.

The wetland is a cut off stream channel (oxbow) with minor banks and low batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had surface water within the channel over approximately 80% of the wetland. The wetland is a typical oxbow which has a long curved stream channel but is closed to the Murray River to the North.

The surface water within the wetland was generally brown and the bottom or lowest point could not be seen visually through the deep (180cm) water column. The surface water had duck weed and macrophytes growing within the stream channel with the edges containing low grasses, reeds and some weeds. The upper channel banks and upper floodplain contained low grasses, shrubs and medium to large trees. Two sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Two sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A single point sampling approach was used at two different areas of the wetland with two sites chosen. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 4** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

- 40553_1: water surface, subaqueous sediments, macrophytes and duck weed, low point, mid stream channel; soil consisted of dark grey, very soft, wet, clay.
- 40553_2: water logged surface, edge of water line, low grasses and reeds, mid point, edge of stream channel; soil consisted of brown, very soft, clay loam overlying dark yellowish brown, very soft clay.

Table 1 – Soil Identification, subtype and general location description for Heppels Lagoon Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40553_1	273708	6013565	Subaqueous soil	Low point, water surface, mid stream channel, subaqueous sediments.
40553_2	273842	6013879	Hydrosol - sandy or loamy	Mid point, edge of water line, low grasses and reeds.

DATE 07/07/2010

SCALE 1:2,000

0 25 50 100 Meters

PAGE SIZE A3

COORDINATE SYSTEM MGA Zone 55

FIG NO. 1

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: Inset Photos show Surface Condition of Site

CREATED BY B. Stewart

LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801

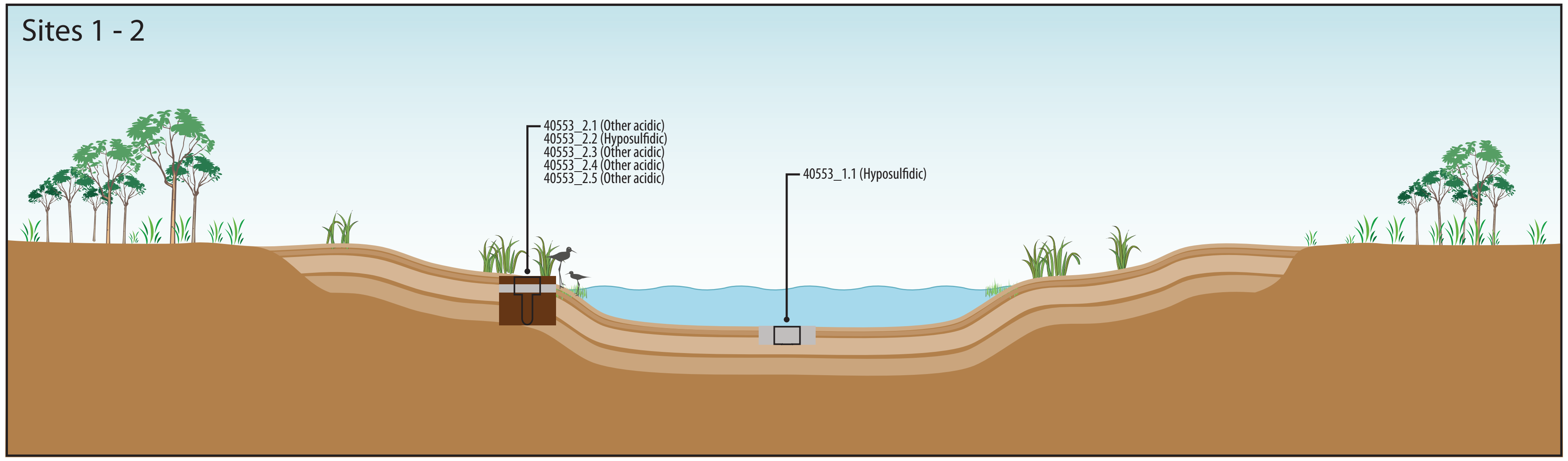
FIGURE TITLE Heppels Lagoon 40553 CMA:NCCMA

SMEC

LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils



40553_2

DATE 15/07/2010

SCALE Not to Scale

FIG NO. 2

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart

LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801

FIGURE TITLE Conceptual Hydrotoposequence Cross Section, Heppels Lagoon 40553

Figure 3 – Photographs of site 40553_1, showing the water surface (water column of 1.80m), and the chip tray soil profile of dark grey, very soft, wet, clay.

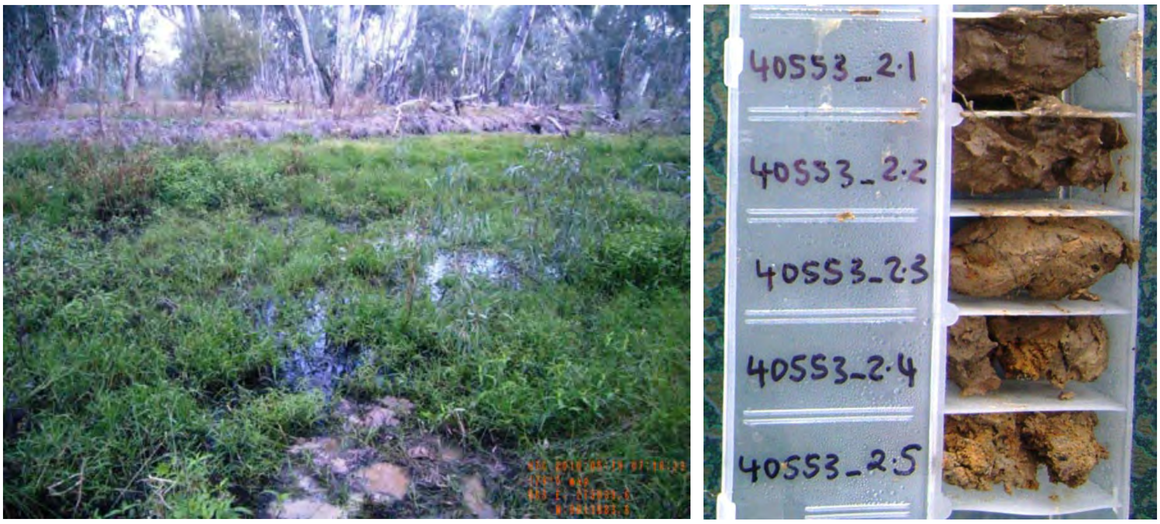


Figure 4 – Photographs of site 40553_2, showing the edge of water surface condition and the chip tray soil profile of brown, very soft, clay loam overlying dark yellowish brown, very soft clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figure 5** on the following page. Summary soil pH profile results indicate:

- 40553_1: the single sample of subaqueous sediments had a pH_w of 5.19 and $pH_{incubation}$ of 5.22 indicating hyposulfidic conditions.
- 40553_2: all samples have $pH_w < 5.5$. Surface soils (0 - 25cm) have pH_w 4.74 – 5.32 with subsoils (25 – 90cm) ranging 4.72 – 5.18. Surface soils $pH_{incubation}$ ranged 5.53 – 6.25 indicating hyposulfidic and other acidic conditions. Subsoils $pH_{incubation}$ ranged 3.63 – 4.03 indicating other acidic conditions.

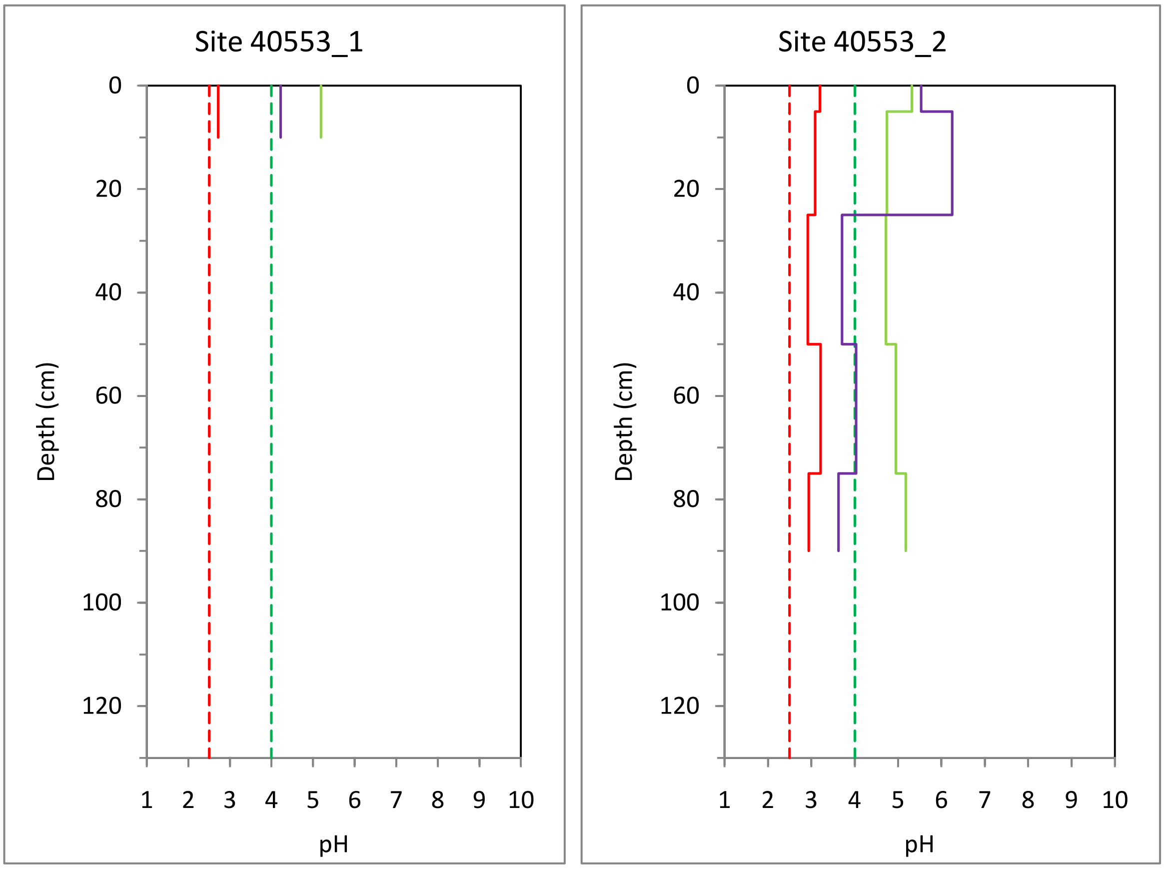


Figure 5 – Depth profiles of soil pH for Heppels Lagoon, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 6** on the following page.

1.3.3 Titratable Actual Acidity (TAA)

All 6 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 30 – 59 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic in situ conditions.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 6 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01 (limit of laboratory detection) to 0.01%S. 4 out of the 6 collected samples (67%) had S_{CR} <0.01%S.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Heppels Lagoon.

1.3.6 Retained Acidity (RA)

Out of the 6 samples collected, 5 were analysed (83%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 0 – 4 mole H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

None of the samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 30 to 63 mol H+/tonne. The highest net acidity result values were from subsoils 25 – 90cm at 40553_2 which were between 19 - 100 mole H+/tonne (moderate). Surface soils typically had slightly lower net acidity values (30 – 46 mole H+/tonne) at both sites ranging between 19 – 100 mole H+/tonne (moderate). All samples had moderate net acidity values.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 60 to 84 mg/L for surface soil samples collected (i.e. 0 – 10cm). Two surface soil samples were analysed for water soluble sulfate in total. No samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential.

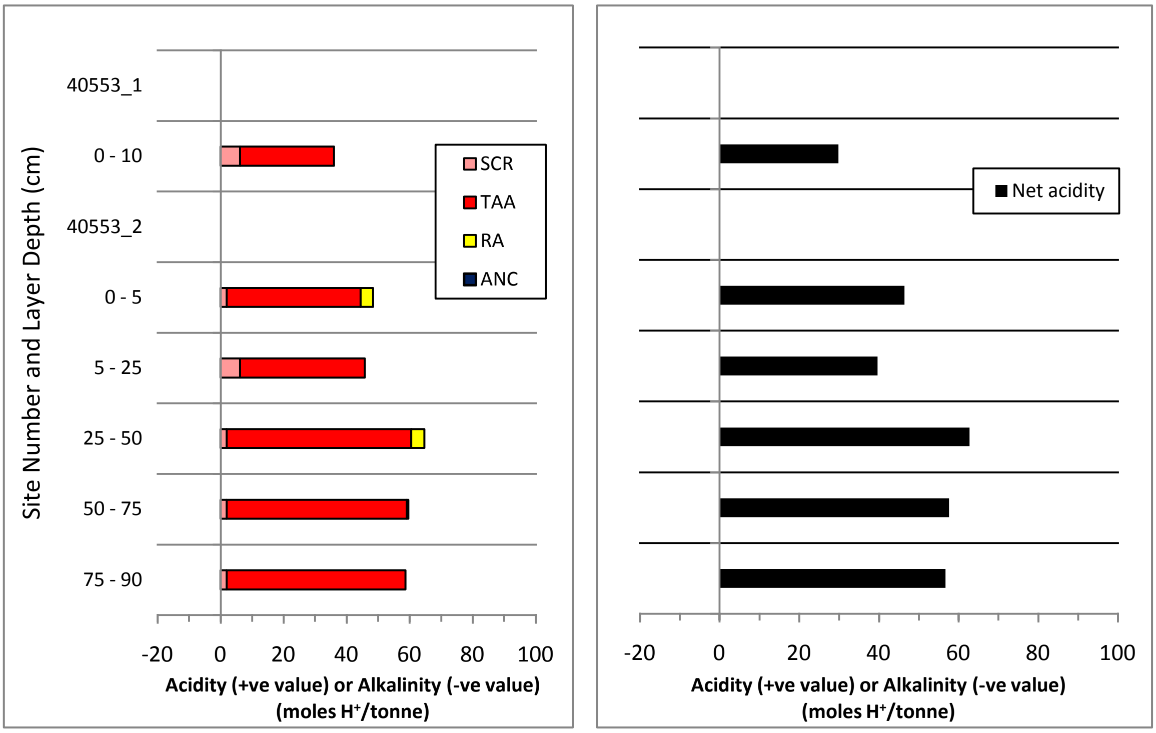


Figure 6 – Acid base accounting depth profiles for Heppels Lagoon. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at both sites from Heppels Lagoon. Measurements were taken from wetland surface waters 40553_1 (deep water) and 40553_2 (shallow). One water sample was collected for laboratory analysis from wetland surface waters (40553_1.W1).

The wetland surface waters were near neutral and very slightly acidic (pH 6.82 – 6.88). Surface waters were within the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0.

Both sites had SEC values were within the Lowland River criterion values of 125 – 2,200µS/cm but outside the criterion values for Freshwater Lakes (20 – 30µS/cm) and ranged 151 – 264 µS/cm. Alkalinity (as HCO_3) ranged 70 – 88 mg/L. Both sites had oxidising conditions (217 to 224 Eh).

The surface water site 40553_1 exceeded the trigger values for some nutrients (NH_4 0.2 mg/L, criterion of 0.01 mg/L, PO_4 0.12 mg/L, criterion of 0.005 mg/L) and some dissolved metals (Al – 180 µg/L, criterion of 55 µg/L, Cu 3 µg/L, criterion of 1.4 µg/L and Fe 2,700 µg/L, criterion of 300 µg/L.

The water data indicates that the surface water has not been affected by acidification and has some minor alkalinity and buffering capacity.

1.5 Discussion

Acid sulfate soils within Heppels Lagoon occurred as areas of hyposulfidic subaqueous soil material and in low elevated areas near water and within the stream channel. Hyposulfidic soil typically was encountered within subaqueous sediments and surface soils at the water line margin of the wetland. Both sites indicated sulfidic conditions but with low S_{CR} values of 0.01% S. No sulfuric materials were encountered at the wetland.

No monosulfidic materials were encountered at the wetland. Water soluble sulfate values ranged between 60 to 84 mg/L with no samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential.

Net acidity results for all sites and samples ranged between 30 to 63 mol H+/tonne. All samples had moderate net acidity values.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are a total of two (2) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10%.

Due to the size of the wetland (4 ha) and the low level of sulfidic materials present (all S_{CR} analysis either <0.01 or 0.01% S) in surface and subsoils the requirement for Phase 2 laboratory analysis may not be warranted. No surface samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential. Surface water had a near neutral pH within the wetland and some alkalinity present. There was however some $pH_{incubation}$ results from subsoils at 40553_2 that fell below pH 4.00 after 8 weeks incubation from other acidic sources.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Heppels Lagoon are:

- Acidification hazard: low level of concern based on the moderate net acidities and sulfidic results (from S_{CR}) with 67% of samples <0.01% S and remainder at 0.01% S. The degree of acidification potential from sulfidic sources only appears to be low. In addition, the wetland has some minor alkalinity and near neutral surface water pH currently. Some $pH_{incubation}$ results from 40553_2 subsoils indicate that other sources of acidity may be present and oxidise if water levels dropped significantly in the wetland.

- De-oxygenation hazard: low level of concern as water soluble sulfate results for all soil materials sampled were within the trigger value for monosulfide formation and no MBO materials were observed in the wetland at the sampling points.

- Metal mobilisation: The low acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation.

1.6 Summary of Key Findings for Heppels Lagoon

The summary of key findings for Heppels Lagoon is detailed in Table 2.

Table 2 – Summary of Key Findings.

Soil materials:	• Sulfuric materials were not observed.
	• Monosulfidic materials were not observed.
	• Water soluble sulfate results did not exceed the trigger value for monosulfide formation from surface soils sampled.
	• Sulfidic materials identified included:
	  o Site 1: hyposulfidic, subaqueous soils.
	  o Site 2: hyposulfidic, surface soils.
	• No hypersulfidic materials were observed.
	• Remaining soils materials were classed as other acidic.
	• Net acidities ranged between 30 to 63 mol H+/tonne.
	• All soil materials had a moderate net acidity.

Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Hydrosol – sandy or loamy occurring at water edge and wetland margin soils.
Hazard assessment:	• Acidification hazard – low level of concern • De-oxygenation hazard – low level of concern • Metal mobilisation hazard – low level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Heppels Lagoon.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40553_1.1	40553_1	0	10	0.1297	0.0958	26	5.19	2.72	4.22	84.15
40553_2.1	40553_2	0	5	0.1170	0.0842	28	5.32	3.20	5.53	60.45
40553_2.2	40553_2	5	25	0.1163	0.0830	29	4.74	3.09	6.25	-
40553_2.3	40553_2	25	50	0.1481	0.1204	19	4.72	2.92	3.71	-
40553_2.4	40553_2	50	75	0.1354	0.1080	20	4.95	3.21	4.03	-
40553_2.5	40553_2	75	90	0.1443	0.1181	18	5.18	2.94	3.63	-

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	%$CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40553_1.1	40553_1	0	10	4.72	30	0.01	0	-	30	-	Hyposulfidic
40553_2.1	40553_2	0	5	4.34	43	<0.01	4	-	46	-	Other acidic
40553_2.2	40553_2	5	25	4.41	40	0.01	0	-	40	-	Hyposulfidic
40553_2.3	40553_2	25	50	3.86	59	<0.01	4	-	63	-	Other acidic
40553_2.4	40553_2	50	75	3.88	57	<0.01	1	-	58	-	Other acidic
40553_2.5	40553_2	75	90	3.77	57	<0.01	0	-	57	-	Other acidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Heppels Lagoon.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40553_1.W1	–
Site ID	(number)	-	-	40553_1	40553_2
Wetland ID	(code)	-	-	40553	40553
Site Number	(number)	-	-	1	2
Upper depth	cm	-	-	-30	-5
Lower depth	cm	-	-	0	0
Temperature	(deg C)	-	-	13.4	12.6
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	264	151.3
Dissolved Oxygen	(%)	-	-	74.6	15.5
Dissolved Oxygen	(mg/l)	-	-	8.18	2.4
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	6.88	6.82
Redox potential	Eh	-	-	224	217
Turbidity	(NTU)	*6 - 50*	*1 - 20*	30	54.6
HCO_3	(mg/l)	-	-	88	70
Comment	-	-	-	SW	SW, no sample collected

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Heppels Lagoon.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	19-05-10
Laboratory	(code)	-	Ecowise/ALS
Laboratory sample ID	number	-	2194050
Sample ID	(number)	-	40553_1.W1 (SW)
Site ID	(number)	-	40553_1
Wetland ID	(code)	-	40553
Site Number	(number)	-	1
Upper depth	cm	-	-30
Lower depth	cm	-	0
Na	$mg\ l^{-1}$	-	28
K	$mg\ l^{-1}$	-	11
Ca	$mg\ l^{-1}$	-	11
Mg	$mg\ l^{-1}$	-	8.0
Si	$mg\ l^{-1}$	-	4.5
Br	$mg\ l^{-1}$	-	<5
Cl	$mg\ l^{-1}$	-	26
NO_3	$mg\ l^{-1}$	0.7	0.14
NH_4-N^K	$mg\ l^{-1}$	0.01	0.2
PO_4-P^E	$mg\ l^{-1}$	0.005	0.12
SO_4	$mg\ l^{-1}$	-	5
Ag	$\mu g\ l^{-1}$	0.05	<1
Al^A	$\mu g\ l^{-1}$	55	180
As^B	$\mu g\ l^{-1}$	13	5
Cd	$\mu g\ l^{-1}$	0.2	<0.2
Co	$\mu g\ l^{-1}$	2.8	2
Cr^C	$\mu g\ l^{-1}$	1	<1
Cu^H	$\mu g\ l^{-1}$	1.4	3
Fe	$\mu g\ l^{-1}$	300	2700
Mn	$\mu g\ l^{-1}$	1700	280
Ni^H	$\mu g\ l^{-1}$	11	6
Pb^H	$\mu g\ l^{-1}$	3.4	2
Se	$\mu g\ l^{-1}$	11	2
Zn^H	$\mu g\ l^{-1}$	8	5
DOC	$mg\ l^{-1}$	-	29

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A] *Trigger value for Aluminium in freshwater where pH > 6.5.*

[B] *Trigger value assumes As in solution as Arsenic (AsV).*

[C] *Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E] *Guideline is for filterable reactive phosphorous (FRP).*

[H] *Hardness affected (refer to Guidelines).*

[K] *Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Heppels Lagoon.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40553_1	40553	1	19-05-10	55	273708	6013565
40553_2	40553	2	19-05-10	55	273842	6013879

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40553_1	-180	water	minor duck weed and macrophytes	low point, subaqueous	Subaqueous sediment samples	80	Subaqueous soil	Sediments collected from deeper section of wetland standing water
40553_2	-5	soft	low grass, weeds	low point	channel sediments close to outlet	20	Hydrosol - sandy or loamy	-

Table 7 - Profile description data for acid sulfate soil assessment of Heppels Lagoon.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40553_1.1	BA	0	10	10YR41	Clay	Clayey	Wet	6.67	1:1
40553_2.1	SS	0	5	10YR43	Clay loam	Clayey	Wet	6.31	1:1
40553_2.2	SS	5	25	10YR43	Clay loam	Clayey	Wet	6.38	1:1
40553_2.3	SA	25	50	10YR44	Clay	Clayey	Wet	5.95	1:1
40553_2.4	SA	50	75	10YR44	Clay	Clayey	Wet	6.06	1:1
40553_2.5	SA	75	90	10YR56	Clay	Clayey	Wet	5.77	1:1

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40553_1.1	0	-	-	-	-	0	VS	organic odour, moderately decomposed organics
40553_2.1	2	FM	5YR66	MAT	-	0	S	difficult to bolus, rootlets, plant materials
40553_2.2	5	FM	5YR66	MAT	-	0	VS	rootlets, plant materials
40553_2.3	5	FM	5YR66	MAT	-	0	VS	rootlets, plant materials
40553_2.4	5	FM	5YR66	MAT	-	0	VS	rootlets, plant materials
40553_2.5	5	FM	5YR66	MAT	-	0	VS	rootlets, plant materials

APPENDIX 8: RICHARDSONS LAGOON (40590) SUMMARY REPORT

APPENDIX 8:

Priority Region:	Victorian Northern Flowing Rivers
Sequence Number:	40590
Wetland Name:	Richardsons Lagoon

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 RICHARDSONS LAGOON 2
1.1 Location and Setting Description 2
1.2 Soil profile Description and Distribution 2
1.3 Summary of Field and Laboratory Results 4
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 4
1.3.2 Acid Base Accounting 7
1.3.3 Titratable Actual Acidity (TAA) 7
1.3.4 Chromium Reducible Sulfur (S_{CR}) 7
1.3.5 Acid Volatile Sulfur (AVS) 7
1.3.6 Retained Acidity (RA) 7
1.3.7 Acid Neutralising Capacity (ANC) 7
1.3.8 Net Acidity 7
1.3.9 Water soluble SO_4 8
1.4 Hydrochemistry 8
1.5 Discussion 8
1.6 Summary of Key Findings for Richardsons Lagoon 10

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Richardsons Lagoon Sites. 3
Table 2 – Summary Of Key Findings 10
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Richardsons Lagoon 11
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Richardsons Lagoon. 13
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Richardsons Lagoon 14
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Richardsons Lagoon 15
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Richardsons Lagoon 16

LIST OF FIGURES

Figure 1 – Richardsons Lagoon 40590 Site Plan.

Figure 2 – Richardsons Lagoon Conceptual Hydrotoposequence Cross Section – 40590.

Figure 3 – Photographs of site 40590_1, showing the surface condition and the soil profile of strong, dark greyish brown clay overlying very firm, brown clay.

Figure 4 – Photographs of site 40590_2, showing the surface condition and the soil profile of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.

Figure 5 – Photographs of site 40590_3, showing the surface condition and the soil profile of strong, dark greyish brown clay overlying very firm, brown clay.

Figure 6 – Photographs of site 40590_4, showing the surface condition and the soil profile of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.

Figure 7 – Depth profiles of soil pH for Richardsons Lagoon, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 8 – Acid base accounting depth profiles for Richardsons Lagoon. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 RICHARDSONS LAGOON

1.1 Location and Setting Description

Richardsons Lagoon is situated on the southern side of the River Murray, approximately 19km North West of the township of Echuca VIC. The wetland is accessed from Baillieu Road off the Murray Valley Highway. The wetland is linear and slightly curved in shape at both ends. The Murray River is 800m to the North and East of the wetland. The wetland is approximately 120m wide by 1,000m in linear curved length, with a total area of 12 hectares.

The wetland appears to be a section of cut off stream channel (oxbow) with minor banks and low to moderately sloping batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had no surface water within the channel. The wetland is a typical section of an oxbow which has a long curved channel but is closed to the Murray River to the North and East. The other curved section of the oxbow is located to the West of this wetland.

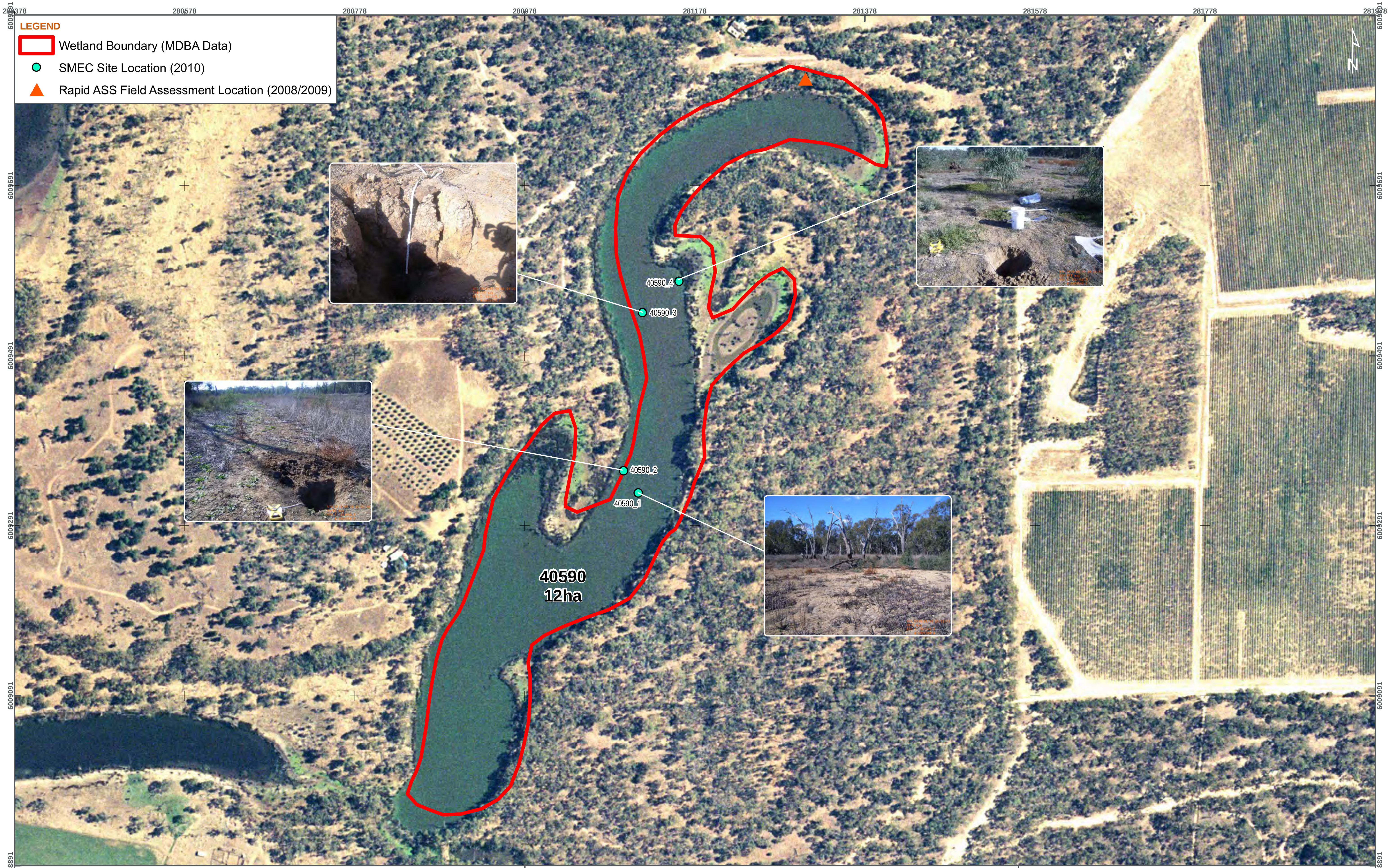
The wetland stream channel was mainly bare with dead sedges with weeds, low grasses and small Eucalypts on the channel edges. The upper channel banks and upper floodplain contained low grasses, shrubs and medium to large Eucalypts. Four sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil profile Description and Distribution

Four sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at two different areas of the wetland with two sites chosen for each transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 6** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the back of this appendix.

Summary soil profile descriptions for each site include:

- 40590_1: loose, mainly bare with dead sedges, low point, mid stream channel; soil consisted of strong, dark greyish brown clay overlying very firm, brown clay.
- 40590_2: cracking, mainly bare with dead sedges and weeds, high point, edge of stream channel; soil consisted of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.
- 40590_3: loose, mainly bare with dead sedges, low point, mid stream channel; soil consisted of strong, dark greyish brown clay overlying very firm, brown clay.
- 40590_4: cracking, mainly bare with dead sedges and weeds, high point, edge of stream channel; soil consisted of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.



DATE 09/07/2010 | SCALE 1:4,000 | 0 50 100 200 Meters | PAGE SIZE A3 | COORDINATE SYSTEM MGA Zone 55

FIG NO. 1 | PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: Inset Photos show Surface Condition of Site

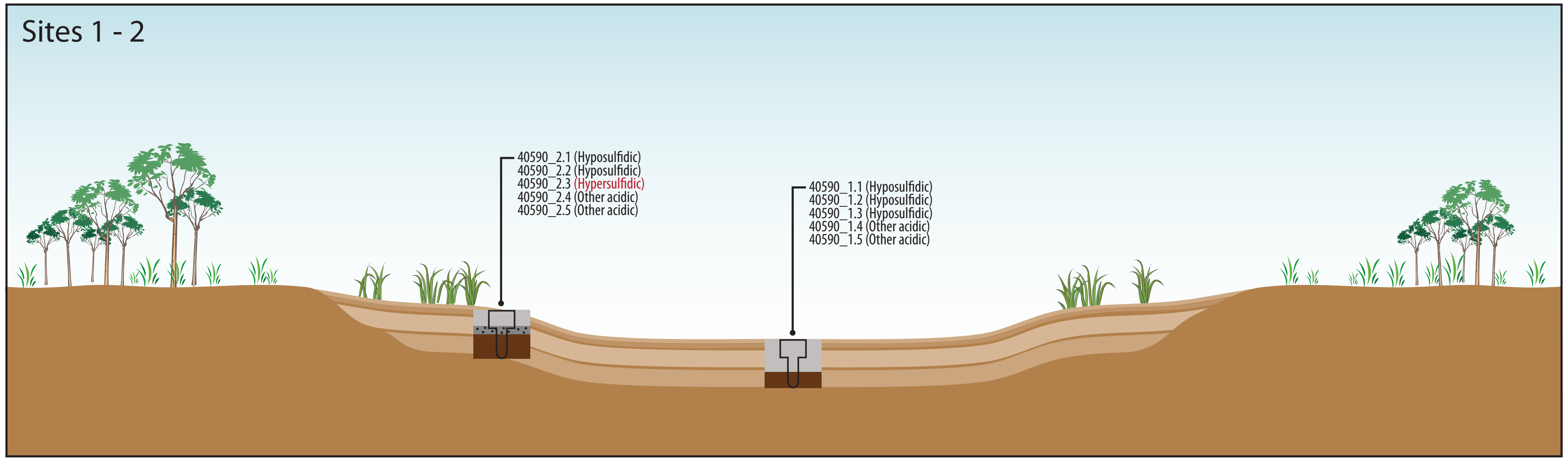
CREATED BY B. Stewart | LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

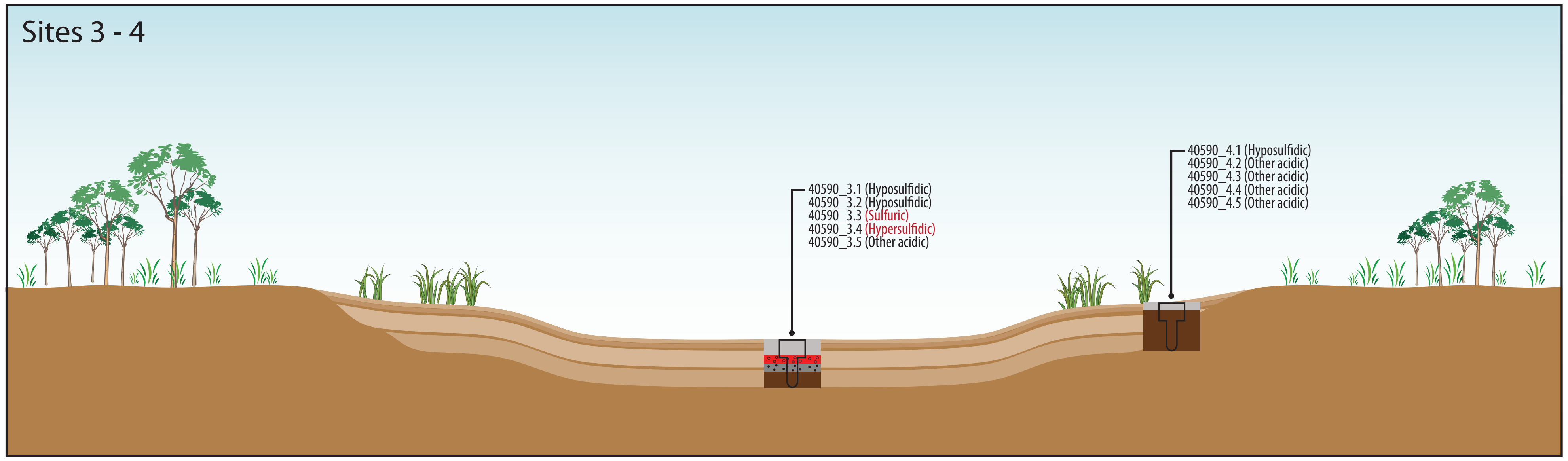
PROJECT NO. 3001801 | FIGURE TITLE Richardsons Lagoon 40590 CMA:NCCMA

SMEC

LEGEND
Soil Types

Sulfuric	Hyposulfidic
Monosulfidic	Other acidic
Hypersulfidic	Other soils





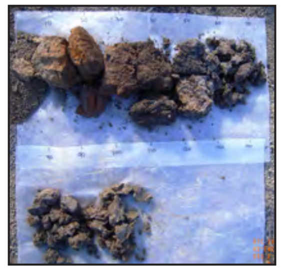

40590_1


40590_1


40590_2


40590_2


40590_3


40590_3


40590_4


40590_4

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2 **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Richardsons Lagoon 40590

Table 1 – Soil Identification, subtype and general location description for Richardsons Lagoon Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40590_1	281112	6009329	Cracking clay soils	Low point, mid stream channel, mainly bare with dead sedges.
40590_2	281094	6009355	Hypersulfidic cracking clay soils	High point, edge of stream channel, mainly bare with dead sedges and weeds.
40590_3	281117	6009541	Hypersulfidic cracking clay soils	Low point, mid stream channel, mainly bare with dead sedges.
40590_4	281160	6009578	Cracking clay soils	High point, edge of stream channel, mainly bare with dead sedges and weeds.

Figure 3 – Photographs of site 40590_1, showing the surface condition and the soil profile of strong, dark greyish brown clay overlying very firm, brown clay.

Figure 4 – Photographs of site 40590_2, showing the surface condition and the soil profile of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.

Figure 5 – Photographs of site 40590_3, showing the surface condition and the soil profile of strong, dark greyish brown clay overlying very firm, brown clay.

Figure 6 – Photographs of site 40590_4, showing the surface condition and the soil profile of strong, very dark greyish brown silty clay loam overlying very firm, dark greyish brown clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide a short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figure 7** on the following pages. Summary soil pH profile results indicate:

- 40590_1: all samples have pH_w < 5.5. Surface soils (0 - 30cm) have pH_w 4.31 – 5.14 with subsoils (30 – 110cm) ranging 4.11 – 4.78. Surface soils $pH_{incubation}$ ranged 4.52 – 5.37 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 3.11 – 4.24 indicating hyposulfidic and other acidic conditions.
- 40590_2: all samples have pH_w < 6.0. Surface soils (0 - 30cm) have pH_w 4.01 – 5.83 with subsoils (30 – 100cm) ranging 4.41 – 4.60. Surface soils $pH_{incubation}$

ranged 3.52 – 4.52 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 3.72 – 3.88 indicating hypersulfidic and other acidic conditions.

- 40590_3: all samples have pH_w < 6.0. Surface soils (0 - 35cm) have pH_w 3.88 – 5.84 with subsoils (35 – 100cm) ranging 4.57 – 4.96. Surface soils $pH_{incubation}$ ranged 3.67 – 6.31 indicating hyposulfidic and sulfuric conditions. Subsoils $pH_{incubation}$ ranged 3.68 – 3.91 indicating hypersulfidic and other acidic conditions.
- 40590_4: all samples have pH_w < 6.0. Surface soils (0 - 35cm) have pH_w 5.32 – 5.51 with subsoils (35 – 90cm) ranging 5.62 – 5.73. Surface soils $pH_{incubation}$ ranged 4.12 – 4.21 indicating hyposulfidic and other acidic conditions. Subsoils $pH_{incubation}$ ranged 4.06 – 4.24 indicating other acidic conditions.

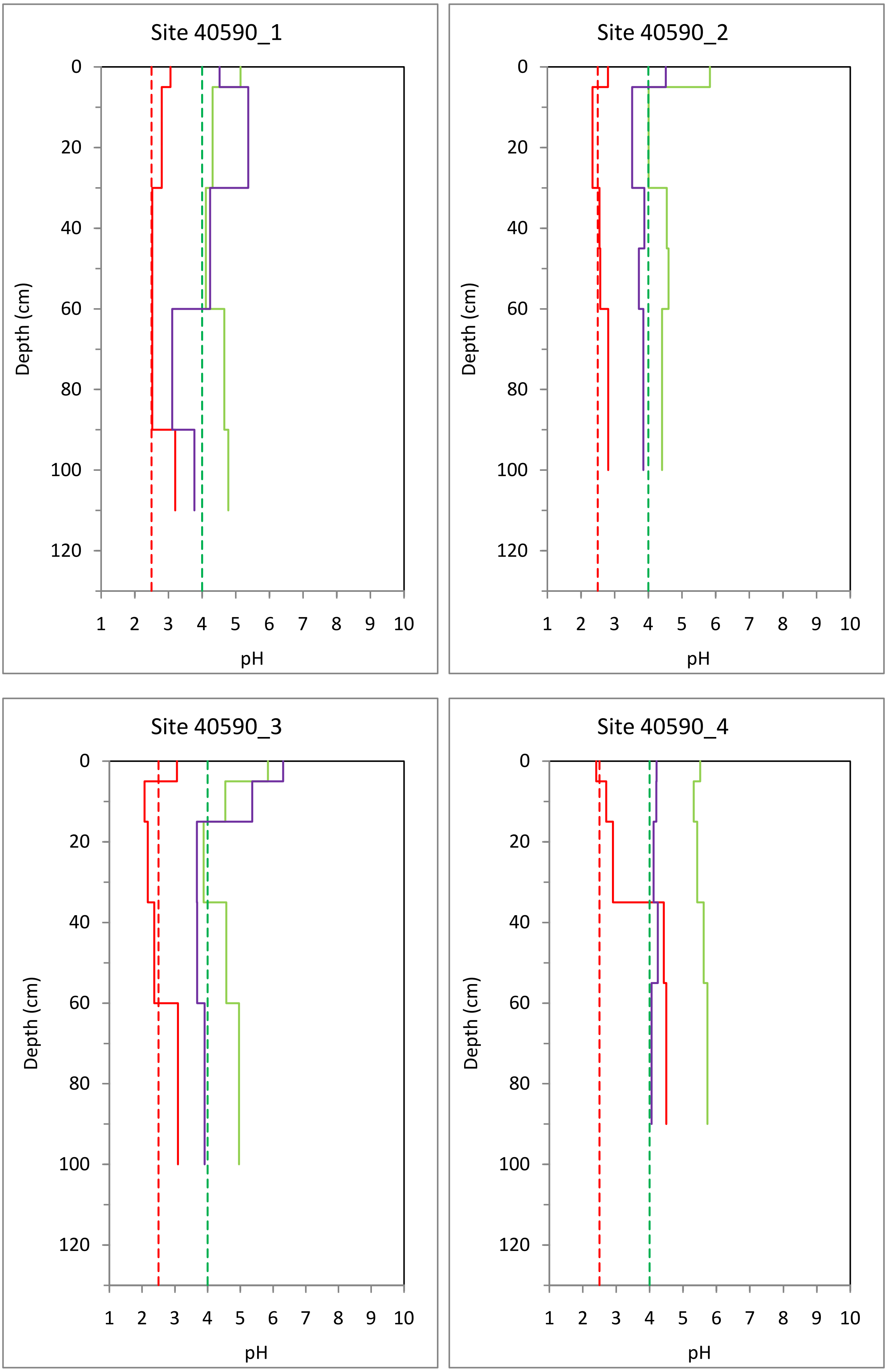


Figure 7– Depth profiles of soil pH for Richardsons Lagoon, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 8** on the following page.

1.3.3 Titratable Actual Acidity (TAA)

All 20 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 23 – 145 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic in situ conditions within the soil profile.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 20 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01 (limit of laboratory detection) to 0.05%S. 9 out of the 20 collected samples (45%) had S_{CR} <0.01% S with 6 out of the 20 samples (30%) having S_{CR} 0.01% S. The majority of sites had a decreasing S_{CR} concentration trend with increasing depth of sample.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Richardsons Lagoon.

1.3.6 Retained Acidity (RA)

Out of the 20 samples collected, 10 were analysed (50%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 0 – 19 mole H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

None of the 20 samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 (indicative acid buffering conditions) that would trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 29 to 158 mol H+/tonne. Results were highest for the sites 40590_1, 40590_2 and 40590_3. The materials sampled from site 40590_4 exhibited typically lower net acidity. The three sites with high net acidity values all had at least one sample with a high net acidity (> 100 mole H+/tonne). On these three sites surface soils (0 – 30cm) typically had the highest net acidity values with TAA the major contributor.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 342 – 2,520 mg/L for surface soil samples collected (i.e. 0 – 10cm). Four surface soil samples were analysed for water soluble sulfate in total. All samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential.

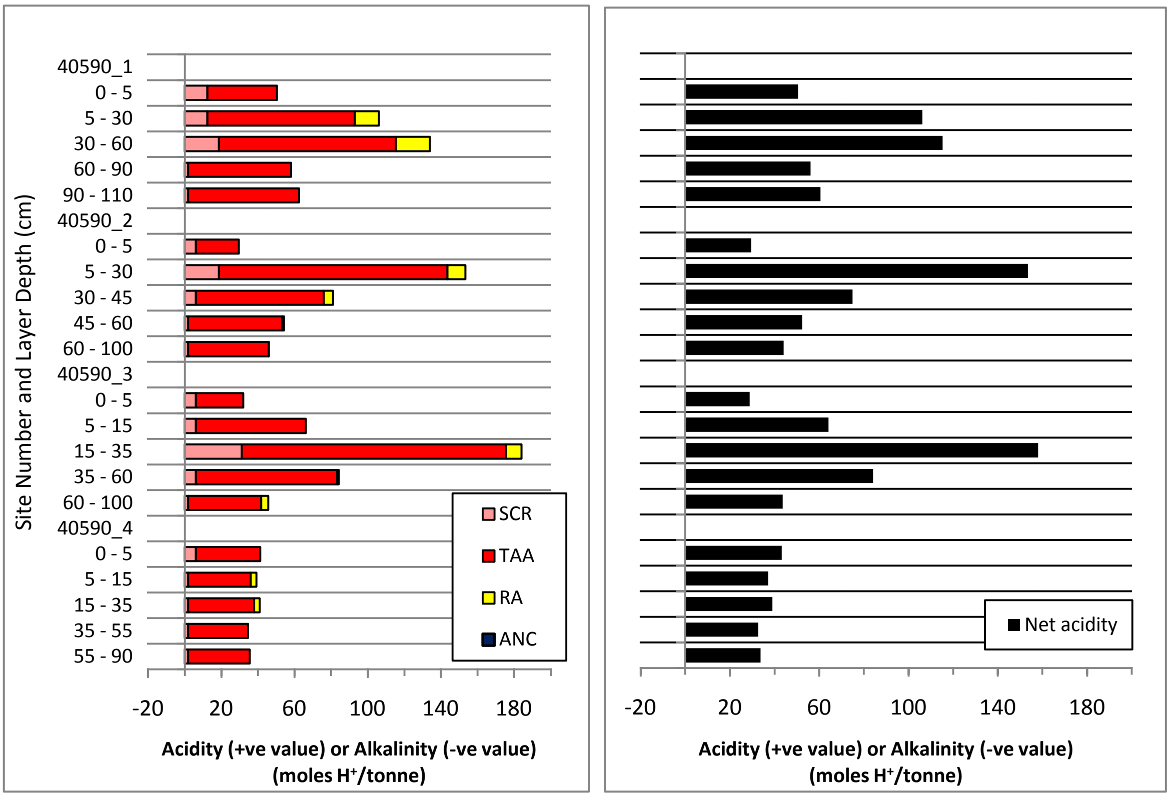


Figure 8 – Acid base accounting depth profiles for Richardsons Lagoon. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

No surface water or pit inflow water was observed during this survey. Therefore, no water samples were collected for analysis. Pits were kept open for several hours to observe potential slow water inflow however; no water was evident during the survey.

1.5 Discussion

Acid sulfate soils within Richardsons Lagoon occurred as areas of hyposulfidic, hypersulfidic and sulfuric soil material within the stream channel. Hyposulfidic soil was typically encountered within surface materials at both the low points (mid channel) and high points (edge of the channel). Sulfuric material was encountered at site 40590_3 within surface soils (15 – 35cm). Hypersulfidic materials were encountered at sites 40590_2 and 40590_3 within subsoils (30 – 60cm).

Results for S_{CR} ranged from <0.01 (limit of laboratory detection) to 0.05%S. 9 out of the 20 collected samples (45%) had S_{CR} <0.01% S with 6 out of the 20 samples (30%) having S_{CR} 0.01% S. The majority of sites had a decreasing S_{CR} concentration trend with increasing depth of sample.

No monosulfidic materials were encountered at the wetland. Water soluble sulfate values ranged between 342 – 2,520 mg/L for surface soil samples collected. All samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential. Net acidity results for all sites and samples ranged between 29 to 158 mol H+/tonne. Surface soils (0 – 30cm) typically had the highest net acidity values with TAA the major contributor.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are a total of four (4) high priority samples based on the presence of water soluble sulfate values that exceed the trigger criterion of 100 mg/L for MBO formation potential, one (1) high priority sample with sulfuric materials and two (2) high priority samples with hypersulfidic materials. There are eight (8) moderate priority samples with hyposulfidic materials S_{CR} <0.10%.

Due to the low level of sulfidic materials present (all S_{CR} analysis <0.05% S) in surface and subsoils the requirement for Phase 2 laboratory analysis may not be warranted. However, all four surface samples analysed for water soluble sulfate exceeded the trigger criterion of 100 mg/L for MBO formation potential. Therefore, Phase 2 analysis for the “Monosulfidic Formation Potential Method” may be suitable for selected surface samples. This would especially be the case if significant re flooding was going to be considered for the wetland.

Although no water was evident in the wetland during this survey, if significant re flooding or wet and dry cycles were to occur dissolved metals may be released due to the current acidic nature of surface soils. Also, there did not appear to be significant buffering capacity in the soils sampled.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Richardsons Lagoon are:

- Acidification hazard: medium level of concern based on the high net acidities encountered at the majority of sites in certain materials, predominantly acidic nature of the wetland currently and low sulfidic results (from S_{CR}). The degree of further acidification potential from sulfidic sources appears to be low to medium for surface soils and subsoils. The wetland is considered to be acidic to slightly acidic based on current soil results from this survey.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results exceeded the trigger value for monosulfide formation at all sites. Currently however, no monosulfides were observed or formed during this survey with no surface or pit inflow water observed in the wetland.

- Metal mobilisation: The medium acidification hazard indicates that future sulfidic sources of acidity may not be sufficient for further significant metals mobilisation. As the wetland soil is acidic to slightly acidic currently, and hypersulfidic materials are not widespread (vertically), further significant decreases in pH may not occur in the near term. The wetland is currently dry and if significant re flooding or wet and dry cycles were to occur dissolved metals may be released. Without water data the current risk of metals mobilisation is only assumed based on soil results. Therefore a medium level of concern.

1.6 Summary of Key Findings for Richardsons Lagoon

The summary of key findings for Richardsons Lagoon is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Acid sulfate soil materials occurred at all sites sampled. • Sulfuric materials were observed at site 40590_3 (surface soils) within the low points of the dry stream channel. • Monosulfidic materials were not observed. • Water soluble sulfate results exceeded the trigger value for monosulfide formation at all sites (surface soils). • Sulfidic materials were identified at all 4 sites. • Sulfidic soils occurred as both hypersulfidic and hyposulfidic materials with the latter being the predominant material type. • Hypersulfidic materials were encountered at sites 40590_2 (subsoils) and 40590_3 (subsoils). • Net acidities ranged between 29 to 158 mol H+/tonne with the majority of acidity coming from TAA (actual acidity). • Hyposulfidic materials were encountered at all sites typically within surface soils and upper subsoils. • Other acidic materials were identified at the base of all sites within subsoils.
Acid sulfate soil identification:	• Site 1: Cracking clay soils, occurring within the low point of the stream channel. • Site 2: Hypersulfidic cracking clay soils, occurring within upper edge of the stream channel. • Site 3: Hypersulfidic cracking clay soils, occurring within the low point of the stream channel. • Site 4: Cracking clay soils, occurring within upper edge of the stream channel.
Hazard assessment:	• Acidification hazard – medium level of concern. • De-oxygenation hazard – medium level of concern. • Metal mobilisation hazard – medium level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Richardsons Lagoon

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40590_1.1	40590_1	0	5	0.0789	0.0752	5	5.14	3.06	4.52	2520
40590_1.2	40590_1	5	30	0.0859	0.0673	22	4.31	2.80	5.37	-
40590_1.3	40590_1	30	60	0.0884	0.0618	30	4.11	2.52	4.24	-
40590_1.4	40590_1	60	90	0.1149	0.0866	25	4.66	2.52	3.11	-
40590_1.5	40590_1	90	110	0.1267	0.0952	25	4.78	3.20	3.77	-
40590_2.1	40590_2	0	5	0.0568	0.0548	4	5.83	2.80	4.52	858
40590_2.2	40590_2	5	30	0.0978	0.0739	24	4.01	2.34	3.52	-
40590_2.3	40590_2	30	45	0.1131	0.0846	25	4.55	2.55	3.88	-
40590_2.4	40590_2	45	60	0.1271	0.1047	18	4.60	2.57	3.72	-
40590_2.5	40590_2	60	100	0.1414	0.1152	19	4.41	2.81	3.85	-
40590_3.1	40590_3	0	5	0.0672	0.0652	3	5.84	3.06	6.31	813
40590_3.2	40590_3	5	15	0.0618	0.0552	11	4.54	2.07	5.36	-
40590_3.3	40590_3	15	35	0.0693	0.0533	23	3.88	2.17	3.67	-
40590_3.4	40590_3	35	60	0.1043	0.0788	24	4.57	2.37	3.68	-
40590_3.5	40590_3	60	100	0.1267	0.1009	20	4.96	3.09	3.91	-
40590_4.1	40590_4	0	5	0.0688	0.0661	4	5.51	2.40	4.21	342
40590_4.2	40590_4	5	15	0.0998	0.0866	13	5.32	2.70	4.20	-
40590_4.3	40590_4	15	35	0.0955	0.0837	12	5.42	2.90	4.12	-
40590_4.4	40590_4	35	55	0.0974	0.0862	11	5.62	4.42	4.24	-
40590_4.5	40590_4	55	90	0.1017	0.0875	14	5.73	4.50	4.06	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Richardsons Lagoon

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	%$CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40590_1.1	40590_1	0	5	4.54	38	0.02	0	-	51	-	Hyposulfidic
40590_1.2	40590_1	5	30	3.91	81	0.02	13	-	106	-	Hyposulfidic
40590_1.3	40590_1	30	60	3.79	97	0.03	19	-	115	-	Hyposulfidic
40590_1.4	40590_1	60	90	4.08	56	<0.01	0	-	56	-	Other acidic
40590_1.5	40590_1	90	110	4.01	61	<0.01	0	-	61	-	Other acidic
40590_2.1	40590_2	0	5	5.35	23	0.01	0	-	30	-	Hyposulfidic
40590_2.2	40590_2	5	30	3.80	125	0.03	10	-	153	-	Hyposulfidic
40590_2.3	40590_2	30	45	4.07	70	0.01	5	-	75	-	Hypersulfidic
40590_2.4	40590_2	45	60	4.04	51	<0.01	1	-	52	-	Other acidic
40590_2.5	40590_2	60	100	4.04	44	<0.01	0	-	44	-	Other acidic
40590_3.1	40590_3	0	5	5.29	26	0.01	0	-	29	-	Hyposulfidic
40590_3.2	40590_3	5	15	4.15	60	0.01	0	-	64	-	Hyposulfidic
40590_3.3	40590_3	15	35	3.64	145	0.05	8	-	158	-	Sulfuric
40590_3.4	40590_3	35	60	4.03	77	0.01	1	-	84	-	Hypersulfidic
40590_3.5	40590_3	60	100	4.18	40	<0.01	4	-	44	-	Other acidic
40590_4.1	40590_4	0	5	4.98	35	0.01	0	-	43	-	Hyposulfidic
40590_4.2	40590_4	5	15	4.45	34	<0.01	3	-	37	-	Other acidic
40590_4.3	40590_4	15	35	4.35	36	<0.01	3	-	39	-	Other acidic
40590_4.4	40590_4	35	55	4.28	33	<0.01	0	-	33	-	Other acidic
40590_4.5	40590_4	55	90	4.27	34	<0.01	0	-	34	-	Other acidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Richardsons Lagoon.

<table>
<tr><th>Sample ID</th><th>(number)</th><th>Lowland River*</th><th>Freshwater Lakes*</th><td rowspan="15">No Water Evident at Wetland

No Samples Taken</td></tr>
<tr><td>Site ID</td><td>(number)</td><td>-</td><td>-</td></tr>
<tr><td>Wetland ID</td><td>(code)</td><td>-</td><td>-</td></tr>
<tr><td>Site Number</td><td>(number)</td><td>-</td><td>-</td></tr>
<tr><td>Upper depth</td><td>cm</td><td>-</td><td>-</td></tr>
<tr><td>Lower depth</td><td>cm</td><td>-</td><td>-</td></tr>
<tr><td>Temperature</td><td>(deg C)</td><td>-</td><td>-</td></tr>
<tr><td>Specific Electrical Conductivity</td><td>(uS/cm)</td><td>125 - 2200</td><td>20 - 30</td></tr>
<tr><td>Dissolved Oxygen</td><td>(%)</td><td>-</td><td>-</td></tr>
<tr><td>Dissolved Oxygen</td><td>(mg/l)</td><td>-</td><td>-</td></tr>
<tr><td>pH</td><td>(unit)</td><td>6.5 - 8.0</td><td>6.5 - 8.0</td></tr>
<tr><td>Redox potential</td><td>Eh</td><td>-</td><td>-</td></tr>
<tr><td>Turbidity</td><td>(NTU)</td><td>6 - 50</td><td>1 - 20</td></tr>
<tr><td>HCO_3</td><td>(mg/l)</td><td>-</td><td>-</td></tr>
<tr><td>Comment</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Richardsons Lagoon

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	
Laboratory	(code)	-	**No Water Evident at Wetland** **No Samples Taken**
Laboratory sample ID	number	-	
Sample ID	(number)	-	
Site ID	(number)	-	
Wetland ID	(code)	-	
Site Number	(number)	-	
Upper depth	cm	-	
Lower depth	cm	-	
Na	$mg\ l^{-1}$	-	
K	$mg\ l^{-1}$	-	
Ca	$mg\ l^{-1}$	-	
Mg	$mg\ l^{-1}$	-	
Si	$mg\ l^{-1}$	-	
Br	$mg\ l^{-1}$	-	
Cl	$mg\ l^{-1}$	-	
NO_3	$mg\ l^{-1}$	0.7	
NH_4-N^K	$mg\ l^{-1}$	0.01	
PO_4-P^E	$mg\ l^{-1}$	0.005	
SO_4	$mg\ l^{-1}$	-	
Ag	$\mu g\ l^{-1}$	0.05	
Al^A	$\mu g\ l^{-1}$	55	
As^B	$\mu g\ l^{-1}$	13	
Cd	$\mu g\ l^{-1}$	0.2	
Co	$\mu g\ l^{-1}$	2.8	
Cr^C	$\mu g\ l^{-1}$	1	
Cu^H	$\mu g\ l^{-1}$	1.4	
Fe	$\mu g\ l^{-1}$	300	
Mn	$\mu g\ l^{-1}$	1700	
Ni^H	$\mu g\ l^{-1}$	11	
Pb^H	$\mu g\ l^{-1}$	3.4	
Se	$\mu g\ l^{-1}$	11	
Zn^H	$\mu g\ l^{-1}$	8	
DOC	$mg\ l^{-1}$	-	

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^{A}Trigger value for Aluminium in freshwater where pH > 6.5.

^{B}Trigger value assumes As in solution as Arsenic (AsV).

^{C}Trigger value for Chromium is applicable to Chromium (CrVI)

^{E}Guideline is for filterable reactive phosphorous (FRP).

^{H}Hardness affected (refer to Guidelines).

^{K}Guideline for South-east Australia-Freshwater Lakes and res

Table 6 - Site description data for acid sulfate soil assessment of Richardsons Lagoon

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40590_1	40590	1	19-05-10	55	281112	6009329
40590_2	40590	2	19-05-10	55	281094	6009355
40590_3	40590	3	19-05-10	55	281117	6009541
40590_4	40590	4	19-05-10	55	281160	6009578

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40590_1	-	loose	mainly bare, dead sedges	low point	lowest point of dry channel	25	Cracking clay soils	No water evident
40590_2	-	cracking	mainly bare, dead sedges, weeds	high point	surface change, cracking clays	25	Hypersulfidic cracking clay soils	No water evident
40590_3	-	loose	mainly bare, dead sedges	low point	lowest point of dry channel	25	Hypersulfidic cracking clay soils	No water evident
40590_4	-	cracking	weeds, small eucalypts	mid point	surface and vegetation change, cracking clays	25	Cracking clay soils	No water evident

Table 7 - Profile description data for acid sulfate soil assessment of Richardsons Lagoon

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40590_1.1	SS	0	5	10YR41	Clay	Clayey	Dry	5.05	1:1
40590_1.2	SS	5	30	10YR42	Clay	Clayey	Moderately	5.01	1:1
40590_1.3	SS	30	60	10YR21	Clay	Clayey	Moist	3.91	1:1
40590_1.4	SA	60	90	10YR42	Clay	Clayey	Moist	4.53	1:1
40590_1.5	SA	90	110	10YR43	Clay	Clayey	Moist	4.88	1:1
40590_2.1	SS	0	5	10YR54	Silty clay loam	Clayey	Moderately	5.03	1:1
40590_2.2	SS	5	30	10YR32	Silty clay loam	Clayey	Moist	4.09	1:1
40590_2.3	SS	30	45	10YR42	Clay	Clayey	Moist	4.20	1:1
40590_2.4	SA	45	60	10YR42	Clay	Clayey	Moist	4.33	1:1
40590_2.5	SA	60	100	10YR52	Clay	Clayey	Moist	4.44	1:1
40590_3.1	SS	0	5	10YR41	Clay	Clayey	Dry	5.40	1:1
40590_3.2	SS	5	15	10YR42	Clay	Clayey	Moderately	4.03	1:1
40590_3.3	SS	15	35	10YR21	Clay	Clayey	Moist	3.36	1:1
40590_3.4	SA	35	60	10YR42	Clay	Clayey	Moist	3.59	1:1
40590_3.5	SA	60	100	10YR43	Clay	Clayey	Moist	4.26	1:1
40590_4.1	SS	0	5	10YR54	Silty clay loam	Clayey	Moderately	4.65	1:1
40590_4.2	SS	5	15	10YR32	Silty clay loam	Clayey	Moist	4.23	1:1
40590_4.3	SS	15	35	10YR42	Clay	Clayey	Moist	4.75	1:1
40590_4.4	SA	35	55	10YR42	Clay	Clayey	Moist	4.60	1:1
40590_4.5	SA	55	90	10YR52	Clay	Clayey	Moist	4.82	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Richardsons Lagoon

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40590_1.1	5	FM	5YR58	MAT, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40590_1.2	25	FM	5YR58	MAT, SPO	CO	3	S	hard peds, difficult to bolus, small pores
40590_1.3	30	FM	5YR58	MAT, SPO	CO	3	S	rootlets, plant materials, small pores, burnt organic matter

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40590_1.4	15	FM	5YR58	MAT		0	VF	minor rootlets
40590_1.5	10	FM	5YR58	MAT		0	VF	-
40590_2.1	5	FM	5YR58	MAT, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores, plant material
40590_2.2	25	FM	5YR58	MAT, SPO	CO	3	S	plant material
40590_2.3	20	FM	5YR58	MAT, SPO	CO	3	S	rootlets, burnt organic matter, charcoal fragments throughout matrix
40590_2.4	15	FM	5YR58	MAT		0	VF	rootlets, charcoal fragments throughout matrix
40590_2.5	15	FM	5YR58	MAT		0	VF	rootlets
40590_3.1	10	FM	5YR58	MAT, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores
40590_3.2	20	FM	5YR58	MAT, SPO	CO	3	S	hard peds, difficult to bolus, small pores
40590_3.3	40	FM	5YR58	MAT, SPO	CO	3	S	rootlets, plant materials, small pores, burnt organic matter
40590_3.4	15	FM	5YR58	MAT		0	VF	minor rootlets
40590_3.5	10	FM	5YR58	MAT		0	VF	-
40590_4.1	5	FM	5YR58	MAT, SPO	CO	3	S	hard peds, gravel size, difficult to bolus, small pores, plant material
40590_4.2	25	FM	5YR58	MAT, SPO	CO	3	S	plant material
40590_4.3	20	FM	5YR58	MAT, SPO	CO	3	S	rootlets, burnt organic matter, charcoal fragments throughout matrix
40590_4.4	15	FM	5YR58	MAT		0	VF	rootlets, charcoal fragments throughout matrix
40590_4.5	15	FM	5YR58	MAT		0	VF	rootlets

APPENDIX 9: AVOCA RIVER AT SCOLLARY ROAD BRIDGE (40851) SUMMARY REPORT

APPENDIX 9:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40851

Wetland Name: Avoca River at Scollary Road Bridge

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 AVOCA RIVER AT SCOLLARY ROAD BRIDGE ... 3
1.1 Location and Setting Description ... 3
1.2 Soil Profile Description and Distribution ... 3
1.3 Summary of Field and Laboratory Results ... 5
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) ... 5
1.3.2 Acid Base Accounting ... 6
1.3.3 Titratable Actual Acidity (TAA) ... 6
1.3.4 Chromium Reducible Sulfur (S_{CR}) ... 6
1.3.5 Acid Volatile Sulfur (AVS) ... 6
1.3.6 Retained Acidity (RA) ... 7
1.3.7 Acid Neutralising Capacity (ANC) ... 7
1.3.8 Net Acidity ... 7
1.3.9 Water soluble SO_4 ... 7
1.4 Hydrochemistry ... 8
1.5 Discussion ... 8
1.6 Summary of Key Findings for Avoca River at Scollary Road Bridge ... 9

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Avoca River At Scollary Road Bridge Sites. ... 4
Table 2 – Summary Of Key Findings. ... 10
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Avoca River At Scollary Road Bridge. ... 11
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Avoca River At Scollary Road Bridge. ... 12
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Avoca River At Scollary Road Bridge. ... 13
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Avoca River At Scollary Road Bridge. ... 14
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Avoca River At Scollary Road Bridge. ... 15
Table 8 – Additional Data: Water Watch Water Quality Data For The Avoca River At Scollary Road Bridge Site Collected By The Nccma. ... 16

LIST OF FIGURES

Figure 1 – Avoca River at Scollary Road Bridge 40851 Site Plan.

Figure 2 – Avoca River at Scollary Road Bridge Conceptual Hydrotoposequence Cross Section – 40851.

Figure 3 – Photographs of site 40851_1, showing the water surface (water column of 50cm), and the laid out soil profile of very soft, dark yellowish brown clay loam overlying very weak, dark greyish brown silty and sandy clay loam.

Figure 4 – Photographs of site 40851_2, showing the surface condition and the soil profile of very soft, dark yellowish brown sandy clay loam overlying very weak, dark greyish brown silty and clay loam sandy.

Figure 5 – Photographs of site 40851, showing wetland during a site visit by SMEC in March 2010. The photographs show the dryer state of the wetland channel and the iron and mineral surface deposits within the channel floor.

Figure 6 – Depth profiles of soil pH for Avoca River at Scollary Road Bridge, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 7 – Acid base accounting depth profiles for Avoca River at Scollary Road Bridge. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 AVOCA RIVER AT SCOLLARY ROAD BRIDGE

1.1 Location and Setting Description

Avoca River at Scollary Road Bridge is situated approximately 22km west of the town of St Arnaud VIC. The wetland is accessed from Synotts Lane off Bendigo St Arnaud Road and is slightly curved to linear in shape, and approximately 50m wide by 440m in length, with a total area of 3 hectares.

The wetland is an incised stream channel with short and steep channel banks leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had surface water covering the majority of the wetland within the channel (80%).

Water within the wetland was generally clear to slight brown and the bottom or lowest point could not be seen visually through the water column (100 - 50cm). The channel contained reeds and rushes where standing water occurred with large woody debris within the channel. Channel banks and upper floodplain contained low grasses and medium to large trees. Two sites were sampled as shown in **Figure 1** on the following page.

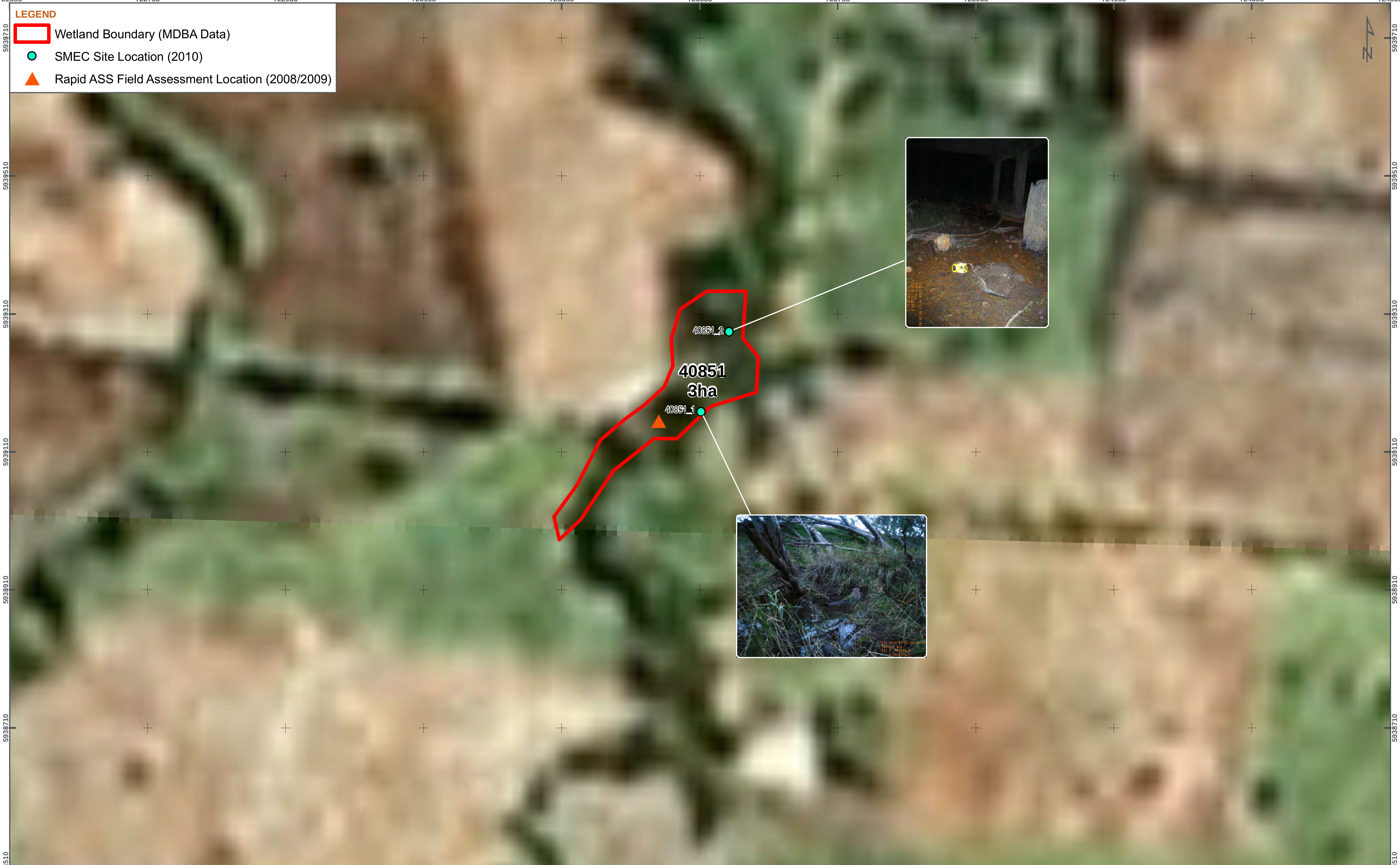
It should be noted that SMEC visited the site in March 2010 and water levels within the channel were much lower and only a small section of the wetland (10%) contained surface water. During the March 2010 site visit notable iron and mineralisation of surfaces within the channel were observed. During April 2010, rainfall in the catchment increased the water levels which then subsided somewhat for the survey to occur in May 2010.

1.2 Soil Profile Description and Distribution

Two sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A single sampling point approach was used at two different areas of the wetland with two sites chosen. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 5** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40581_1: water surface, subaqueous sediments, leaf and twig litter, reeds and rushes, low point, mid channel and the soil consisted of very soft, dark yellowish brown clay loam overlying very weak, dark greyish brown silty and sandy clay loam.
- 40581_2: soft, mainly bare with some reeds, low point, mid channel and the soil consisted of very soft, dark yellowish brown sandy clay loam overlying very weak, dark greyish brown silty and clay loam sandy.



DATE 09/07/2010 SCALE 1:5,000 (0 50 100 200 Meters) PAGE SIZE A3 COORDINATE SYSTEM MGA Zone 54

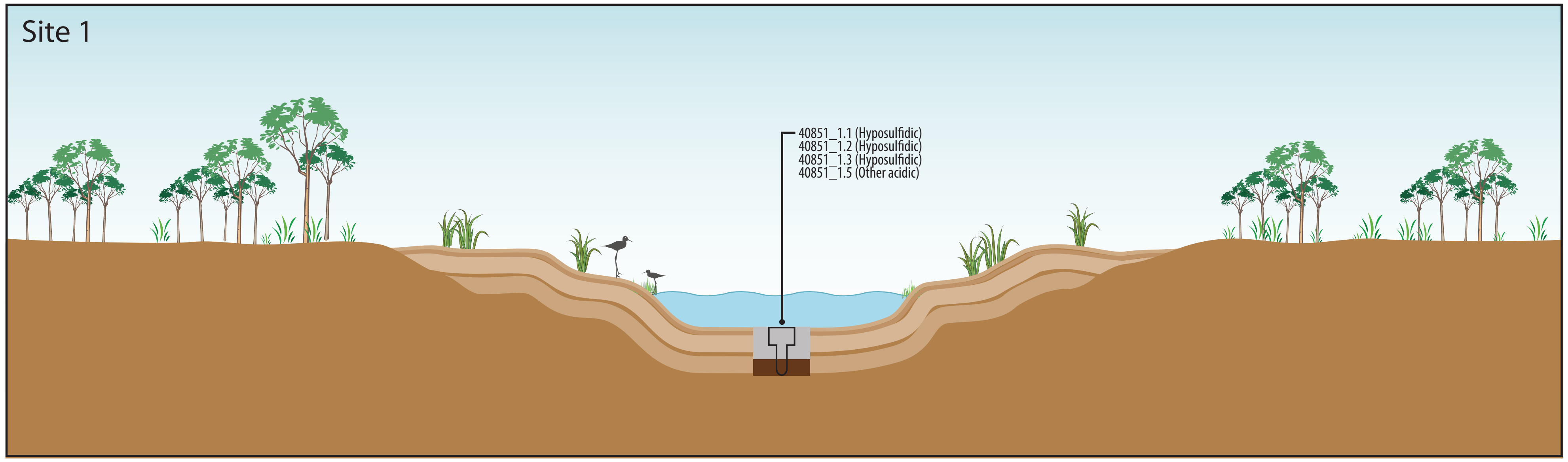
FIG NO. 1 PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

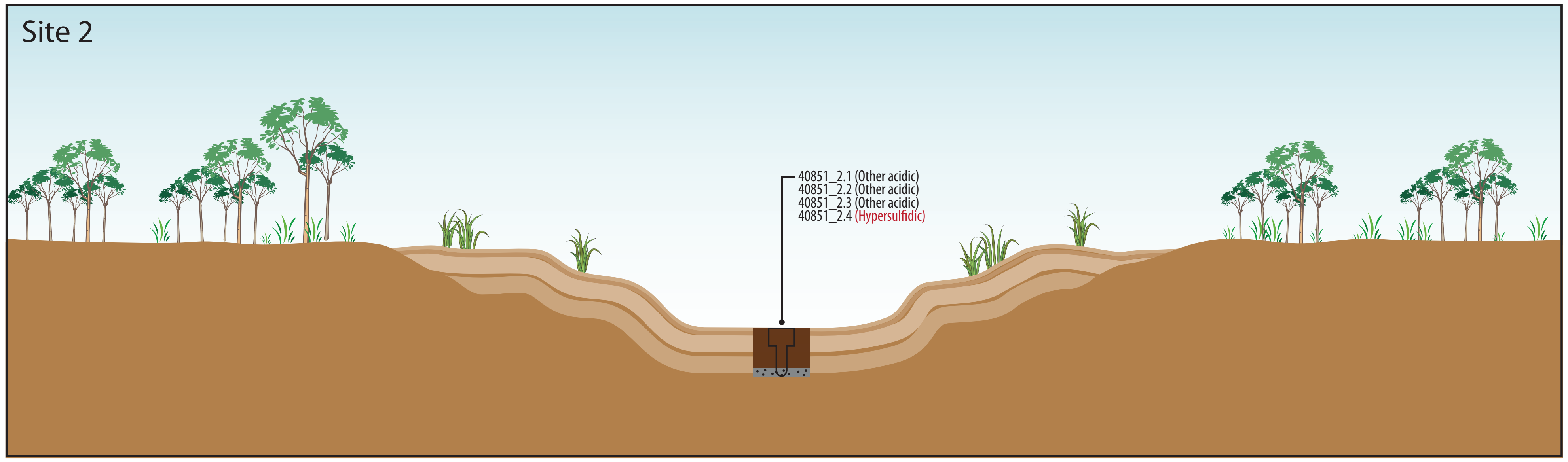
Note: Inset Photos show Surface Condition of Site

CREATED BY B. Stewart LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 FIGURE TITLE Avoca River at Scollary Road Bridge 40851 CMA:NCCMA

SMEC





LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

40851_1

40851_2

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2 **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Avoca River at Scolllary Road Bridge 40851

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

Table 1 – Soil Identification, subtype and general location description for Avoca River at Scollary Road Bridge Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40851_1	187337	5936381	Subaqueous soil	Low point, subaqueous sediments, mid channel.
40851_2	187370	5936499	Hypersulfidic soil	Low point, mainly bare with some reeds, mid channel, near bridge.

Figure 3 – Photographs of site 40851_1, showing the water surface (water column of 50cm), and the laid out soil profile of very soft, dark yellowish brown clay loam overlying very weak, dark greyish brown silty and sandy clay loam.

Figure 4 – Photographs of site 40851_2, showing the surface condition and the soil profile of very soft, dark yellowish brown sandy clay loam overlying very weak, dark greyish brown silty and clay loam sandy.

Figure 5 – Photographs of site 40851, showing wetland during a site visit by SMEC in March 2010. The photographs show the dryer state of the wetland channel and the iron and mineral surface deposits within the channel floor.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The sub headings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figure 6** on the following page. Summary soil pH profile results indicate:

- 40851_1: all samples have $pH_w < 6.0$. Surface soils (0 - 30cm) have pH_w 5.41 – 5.57 with subsoils (30 – 100cm) ranging 4.17 – 5.85. Surface soils $pH_{incubation}$ ranged between 5.08 – 5.68 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged between 3.52 – 5.33 indicating hyposulfidic and other acidic conditions.
- 40851_2: all samples have $pH_w < 5.5$. Surface soils (0 - 20cm) have pH_w 4.93 – 5.40 with subsoils (20 – 60cm) ranging 4.68 – 5.37. Surface soils $pH_{incubation}$ ranged between 4.41 – 5.35 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged between 3.65 – 4.55 indicating hypersulfidic and other acidic conditions.

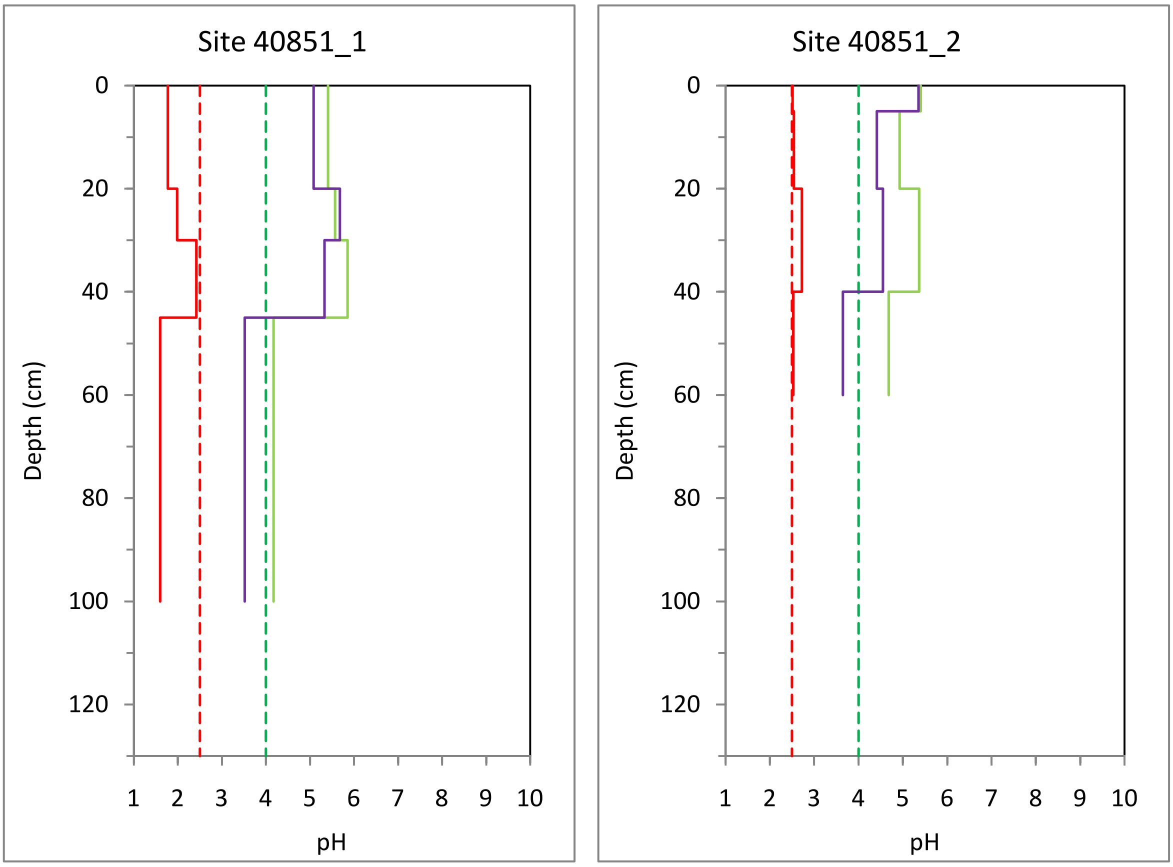


Figure 6 – Depth profiles of soil pH for Avoca River at Scollary Road Bridge, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 7** on the following page.

1.3.3 Titratable Actual Acidity (TAA)

All 8 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 9 – 50 mol H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating increasing acidity with depth.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 8 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01 (limit of laboratory detection) to 0.03% S. Of the 8 samples analysed, 4 (50%) were <0.01 % S. Site 40851_1 contained the majority of sulfidic materials with site 40851_2 containing 0.01% S at the deepest subsoil sample.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Avoca River at Scollary Road Bridge.

1.3.6 Retained Acidity (RA)

No pH_{KCL} results were below the threshold of 4.50 for retained acidity analysis. Therefore, no samples were analysed for Retained Acidity (RA).

1.3.7 Acid Neutralising Capacity (ANC)

None of the 8 samples were analysed for ANC as no samples had a pH_{KCL} higher than 6.50 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 15 to 61 mol H+/tonne. Six out of the eight samples analysed had a moderate net acidity with the remaining two samples having a low net acidity. Site 40851_1 had a higher net acidity in the majority of samples collected. TAA was the major contributor to the net acidity of both sites.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 294 to 450 mg/L for surface soil samples collected (i.e. 0 – 10cm). Two surface soil samples were analysed for water soluble sulfate in total. Both surface samples exceed the trigger criterion of 100 mg/L for MBO formation potential.

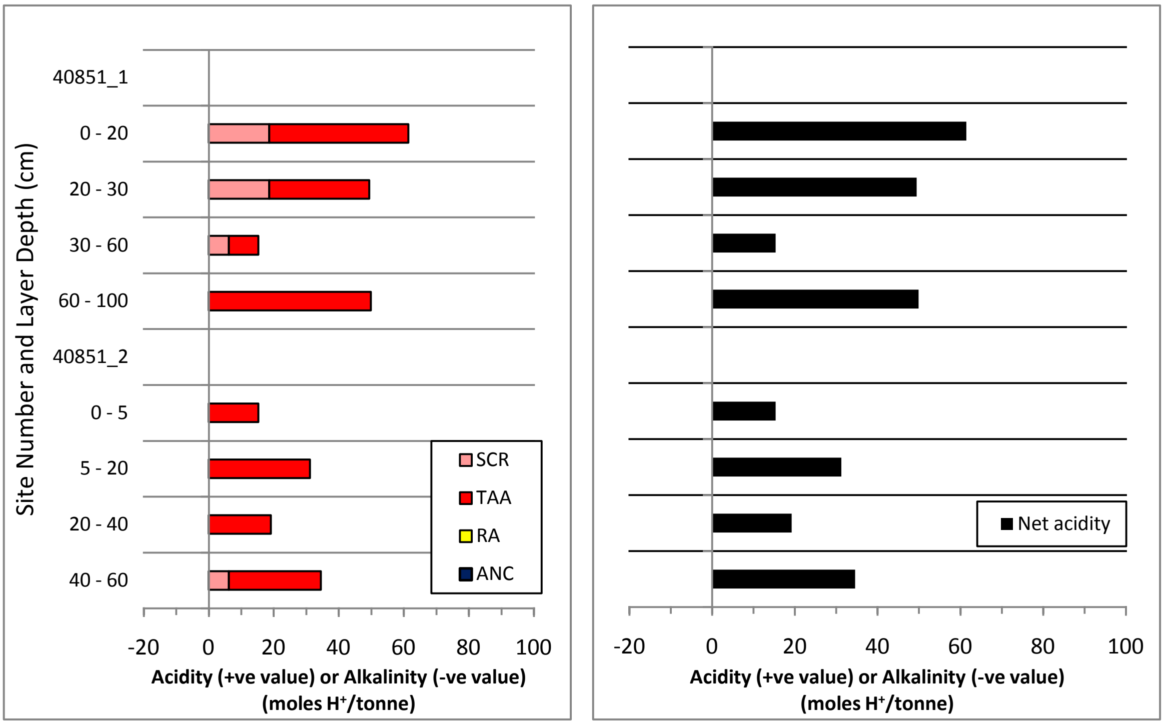


Figure 7 – Acid base accounting depth profiles for Avoca River at Scollary Road Bridge. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two sites from Avoca River at Scollary Road Bridge. One measurement was from pit inflow waters (40851_2) and one from wetland surface waters (40851_1). Two water samples were collected for laboratory analysis from the wetland. **Table 8** provides water watch data for the Avoca River at Scollary Road Bridge collected by the NCCMA between 2003 – 2008.

The wetland surface waters were alkaline (pH 8.21) and pit inflow waters were acidic (pH 5.12). Surface and pit inflow waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 – 8.0.

SEC ranged between 17.1 – 4,720µS/cm with the higher value from the pit water sample (40851_2). Site 40851_2 had a high SEC value 4,720 µS/cm which is greater than the Lowland River trigger values of 125 – 2,200µS/cm. Alkalinity (as HCO_3) ranged between 0 - 60 HCO_3 with the higher value from the surface water sample. Both sites had oxidising conditions (69 to 122Eh) and low DO levels ranging 2.03 – 1.65 mg/L.

The surface water site (40851_1) exceeded the ANZECC 2000 trigger values for nutrients (NH_4 and PO_4) and for some dissolved metals (Al, Co, Cr, and Fe). Both Al and Fe were greater than 10 times the ANZECC 2000 trigger values for surface water.

The pit inflow water site (40851_2) exceeded the ANZECC 2000 trigger values for nutrients (NH_4) and for some dissolved metals (Al, As, Cd, Co, Cr, Fe, Mn, Ni, Si and Zn). The majority of dissolved metals results were greater than 10 times the ANZECC 2000 trigger values. Both Fe and Mn respectively were greater than 50 times the trigger values.

The water data indicates that the surface water has not been affected by acidification and pit inflow water is currently acidic with very high Fe and other dissolved metal concentrations. There is low buffering capacity in subsoils and water to counteract any significant sulfidic or other acidic acidification if drying, oxidation and re wetting were to occur.

1.5 Discussion

Acid sulfate soils within Avoca River at Scollary Road Bridge occurred as hyposulfidic and hypersulfidic materials. Sulfidic sediments occurred as hyposulfidic materials in surface and upper subsoils at site 40851_1 (subaqueous) with other acidic soils at the base of the site. Sulfidic sediments occurred as hypersulfidic materials in lower subsoils at site 40851_2 with other acidic soils within the surface soils and upper subsoils.

Chromium Reducible Sulfur (S_{CR}) results ranged from <0.01 (limit of laboratory detection) to 0.03% S. No sulfuric (pH_W <4.00) or monosulfidic materials were encountered at the wetland. Both water soluble sulfate surface samples collected from each site exceeded the trigger criterion of 100 mg/L for MBO formation potential. Results for water soluble sulfate ranged between 294 to 450 mg/L and indicate that MBO could form under the right environmental conditions.

Net acidity results for all sites and samples ranged between 15 to 61 mol H+/tonne. Site 40851_1 had a higher net acidity in the majority of samples collected. TAA was the major contributor to the net acidity of both sites.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are two (2) high priority samples based on the presence of water soluble sulfate results above the trigger criterion of 100 mg/L and one (1) sample based on the presence of hypersulfidic materials. There are three (3) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10%.

Due to the low level of sulfidic materials present (all S_{CR} analysis either <0.01 or <0.03% S) in surface and subsoils the requirement for Phase 2 laboratory analysis may not be warranted. However, two surface samples analysed exceeded the trigger criterion of 100 mg/L for MBO formation potential. Therefore, Phase 2 analysis for the “Monosulfidic Formation Potential Method” may be suitable for selected surface samples. The lack of MBO formation observed during this survey however indicates that conditions may not be suitable for the formation of MBO currently. In addition, the wetland area is very small (<3 ha) and is not spatially extensive with sulfidic sediments focused within the stream channel.

The potential hazards at a wetland scale posed by acid sulfate soil materials at Avoca River at Scollary Road Bridge are:

- Acidification hazard: low to medium level of concern based on the moderate net acidities and low sulfidic results (from S_{CR}). The degree of acidification potential from sulfidic sources appears to be low for surface soils and medium for subsoils. However, pit inflow water indicates that Fe and other dissolved metals results are very high (with low pH <5.5 water) which indicates subsoils may provide acidity inputs after periods of dry weather and subsequent re flooding.

- De-oxygenation hazard: low to medium level of concern as water soluble sulfate results exceeded the trigger value for monosulfide formation at both sites. Currently however, no monosulfides were observed or formed during this survey.

- Metal mobilisation: The low to medium acidification hazard indicates that sulfidic sources of acidity in surface soils may not be sufficient for additional metals mobilisation currently; however the lower $pH_{incubation}$ results for lower subsoils (pH 3.52 – 3.65) indicate that subsoils could oxidise further and generate acidity levels low enough for the mobilisation of aluminium and other metals in other parts of the wetland (than is currently the case for Site 40851_2). Therefore a low to medium level of concern.

1.6 Summary of Key Findings for Avoca River at Scollary Road Bridge

The summary of key findings for Avoca River at Scollary Road Bridge is detailed in Table 2 on the following page.

Table 2 – Summary of Key Findings.

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Sulfidic materials identified included hyposulfidic and hypersulfidic materials. • Sulfidic soils occurred as hyposulfidic materials in surface and upper subsoils at site 40851_1. • Sulfidic soils occurred as hypersulfidic materials in lower subsoils at site 40851_2. • The remaining materials observed were other acidic soils within the surface soils and upper subsoils at both sites. • Net acidity results for all sites and samples ranged between 15 to 61 mol H+/tonne. • TAA was the major contributor to the net acidity of both sites.
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland, mid stream channel. • Site 2: Hypersulfidic soil occurring above water level, mid stream channel.
Hazard assessment:	• Acidification hazard – low to medium level of concern. • De-oxygenation hazard – low to medium level of concern. • Metal mobilisation hazard – low to medium level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Avoca River at Scollary Road Bridge.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40851_1.1	40851_1	0	20	0.1076	0.0632	41	5.41	1.77	5.08	294
40851_1.2	40851_1	20	30	0.1047	0.0588	44	5.57	1.98	5.68	-
40851_1.3	40851_1	30	45	0.1143	0.0738	35	5.85	2.42	5.33	-
40851_1.5	40851_1	60	100	0.1397	0.1049	25	4.17	1.60	3.52	-
40851_2.1	40851_2	0	5	0.1501	0.1219	19	5.40	2.51	5.35	450
40851_2.2	40851_2	5	20	0.1415	0.1096	23	4.93	2.54	4.41	-
40851_2.3	40851_2	20	40	0.1406	0.1129	20	5.37	2.72	4.55	-
40851_2.4	40851_2	40	60	0.1415	0.1088	23	4.68	2.53	3.65	-

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40851_1.1	40851_1	0	20	5.19	43	0.03	0	-	61	-	Hyposulfidic
40851_1.2	40851_1	20	30	5.28	31	0.03	0	-	49	-	Hyposulfidic
40851_1.3	40851_1	30	45	5.86	9	0.01	0	-	15	-	Hyposulfidic
40851_1.5	40851_1	60	100	4.53	50	<0.01	0	-	50	-	Other acidic
40851_2.1	40851_2	0	5	5.24	15	<0.01	0	-	15	-	Other acidic
40851_2.2	40851_2	5	20	4.89	31	<0.01	0	-	31	-	Other acidic
40851_2.3	40851_2	20	40	5.15	19	<0.01	0	-	19	-	Other acidic
40851_2.4	40851_2	40	60	5.19	28	0.01	0	-	35	-	Hypersulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Avoca River at Scollary Road Bridge.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40851_1.W1	40851_2.W1
Site ID	(number)	-	-	40851_1	40851_2
Wetland ID	(code)	-	-	40851	40851
Site Number	(number)	-	-	1	2
Upper depth	cm	-	-	-45	25
Lower depth	cm	-	-	0	35
Temperature	(deg C)	-	-	10.1	9.6
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	17.1	4720
Dissolved Oxygen	(%)	-	-	18.2	12.9
Dissolved Oxygen	(mg/l)	-	-	2.03	1.65
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	8.21	5.12
Redox potential	Eh	-	-	69	122
Turbidity	(NTU)	*6 - 50*	*1 - 20*	41.4	-0.4
HCO_3	(mg/l)	-	-	60	0
Comment	-	-	-	SW	PW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Avoca River at Scollary Road Bridge.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	23-05-10	23-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201597	2201598
Sample ID	(number)	-	40851_1.W1	40851_2.W1
Site ID	(number)	-	40851_1	40851_2
Wetland ID	(code)	-	40851	40851
Site Number	(number)	-	1	2
Upper depth	cm	-	-45	25
Lower depth	cm	-	0	35
Na	mg l^{-1}	-	130	640
K	mg l^{-1}	-	9	16
Ca	mg l^{-1}	-	14	220
Mg	mg l^{-1}	-	26	220
Si	mg l^{-1}	-	13	41
Br	mg l^{-1}	-	<5	<5
Cl	mg l^{-1}	-	250	1100
NO_3	mg l^{-1}	0.7	<0.01	<1 LINT
NH_4-N^K	mg l^{-1}	0.01	0.7	1.7
PO_4-P^E	mg l^{-1}	0.005	0.07	<0.01
SO_4	mg l^{-1}	-	64	1700
Ag	µg l^{-1}	0.05	<1	<1
Al^A	µg l^{-1}	55	660	13000
As^B	µg l^{-1}	13	4	30
Cd	µg l^{-1}	0.2	<0.2	3
Co	µg l^{-1}	2.8	3	2300
Cr^C	µg l^{-1}	1	2	20
Cu^H	µg l^{-1}	1.4	<1	30
Fe	µg l^{-1}	300	5800	1400000
Mn	µg l^{-1}	1700	240	160000
Ni^H	µg l^{-1}	11	4	1100
Pb^H	µg l^{-1}	3.4	<1	<1
Se	µg l^{-1}	11	<1	80
Zn^H	µg l^{-1}	8	3	1600
DOC	mg l^{-1}	-	27	30

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]Trigger value for Aluminium in freshwater where pH > 6.5.

[B]Trigger value assumes As in solution as Arsenic (AsV).

[C]Trigger value for Chromium is applicable to Chromium (CrVI) only.

[E]Guideline is for filterable reactive phosphorous (FRP).

[H]Hardness affected (refer to Guidelines).

[K]Guideline for South-east Australia-Freshwater Lakes and reservoirs.

Table 6 - Site description data for acid sulfate soil assessment of Avoca River at Scollary Road Bridge.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40851_1	40851	1	23-05-10	54	187337	5936381
40851_2	40851	2	23-05-10	54	187370	5936499

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40851_1	-45	water	leaf and twig litter, reeds, rushes	low point, subaqueous	Subaqueous sediment samples	60	Subaqueous soil	Water level higher than previous dry site inspection and recent flush event detailed by CMA officer
40851_2	25	soft	mainly bare, some reeds	low point	iron staining on surface sediments	40	Hypersulfidic soil	Water level higher than previous dry site inspection and recent flush event detailed by CMA officer

Table 7 - Profile description data for acid sulfate soil assessment of Avoca River at Scollary Road Bridge.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40851_1.1	SS	0	20	10YR54	Clay loam	Loamy	Wet	5.77	1:1
40851_1.2	SS	20	30	10YR34	Clay loam	Loamy	Wet	5.67	1:1
40851_1.3	SS	30	45	2.5Y42	Silty clay loam	Clayey	Wet	6.15	1:1
40851_1.5	PT	60	100	2.5Y42	Sandy clay loam	Clayey	Wet	3.89	1:1
40851_2.1	SS	0	5	10YR44	Clayey sand	Sandy	Moist	5.13	1:1
40851_2.2	SS	5	20	10YR44	Sandy clay loam	Loamy	Moist	4.91	1:1
40851_2.3	SS	20	40	10YR42	Clay loam	Clayey	Wet	5.47	1:1
40851_2.4	PT	40	60	10YR42	Clay loam sandy	Clayey	Wet	4.44	1:1

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40851_1.1	0	-	-	-	-	0	VS	Plant material, leaf and twig litter
40851_1.2	2	FM	2.5YR56	MAT	-	0	VS	Plant material, leaf and twig litter
40851_1.3	0	-	-	-	-	0	VS	rootlets
40851_1.5	5	FM	7.5YR58	MAT	-	0	VW	Plant material
40851_2.1	0	-	-	-	-	-	VS	Ferric iron on surface, rounded quartz gravels, minor organics
40851_2.2	20	FM	2.5YR56	MAT, RPO	MA	1	VS	rounded quartz gravels, minor organics
40851_2.3	10	FM	2.5YR56	MAT, RPO	MA	1	VS	Plant material, rootlets
40851_2.4	10	FM	2.5YR56	MAT, RPO	-	0	VW	Plant material, rootlets

Table 8 – Additional Data: Water watch Water Quality Data for the Avoca River at Scollary Road Bridge Site Collected by the NCCMA.

AVO270 - Avoca River, Scollary Rd Bridge					
Date and (notes)	**Electrical Conductivity (µS/cm)**	**pH (pH Units)**	**Reactive Phosphorus (mg/L P)**	**Temperature (° C)**	**Turbidity (NTU)**
08/10/2003 ()	3310	7.00	0.02	16.3	14
09/11/2003 ()	3430	7.00	0.01	-	10
16/12/2003 ()	5980	8.00	0.01	-	10
10/01/2004 ()	6210	7.50	0.02	-	10
16/01/2005 (Stagnant (pool))	3630	7.00	0.02	19.5	11
12/02/2005 ()	2430	7.00	0.01	22	25
12/03/2005 (Stagnant (pool))	2030	7.00	0.01	17.7	10
11/04/2005 (Stagnant (pool))	2230	7.00	0.01	18.9	15
07/05/2005 (Stagnant (pool))	2300	7.00	0.02	9.8	80
21/12/2005 (Stagnant (pool))	1072	7.00	0.01	20.9	20
10/01/2006 (Stagnant (pool))	1422	7.00	0	20.3	24
14/02/2006 (Stagnant (pool))	1687	7.00	0	18.7	32
16/03/2006 ()	2010	7.65	0.02	16.3	30
20/05/2006 (Stagnant (pool))	1952	7.79	0.01	6.9	35
07/05/2007 (Stagnant (pool))	4690	4.50	-	17	30
04/06/2007 (Steady)	1693	6.50	0.01	13	33
16/07/2007 (Steady)	1006	6.50	0.01	8.5	27
08/08/2007 (Steady)	1248	7.00		11	12
03/09/2007 (Stagnant (pool))	1445	7.00	0.03	13	12
05/10/2007 (Stagnant (pool))	1771	7.00	0.02	18.8	<10
07/11/2007 (Stagnant (pool))	1818	6.50	-	15	18
31/12/2007 (Stagnant (pool))	880	7.00	-	27	35
18/01/2008 (Stagnant (pool))	1129	7.00	-	18.9	50
21/02/2008 (Stagnant (pool))	1511	7.00	-	16.7	72
28/03/2008 (Stagnant (pool))	999	6.50	-	15.3	100
29/04/2008 ()	1635	6.50	-	8.1	100
05/05/2008 ()	1636	7.00	-	13.2	38
23/06/2008 ()	1373	6.50	-	12.9	150
17/07/2008 ()	1067	6.50	-	11.1	90

AVO270 - Avoca River, Scollary Rd Bridge					
Date and (notes)	**Electrical Conductivity (µS/cm)**	**pH (pH Units)**	**Reactive Phosphorus (mg/L P)**	**Temperature (° C)**	**Turbidity (NTU)**
23/07/2009 (Steady)	3080	7.10	0.02	9.1	20
05/08/2009 (Stagnant (pool))	3450	6.80	0.05	12.1	<10
04/09/2009 (Stagnant (pool))	3310	7.00	-	11.8	38
02/10/2009 (Steady)	828	7.40	-	14.8	38
09/11/2009 (Steady)	1269	7.30	-	26.1	28
11/12/2009 (Steady)	1400	7.30	-	20.5	80
28/01/2010 ()	4590	8.00	-	29.2	25

APPENDIX 10: BUFFALO SWAMP (40853) SUMMARY REPORT

APPENDIX 10:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40853

Wetland Name: Buffalo Swamp

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 BUFFALO SWAMP 3

1.1 Location and Setting Description 3

1.2 Soil Profile Description and Distribution 3

1.3 Summary of Field and Laboratory Results 5

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 6

1.3.2 Acid Base Accounting 8

1.3.3 Titratable Actual Acidity (TAA) 8

1.3.4 Chromium Reducible Sulfur (S_{CR}) 8

1.3.5 Acid Volatile Sulfur (AVS) 8

1.3.6 Retained Acidity (RA) 9

1.3.7 Acid Neutralising Capacity (ANC) 9

1.3.8 Net Acidity 9

1.3.9 Water soluble SO_4 9

1.4 Hydrochemistry 10

1.5 Discussion 11

1.6 Summary of Key Findings for Buffalo Swamp 11

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Buffalo Swamp Sites. 4
Table 2 – Summary Of Key Findings 12
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Buffalo Swamp. 13
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Buffalo Swamp. 15
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Buffalo Swamp 16
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Buffalo Swamp. 17
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Buffalo Swamp. 18

LIST OF FIGURES

Figure 1 – Buffalo Swamp 40853 Site Plan.

Figure 2 – Buffalo Swamp Conceptual Hydrotoposequence Cross Section – 40853.

Figure 3 – Photographs of site 40853_1, showing the water surface (water column of 220cm) and the chip tray soil profile of very soft, dark greenish grey silty clay.

Figure 4 – Photographs of site 40853_2, showing the surface condition and the soil profile of soft, dark yellowish brown clay loam and clay overlying firm, yellowish brown clay.

Figure 5 – Photographs of site 40853_3, showing the surface condition and the soil profile of weak, brown clay overlying very firm, brown clay.

Figure 6 – Photographs of site 40853_4, showing the surface condition and the soil profile of weak, dark brown clay loam and clay overlying firm, olive brown clay

Figure 7 – Photographs of site 40853_5, showing the surface condition and the soil profile of weak, brown silty clay loam overlying firm, dark yellowish brown clay

Figure 8 – Depth profiles of soil pH for Buffalo Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 9 – Depth profiles of soil pH for Buffalo Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line).

Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 10 – Acid base accounting depth profiles for Buffalo Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

1 BUFFALO SWAMP

1.1 Location and Setting Description

Buffalo Swamp is situated on the western side of the Goulburn River, approximately 10km north of the township of Nagambie, VIC and 2.5km north of the Goulburn Weir. The wetland is accessed from Goulburn Weir Murchison Road off the Goulburn Valley Highway. The wetland is generally curved in shape, and approximately 150m wide by 650m in length, with a total area of 8 hectares.

The wetland appears to be a modified cut off stream channel (oxbow) and is connected to the Goulburn River at times of higher water levels via a culvert under Goulburn Weir Murchison Road. The wetland has minor banks and low to moderately sloping batters leading up onto the floodplain. There is a walnut farm to the immediate South East of the site and an irrigation channel to the west.

At the time of inspection in April 2010, the wetland contained approximately 70% surface water coverage. Water within the wetland was slight brown to clear and the bottom or lowest point could not be seen visually through the water column (220cm). The water line and lower shallow banks around the periphery of the wetland contained low grasses and rushes. The higher banks and water line of the wetland contained medium sized trees. Five sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Five sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at different areas of the wetland with five sites chosen. The original requirement for this wetland based on surface area was four sites, however a fifth site was chosen due to the larger area of inundation that was currently dry to the south of the wetland. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 7** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40853_1: water surface, low point subaqueous, mid old flooded channel; soil consisted of very soft, dark greenish grey silty clay.
- 40853_2: soft, reeds, mid point, waters edge; soil consisted of soft, dark yellowish brown clay loam and clay overlying firm, yellowish brown clay.
- 40853_3: loose, reeds, weeds and low grass, mid point, upper bank deposits; soil consisted of weak, brown clay overlying very firm, brown clay.
- 40853_4: soft, reeds, high point, vegetation change with more organics; soil consisted of weak, dark brown clay loam and clay overlying firm, olive brown clay.
- 40853_5: soft, low grasses and reeds, mid point, inundation area; soil consisted of weak, brown silty clay loam overlying firm, dark yellowish brown clay.

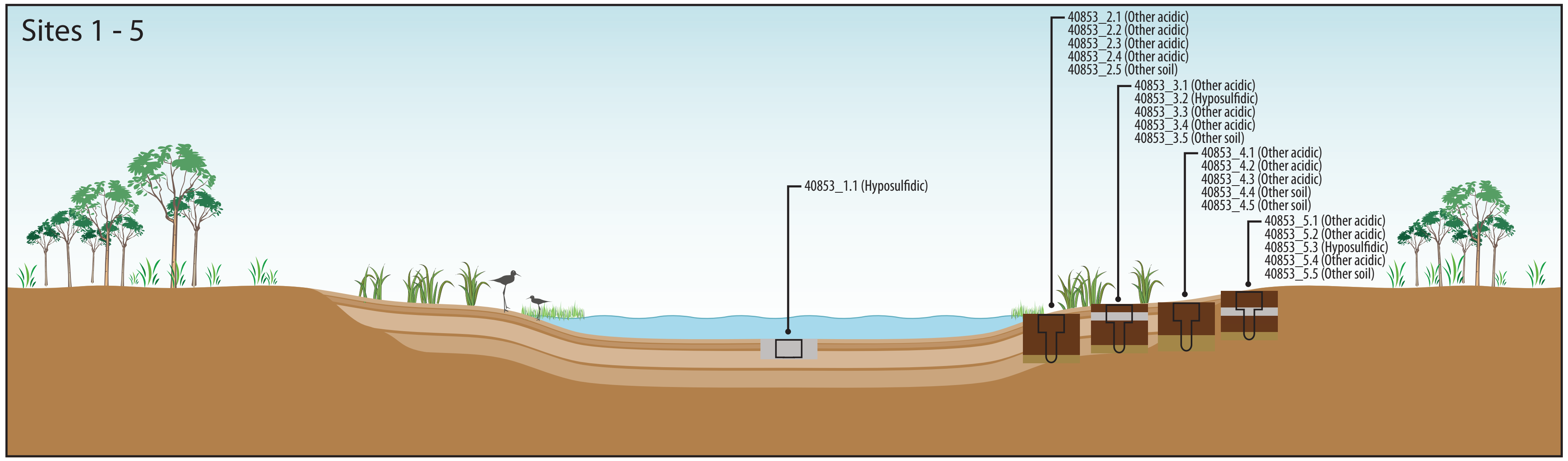
DATE 09/07/2010	SCALE 1:3,000 (0, 37.5, 75, 150 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 55
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS		

FIG NO. 1 PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 FIGURE TITLE Buffalo Swamp 40853 CMA:GBCMA

Note: Inset Photos show Surface Condition of Site

SMEC



LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

40853_2

40853_3

40853_4

40853_5

DATE 15/07/2010	**SCALE** Not to Scale	**FIG NO.** 2	**PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS	**PROJECT NO.** 3001801	**FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Buffalo Swamp 40853

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

Table 1 – Soil Identification, subtype and general location description for Buffalo Swamp Sites.

Site ID	Easting UTM Zone 55	Northing UTM Zone 55	Acid sulfate soil subtype class	General location description
40853_1	336757	5937422	Subaqueous soil	Low point, subaqueous sediments, middle of old channel.
40853_2	336396	5937320	Hydrosol - sandy or loamy	Mid point, reeds, waters edge.
40853_3	336376	5937329	Hydrosol - sandy or loamy	Mid point, reeds, weeds and low grass, upper bank deposits.
40853_4	336285	5937325	Hydrosol - sandy or loamy	High point, reeds, vegetation change with more organics.
40853_5	336319	5937017	Hydrosol - sandy or loamy	Mid point, low grasses and reeds, inundation area.

Figure 3 – Photographs of site 40853_1, showing the water surface (water column of 220cm), and the chip tray soil profile of very soft, dark greenish grey silty clay.

Figure 4 – Photographs of site 40853_2, showing the surface condition and the soil profile of soft, dark yellowish brown clay loam and clay overlying firm, yellowish brown clay.

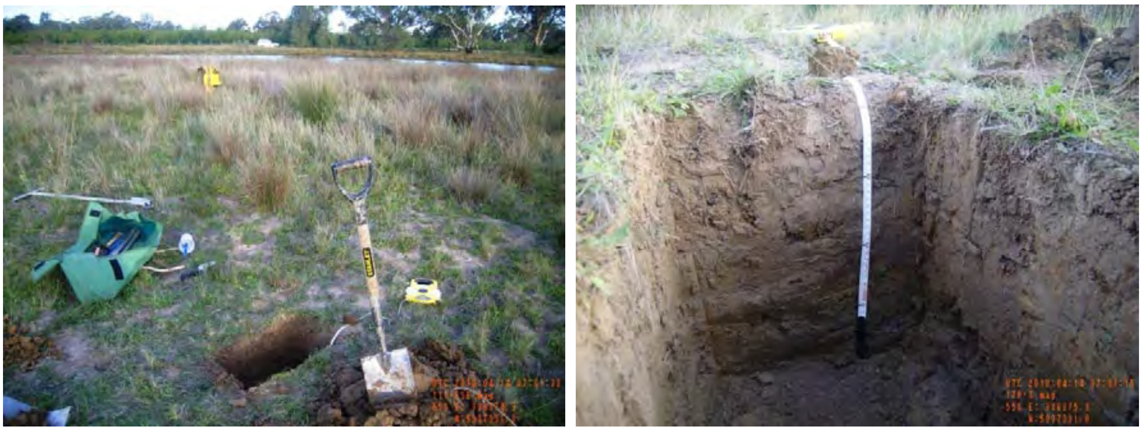


Figure 5 – Photographs of site 40853_3, showing the surface condition and the soil profile of weak, brown clay overlying very firm, brown clay.

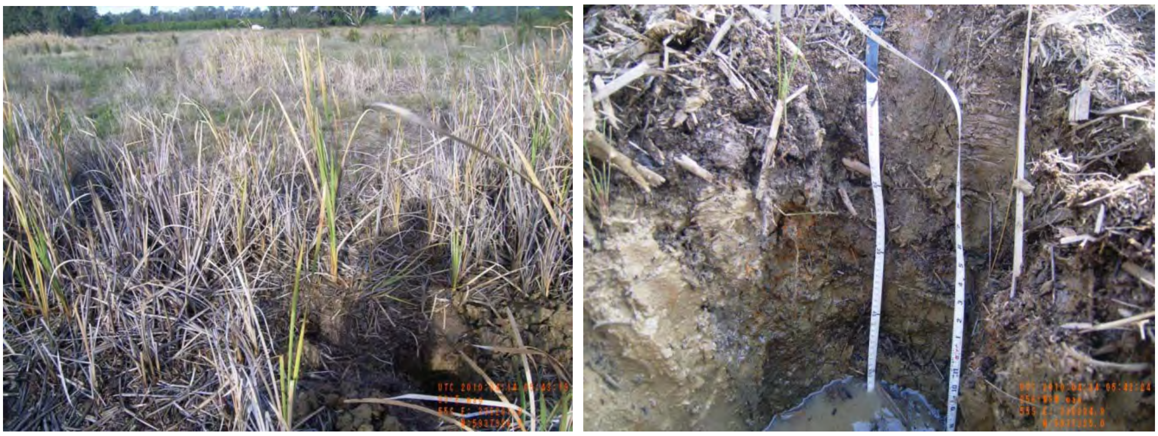


Figure 6 – Photographs of site 40853_4, showing the surface condition and the soil profile of weak, dark brown clay loam and clay overlying firm, olive brown clay.

Figure 7 – Photographs of site 40853_5, showing the surface condition and the soil profile of weak, brown silty clay loam overlying firm, dark yellowish brown clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the five sites are presented in **Figures 8 and 9** on the following pages. Summary soil pH profile results indicate:

- 40853_1: pH_w 4.99 with $pH_{incubation}$ 4.02 indicating hyposulfidic conditions.
- 40853_2: all samples have pH_w < 7.5. Surface soils (0 - 20cm) have pH_w 4.69 – 5.21 with subsoils (20 – 70cm) ranging 5.15 – 7.05. Surface soils $pH_{incubation}$ ranged 4.25 – 5.84 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged 4.33 – 6.15 indicating other acidic and other soil conditions.
- 40853_3: all samples have pH_w < 8.5. Surface soils (0 - 20cm) have pH_w 5.45 – 6.17 with subsoils (20 – 100cm) ranging 6.57 – 8.18. Surface soils $pH_{incubation}$ ranged 4.61 – 5.25 indicating other acidic and hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.37 – 7.33 indicating other acidic and other soil conditions.
- 40853_4: all samples have pH_w < 7.5. Surface soils (0 - 20cm) have pH_w 4.81 – 5.27 with subsoils (20 – 90cm) ranging 6.76 – 7.40. Surface soils $pH_{incubation}$ ranged 4.21 – 5.66 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged 5.77 – 6.54 indicating other acidic and other soil conditions.
- 40853_5: all samples have pH_w < 7.0. Surface soils (0 - 20cm) have pH_w 4.84 – 5.41 with subsoils (20 – 90cm) ranging 5.17 – 6.61. Surface soils $pH_{incubation}$ ranged 4.30 – 4.95 indicating other acidic conditions. Subsoils $pH_{incubation}$ ranged 4.24 – 6.73 indicating hyposulfidic, other acidic and other soil conditions.

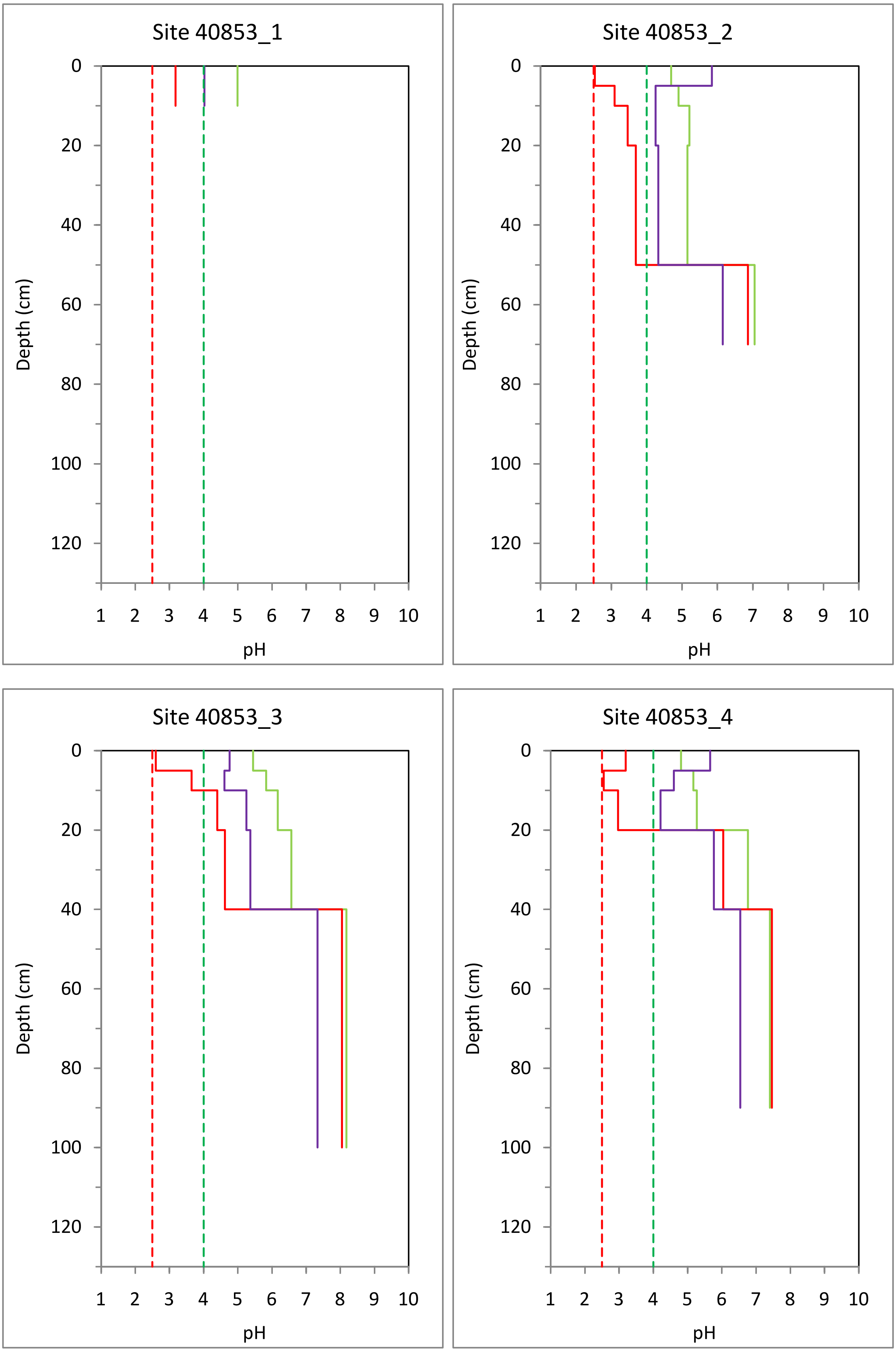


Figure 8 – Depth profiles of soil pH for Buffalo Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

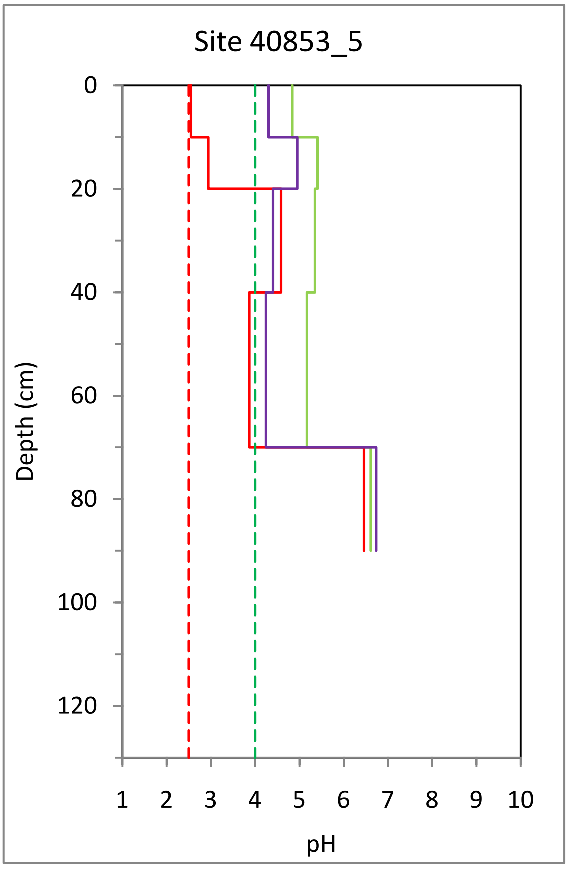


Figure 9 – Depth profiles of soil pH for Buffalo Swamp, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figure 10** on the following page.

1.3.3 Titratable Actual Acidity (TAA)

All 21 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 0 – 88 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating acidic conditions decreasing moving vertically down the soil profile.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 21 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01 (limit of laboratory detection) to 0.01%S. 18 out of the 21 collected samples (86%) had S_{CR} <0.01% S with only 3 samples above the threshold criteria.

1.3.5 Acid Volatile Sulfur (AVS)

One sample was analysed for S_{AV} from the subaqueous site (40853_1). The sample matrix was made up of highly decomposed organics with a value of <0.000 %S_{AV} dry weight (below limit of laboratory detection). No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no other samples were analysed for Acid Volatile Sulfur (S_{AV}) from Buffalo Swamp.

1.3.6 Retained Acidity (RA)

8 out of the 21 samples had pH_{KCL} results below the threshold of 4.50 for retained acidity analysis. Of the 8 samples analysed for RA, only one sample from Site 40853_4.1 had a detectable level of 1 mol H+/tonne.

1.3.7 Acid Neutralising Capacity (ANC)

2 out of the 21 samples had pH_{KCL} results above the threshold of 6.50 for ANC analysis. Both samples analysed had ANC values of 1 mol H+/tonne. None of the remaining samples were analysed for ANC as no samples had a pH higher than 6.5 that may indicate acid buffering conditions and trigger the requirement for ANC analysis.

1.3.8 Net Acidity

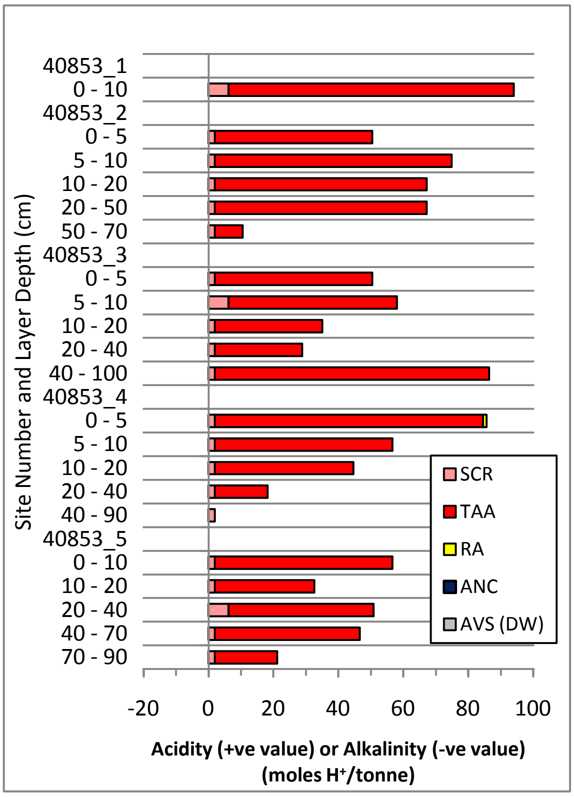
The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 0 to 94 mol H+/tonne. 18 out of the 21 samples (86%) have a moderate net acidity with the 3 remaining samples having a low net acidity. Surface soils (0 – 30cm) typically had high net acidity values with the major contributor to the net acidity values for all sites coming from TAA (actual acidity).

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 9 to 29 mg/L for surface soil samples collected (i.e. 0 – 10cm). Five surface soil samples were analysed for water soluble sulfate in total. No surface samples exceeded the trigger criterion of 100 mg/L for MBO formation potential.



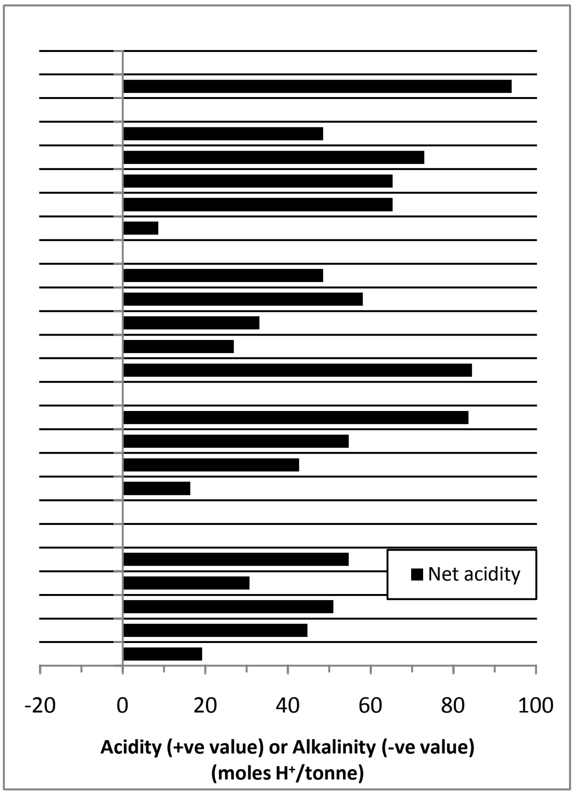


Figure 10 – Acid base accounting depth profiles for Buffalo Swamp. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two out of the five sites from Buffalo Swamp. Measurements were taken from both pit inflow waters and surface waters. One water sample was collected for laboratory analysis from the surface water site 40853_1. The remaining sites had inadequate water inflow to collect a sample for laboratory analysis purposes.

The surface waters were slightly acidic (pH 6.55) and within the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0. Pit inflow water was acidic (pH 5.86) from site 40583_4. SEC values were within the upper Lowland River criterion values of 125 – 2,200µS/cm and outside the criterion values for Freshwater Lakes (20 – 30µS/cm) with a range of 115 – 497µS/cm. Alkalinity (as HCO_3) ranged between 20 – 40mg/L and the surface and pit inflow water had oxidising conditions (135 - 187 Eh) respectively. Surface water had a DO concentration of 7.08 mg/L with a lower concentration from pit inflow water of 3.18 mg/L.

The surface water site 40853_1 exceeded the ANZECC 2000 trigger values for some nutrients (NH_4 0.1 mg/L, criterion of 0.01 mg/L) and some dissolved metals (Al 400 µg/L, criterion of 55 µg/L and Fe 1,900 µg/L, criterion of 300 µg/L).

The water data indicates that the surface water has not been significantly affected by acidification with a pH of 6.55 (slightly acidic). The wetland has some alkalinity and low SEC for surface waters.

1.5 Discussion

Acid sulfate soils within Buffalo Swamp occurred as hyposulfidic materials forming in low subaqueous areas and within occasional soil layers on the upper bank and inundation area only. The remaining soils were either other acidic within surface and subsoils or other soils at the base of all sites above the water line.

The highest S_{CR} was 0.01%S for the three hyposulfidic classified materials. 18 out of the 21 collected samples (86%) had S_{CR} <0.01% S. No monosulfidic or sulfuric materials were encountered at the wetland from sites sampled. Water soluble sulfate values ranged between 9 to 29 mg/L and did not exceed the trigger criterion of 100 mg/L for MBO formation potential.

Net acidity results for all sites and samples ranged between 0 to 94 mol H+/tonne. Surface soils (0 – 30cm) typically had high net acidity values with the major contributor to the net acidity values coming from TAA (actual acidity).

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are three (3) moderate priority samples based on the presence of hyposulfidic materials (S_{CR} < 0.10%). However, the remaining soil materials sampled are classified as “no further assessment”.

Due to the low levels of sulfidic materials present (all samples collected were equal to or less than 0.01% S from S_{CR}) the requirement for Phase 2 laboratory analysis may not be warranted for Buffalo Swamp. In addition, the wetland area is relatively small (<8 ha) with a lower risk of significant oxidation and acidity generation except when the water level of the wetland is significantly reduced or dries out completely. As the wetland is connected to the Goulburn River through culverts, this is unlikely to occur currently assuming these conditions ensue long term.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Buffalo Swamp are:

- Acidification hazard: low level of concern based on the low sulfidic results from S_{CR} and moderate to low net acidities. The degree of acidification potential from sulfidic sources only appears to be low.

- De-oxygenation hazard: low level of concern as water soluble sulfate results for the surface soil materials did not exceed the trigger value for monosulfide formation. No MBO materials were observed at the wetland and at sites sampled.

- Metal mobilisation: The low acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation. Acidity from non sulfidic (i.e. organic or other acidic materials) may promote the solubility of metals if these materials were dried and then re wet based on $pH_{incubation}$ results where 14 out of 21 samples (67%) were between pH 4.00 – 5.50 after 8 weeks incubation. Therefore a low level of concern.

1.6 Summary of Key Findings for Buffalo Swamp

The summary of key findings for Buffalo Swamp is detailed in Table 2 on the following page.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Hypersulfidic materials were not observed. • Sulfidic materials identified included hyposulfidic materials occurring in low subaqueous areas and within occasional soil layers on the upper bank and inundation area only. • The remaining soils were either other acidic within surface and subsoils or other soils at the base of all sites above the water line. • Net acidities ranged between 0 to 94 mol H+/tonne (moderate).
Acid sulfate soil identification:	• Site 1: Subaqueous soil occurring under current standing water level in the wetland. • Site 2: Hydrosol – sandy or loamy occurring at water edge and wetland margin soils. • Site 3: Hydrosol – sandy or loamy occurring at wetland upper bank deposits. • Site 4: Hydrosol – sandy or loamy occurring at high point of transect where vegetation changed with organic surface materials. • Site 5: Hydrosol – sandy or loamy occurring at high point are where inundation may occur.
Hazard assessment:	• Acidification hazard – low level of concern • De-oxygenation hazard – low level of concern • Metal mobilisation hazard – low level of concern

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Buffalo Swamp.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40853_1.1	40853_1	0	10	0.0878	0.0401	54	4.99	3.18	4.02	29
40853_2.1	40853_2	0	5	0.1254	0.0968	23	4.69	2.53	5.84	9
40853_2.2	40853_2	5	10	0.1243	0.0973	22	4.90	3.09	4.25	-
40853_2.3	40853_2	10	20	0.1241	0.0958	23	5.21	3.46	4.25	-
40853_2.4	40853_2	20	50	0.1385	0.1088	21	5.15	3.69	4.33	-
40853_2.5	40853_2	50	70	0.1405	0.1108	21	7.05	6.86	6.15	-
40853_3.1	40853_3	0	5	0.1138	0.0987	13	5.45	2.60	4.76	16
40853_3.2	40853_3	5	10	0.1367	0.1093	20	5.83	3.65	4.61	-
40853_3.3	40853_3	10	20	0.1372	0.1071	22	6.17	4.40	5.25	-
40853_3.4	40853_3	20	40	0.1362	0.1054	23	6.57	4.62	5.37	-
40853_3.5	40853_3	40	100	0.1276	0.1049	18	8.18	8.05	7.33	-
40853_4.1	40853_4	0	5	0.1167	0.0802	31	4.81	3.19	5.66	28
40853_4.2	40853_4	5	10	0.1370	0.1005	27	5.17	2.55	4.60	-
40853_4.3	40853_4	10	20	0.1231	0.0957	22	5.27	2.97	4.21	-
40853_4.4	40853_4	20	40	0.1336	0.1013	24	6.76	6.04	5.77	-
40853_4.5	40853_4	40	90	0.1341	0.1050	22	7.40	7.46	6.54	-
40853_5.1	40853_5	0	10	0.1326	0.0995	25	4.84	2.55	4.30	20
40853_5.2	40853_5	10	20	0.1318	0.1006	24	5.41	2.94	4.95	-
40853_5.3	40853_5	20	40	0.1341	0.1034	23	5.35	4.58	4.40	-
40853_5.4	40853_5	40	70	0.1316	0.1060	19	5.17	3.87	4.24	-
40853_5.5	40853_5	70	90	0.1353	0.1085	20	6.61	6.46	6.73	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Buffalo Swamp.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	%$CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40853_1.1	40853_1	0	10	4.56	88	0.01	-	-	94	0.0000	Hyposulfidic
40853_2.1	40853_2	0	5	4.41	49	<0.01	0	-	49	-	Other acidic
40853_2.2	40853_2	5	10	4.34	73	<0.01	0	-	73	-	Other acidic
40853_2.3	40853_2	10	20	4.45	65	<0.01	0	-	65	-	Other acidic
40853_2.4	40853_2	20	50	4.33	65	<0.01	0	-	65	-	Other acidic
40853_2.5	40853_2	50	70	6.43	9	<0.01	-	-	9	-	Other soil
40853_3.1	40853_3	0	5	4.70	49	<0.01	-	-	49	-	Other acidic
40853_3.2	40853_3	5	10	4.90	52	0.01	-	-	58	-	Hyposulfidic
40853_3.3	40853_3	10	20	5.18	33	<0.01	-	-	33	-	Other acidic
40853_3.4	40853_3	20	40	5.74	27	<0.01	-	-	27	-	Other acidic
40853_3.5	40853_3	40	100	7.07	85	<0.01	-	0	85	-	Other soil
40853_4.1	40853_4	0	5	4.19	83	<0.01	1	-	84	-	Other acidic
40853_4.2	40853_4	5	10	4.36	55	<0.01	0	-	55	-	Other acidic
40853_4.3	40853_4	10	20	4.52	43	<0.01	-	-	43	-	Other acidic
40853_4.4	40853_4	20	40	5.90	16	<0.01	-	-	16	-	Other soil
40853_4.5	40853_4	40	90	6.50	0	<0.01	-	0	0	-	Other soil
40853_5.1	40853_5	0	10	4.34	55	<0.01	0	-	55	-	Other acidic
40853_5.2	40853_5	10	20	4.81	31	<0.01	-	-	31	-	Other acidic
40853_5.3	40853_5	20	40	4.55	45	0.01	-	-	51	-	Hyposulfidic
40853_5.4	40853_5	40	70	4.43	45	<0.01	0	-	45	-	Other acidic
40853_5.5	40853_5	70	90	5.76	19	<0.01	-	-	19	-	Other soil

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Buffalo Swamp.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40853_1.W1	-
Site ID	(number)	-	-	40853_1	40853_4
Wetland ID	(code)	-	-	40853	40853
Site Number	(number)	-	-	1	4
Upper depth	cm	-	-	-30	30
Lower depth	cm	-	-	0	40
Temperature	(deg C)	-	-	18.6	17
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	115.3	497
Dissolved Oxygen	(%)	-	-	73.2	33
Dissolved Oxygen	(mg/l)	-	-	7.08	3.18
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	6.55	5.86
Redox potential	Eh	-	-	135	187
Turbidity	(NTU)	*6 - 50*	*1 - 20*	40.1	407
HCO_3	(mg/l)	-	-	40	20
Comment	-	-	-	SW	PW, no sample collected

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Buffalo Swamp

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	14-04-10
Laboratory	(code)	-	Ecowise/ALS
Laboratory sample ID	number	-	2155289
Sample ID	(number)	-	40853_1.W1
Site ID	(number)	-	40853_1
Wetland ID	(code)	-	40853
Site Number	(number)	-	1
Upper depth	cm	-	-30
Lower depth	cm	-	0
Na	$mg\ l^{-1}$	-	11
K	$mg\ l^{-1}$	-	4.1
Ca	$mg\ l^{-1}$	-	3.6
Mg	$mg\ l^{-1}$	-	3.2
Si	$mg\ l^{-1}$	-	5.8
Br	$mg\ l^{-1}$	-	<5
Cl	$mg\ l^{-1}$	-	19
NO_3	$mg\ l^{-1}$	0.7	<0.01
NH_4-N[K]	$mg\ l^{-1}$	0.01	0.1
PO_4-P[E]	$mg\ l^{-1}$	0.005	<0.01
SO_4	$mg\ l^{-1}$	-	1
Ag	$\mu g\ l^{-1}$	0.05	<1
Al[A]	$\mu g\ l^{-1}$	55	400
As[B]	$\mu g\ l^{-1}$	13	2
Cd	$\mu g\ l^{-1}$	0.2	<0.2
Co	$\mu g\ l^{-1}$	2.8	<1
Cr[C]	$\mu g\ l^{-1}$	1	<1
Cu[H]	$\mu g\ l^{-1}$	1.4	1
Fe	$\mu g\ l^{-1}$	300	1900
Mn	$\mu g\ l^{-1}$	1700	66
Ni[H]	$\mu g\ l^{-1}$	11	2
Pb[H]	$\mu g\ l^{-1}$	3.4	1
Se	$\mu g\ l^{-1}$	11	<1
Zn[H]	$\mu g\ l^{-1}$	8	3
DOC	$mg\ l^{-1}$	-	12

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]*Trigger value for Aluminium in freshwater where pH > 6.5.*

[B]*Trigger value assumes As in solution as Arsenic (AsV).*

[C]*Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E]*Guideline is for filterable reactive phosphorous (FRP).*

[H]*Hardness affected (refer to Guidelines).*

[K]*Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Buffalo Swamp.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40853_1	40853	1	14-04-10	55	336757	5937422
40853_2	40853	2	14-04-10	55	336396	5937320
40853_3	40853	3	14-04-10	55	336376	5937329
40853_4	40853	4	14-04-10	55	336285	5937325
40853_5	40853	5	15-04-10	55	336319	5937017

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40853_1	-220	water	water	low point, subaqueous	Subaqueous sediment samples	60	Subaqueous soil	Old dead tree stumps mark the previous channel in wetland prior to flooding due to road and culvert, this is likely deepest part of wetland as noted by land owner
40853_2	-5	soft	reeds	mid point	waters edge	10	Hydrosol - sandy or loamy	-
40853_3		loose	reeds, weeds, low grass	mid point	upper bank deposits, dryer in hydro toposequence	10	Hydrosol - sandy or loamy	No water evident
40853_4	30	soft	reeds	high point	vegetation change, moist surface, organics	10	Hydrosol - sandy or loamy	Section of wetland that may be inundated first if higher water levels occur in wetland
40853_5	70	soft	low grass, reeds	mid point	large portion of wetland to be submerged if water level increases	10	Hydrosol - sandy or loamy	-

Table 7 - Profile description data for acid sulfate soil assessment of Buffalo Swamp.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40853_1.1	BA	0	10	1GLEY410Y	Silty clay	Clayey	Wet	6.69	1:1
40853_2.1	SS	0	5	10YR42	Clay loam	Loamy	Moist	5.96	1:1
40853_2.2	SS	5	10	10YR44	Clay	Clayey	Moist	5.41	1:1
40853_2.3	SS	10	20	7.5YR46	Clay	Clayey	Moist	5.13	1:1
40853_2.4	SS	20	50	10YR44	Clay	Clayey	Moist	5.17	1:1
40853_2.5	SA	50	70	10YR54	Clay	Clayey	Moist	7.05	1:1
40853_3.1	SS	0	5	7.5YR43	Clay	Clayey	Moist	5.83	1:1
40853_3.2	SS	5	10	7.5YR44	Clay	Clayey	Moist	6.14	1:1
40853_3.3	SA	10	20	7.5YR53	Clay	Clayey	Moist	6.55	1:1
40853_3.4	SA	20	40	7.5YR44	Clay	Clayey	Moist	6.70	1:1
40853_3.5	SA	40	100	7.5YR44	Clay	Clayey	Moist	8.78	1:1
40853_4.1	SS	0	5	10YR36	Clay loam	Loamy	Moist	5.87	1:1
40853_4.2	SS	5	10	10YR33	Clay	Clayey	Moist	5.85	1:1
40853_4.3	SS	10	20	10YR33	Clay	Clayey	Moist	5.81	1:1
40853_4.4	SA	20	40	2.5Y43	Clay	Clayey	Wet	7.08	1:1
40853_4.5	SA	40	90	2.5Y43	Clay	Clayey	Wet	7.65	1:1
40853_5.1	SS	0	10	10YR43	Silty clay loam	Loamy	Moist	5.76	1:1
40853_5.2	SS	10	20	10YR43	Silty clay loam	Clayey	Moist	6.04	1:1
40853_5.3	SS	20	40	10YR44	Clay	Clayey	Moist	6.16	1:1
40853_5.4	SA	40	70	10YR44	Clay	Clayey	Moist	6.07	1:1
40853_5.5	SA	70	90	10YR44	Clay	Clayey	Moist	7.08	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Buffalo Swamp.

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40853_1.1	0	-	-	-	MA	0	VS	Decomposing organics, organic odour
40853_2.1	0	-	-	-	MA	1	S	plant materials, rootlets
40853_2.2	30	FM	2.5YR58	MAT	MA	1	W	plant materials, rootlets
40853_2.3	20	FM	2.5YR58	MAT	MA	1	F	plant materials, rootlets
40853_2.4	5	FM	2.5YR58	MAT	MA	1	F	rootlets
40853_2.5	0	-	-	-	MA	0	F	-
40853_3.1	15	FM	2.5YR58	MAT	MA	1	W	plant materials, rootlets
40853_3.2	30	FM	2.5YR58	MAT	MA	1	F	rootlets
40853_3.3	5	FM	2.5YR58	MAT	MA	1	F	rootlets
40853_3.4	0	-	-	-	-	0	VF	rootlets
40853_3.5	0	-	-	-	-	0	VF	-
40853_4.1	0	-	-	-	MA	1	W	plant materials, rootlets
40853_4.2	2	FM	2.5YR58	MAT, RPO	MA	1	F	rootlets
40853_4.3	15	FM	2.5YR58	MAT, RPO	MA	1	F	rootlets
40853_4.4	0	-	-	-	-	0	F	rootlets
40853_4.5	0	-	-	-	-	0	F	-
40853_5.1	20	FM	5YR56	MAT, RPO	MA	1	W	plant materials, rootlets
40853_5.2	20	FM	5YR56	MAT, RPO	MA	1	W	rootlets
40853_5.3	15	FM	5YR56	MAT, RPO	MA	1	F	rootlets
40853_5.4	15	FM	5YR56	MAT	-	0	F	rootlets
40853_5.5	2	FM	5YR56	MAT	-	0	F	-

APPENDIX 11: WIMMERA RIVER (40855) SUMMARY REPORT

APPENDIX 11:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40855

Wetland Name: Wimmera River

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 WIMMERA RIVER 3
1.1 Location and Setting Description 3
1.2 Soil Profile Description and Distribution 3
1.3 Summary of Field and Laboratory Results 8
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 8
1.3.2 Acid Base Accounting 11
1.3.3 Titratable Actual Acidity (TAA) 11
1.3.4 Chromium Reducible Sulfur (S_{CR}) 11
1.3.5 Acid Volatile Sulfur (AVS) 11
1.3.6 Retained Acidity (RA) 11
1.3.7 Acid Neutralising Capacity (ANC) 11
1.3.8 Net Acidity 11
1.3.9 Water soluble SO_4 11
1.4 Hydrochemistry 13
1.5 Discussion 13
1.6 Summary of Key Findings for Wimmera River 14

LIST OF TABLES

table 1 – Soil Identification, Subtype And General Location Description For Wimmera River Sites. 4
Table 2 – Summary Of Key Findings 14
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Wimmera River. 16
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Wimmera River. 19
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Wimmera River. 20
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Wimmera River. 21
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Wimmera River. 23

LIST OF FIGURES

Figure 1 – Wimmera River 40855 Site Plan.

Figure 2 – Wimmera River Conceptual Hydrotoposequence Cross Section – 40855.

Figure 4 – Photographs of site 40855_2, showing the surface condition and the soil profile of very weak, very dark grey silty clay loam overlying firm, greyish brown, silty clayey sand.

Figure 5 – Photographs of site 40855_3, showing the water surface (water column of 70cm), and the laid out soil profile of very soft, greyish brown clayey sand overlying weak, dark grey clayey sand and sandy clay.

Figure 6 – Photographs of site 40855_4, showing the surface condition and the laid out soil profile of very weak, dark greyish brown sandy clay loam overlying weak, very dark grey, loamy sand and clay loam.

Figure 7 – Photographs of site 40855_5, showing the water surface (water column of 40cm), and the laid out soil profile of very weak, dark grey sandy loam overlying weak, dark grey to bluish grey sandy clay loam.

Figure 8 – Photographs of site 40855_6, showing the surface condition and the soil profile of loose, black sand and loamy sand overlying firm, dark grey, silty clay loam.

Figure 9 – Photographs of site 40855_7, showing the water surface (water column of 18cm), and the laid out soil profile of very soft, dark grey silty loam overlying weak, dark grey silty clay loam.

Figure 10 – Photographs of site 40855_8, showing the surface condition and the soil profile of very soft, very dark grey, silty clay loam overlying firm, very dark grey, sandy clay loam.

Figure 11 – Depth profiles of soil pH for Wimmera River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 12 (continued) – Depth profiles of soil pH for Wimmera River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 13 – Acid base accounting depth profiles for Wimmera River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

Figure 14 – Acid base accounting depth profiles for Wimmera River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 WIMMERA RIVER

1.1 Location and Setting Description

Wimmera River is situated in western Victoria, approximately 1km west of the township of Jeparit and 66km North West of Horsham VIC. The wetland is accessed from Nhill Jeparit Road and other local streets within Jeparit. The wetland is linear to curved in shape with meander bends and several circular, shallow water oxbow like channels throughout. The wetland area is 2 kilometre in length and typically 300 metres wide, with a total area of 71 hectares.

The wetland is typically a stream channel with several circular sections off the main river channel. The oxbow like circular channels appear to be connected to the Wimmera River at times of higher water levels. The wetland has minor (moderately sloping) channel banks in the southern section with more pronounced banks in the northern sections. The northern sections have higher and steeply sloping channel banks leading up onto the floodplain.

At the time of inspection in May 2010, the wetland stream channel contained deep surface water with remaining areas of the wetland often containing shallow surface water. Water within the wetland was slight brown to clear and the bottom or lowest point could be seen visually through the water column (>1.50m). The water line and banks around the periphery of the stream channel contained salt bushes and some medium shrubs at sites sampled. The higher banks and water line of the wetland contained medium sized trees, salt bush and decomposed reeds and rush matting.

Anecdotally, the wetland was dry for almost a decade with flow only returning within the past 2 years from environmental flows. This information was provided by the cultural heritage officer during sampling who lives within the region. Eight sites were sampled as shown in **Figure 1** on the following page.

1.2 Soil Profile Description and Distribution

Eight sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at four different areas of the wetland with two sites chosen for each transect. **Figure 1** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figure 2** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 10** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40855_1: soft, salt bush, low point, subaqueous; soil consisted of very soft, dark greyish brown silty clay loam overlying very weak, dark greyish brown and very dark greenish grey silty clay loam and clay.
- 40855_2: soft, bare, high point, upper bank; soil consisted of very weak, very dark grey silty clay loam overlying firm, greyish brown, silty clayey sand.
- 40855_3: soft, bare, low point, subaqueous; soil consisted of very soft, greyish brown clayey sand overlying weak, dark grey clayey sand and sandy clay.

DATE 09/07/2010

SCALE 1:7,000 (0 – 87.5 – 175 – 350 Meters)

PAGE SIZE A3

COORDINATE SYSTEM MGA Zone 54

FIG NO. 1

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: Inset Photos show Surface Condition of Site

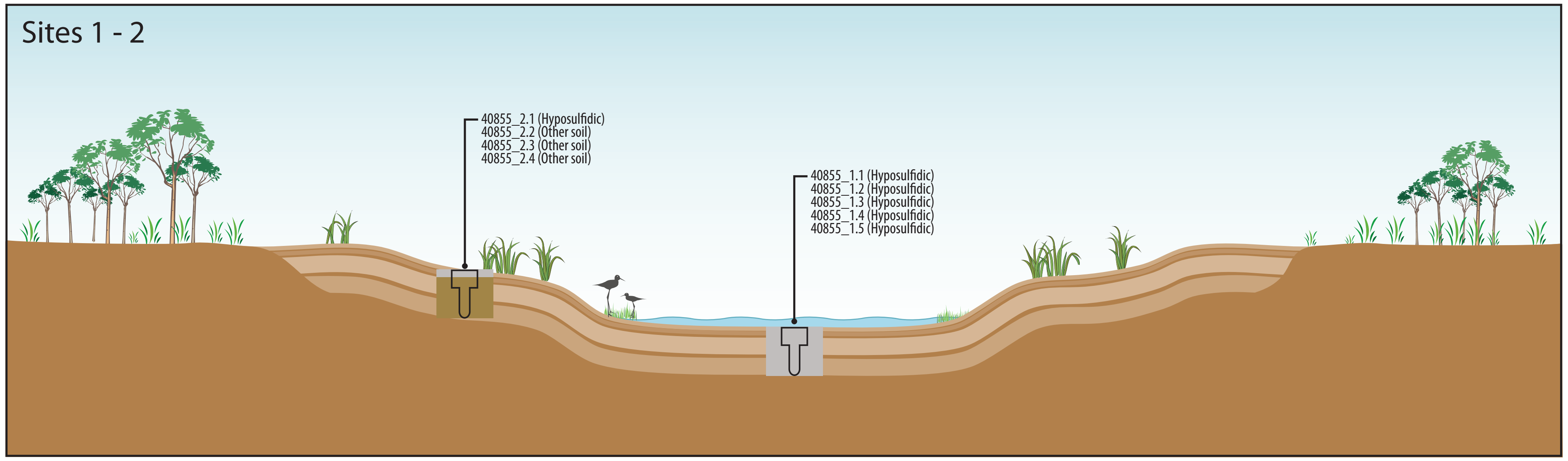
CREATED BY B. Stewart

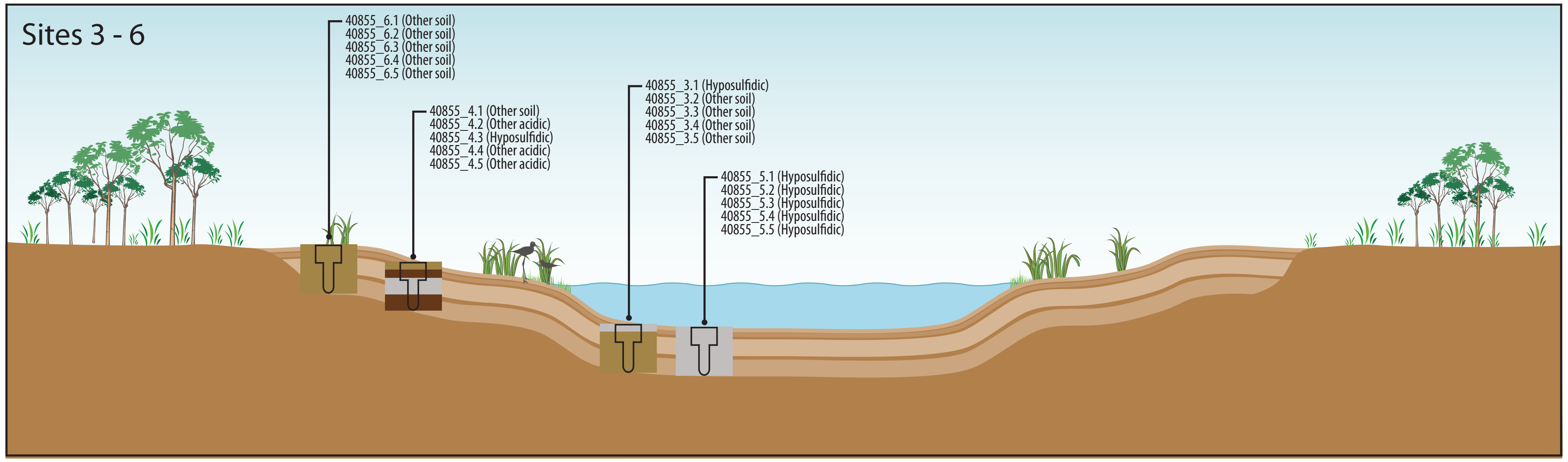
LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

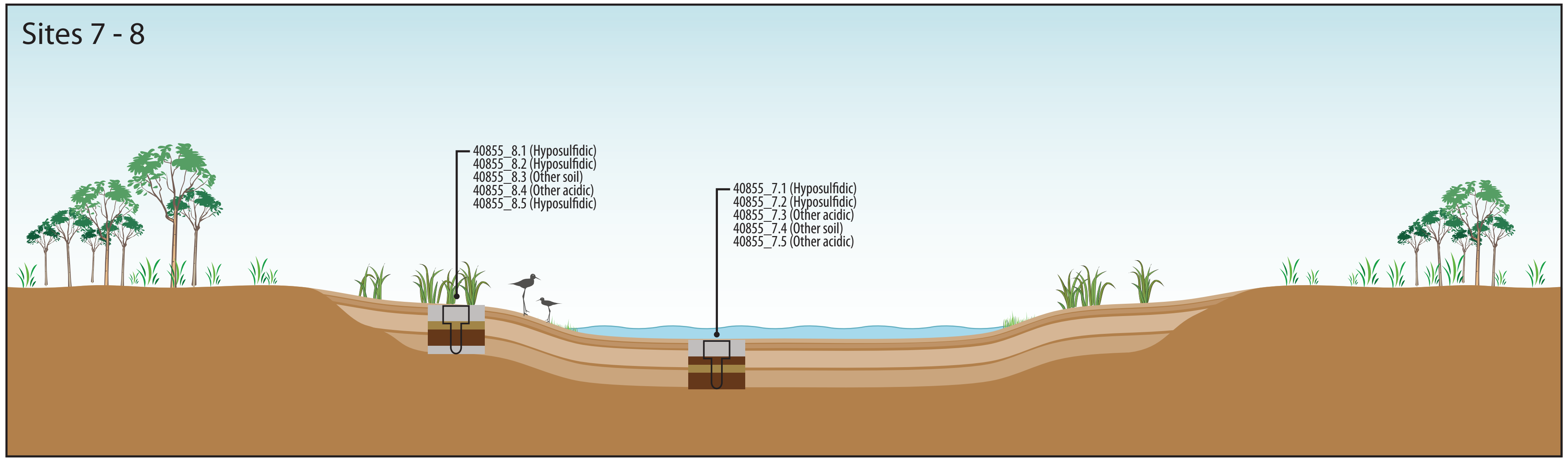
PROJECT NO. 3001801

FIGURE TITLE Wimmera River 40855 CMA:GBCMA

SMEC







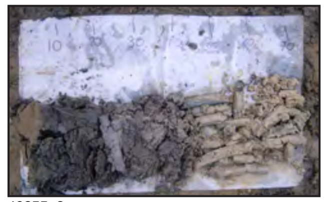
LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils


40855_1


40855_2


40855_2


40855_3


40855_4


40855_4


40855_5


40855_6


40855_7


40855_8


40855_8

DATE 15/07/2010	**SCALE** Not to Scale	**FIG NO.** 2	**PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS	**PROJECT NO.** 3001801	**FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Wimmera River 40855

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

Australian Government

MURRAY–DARLING BASIN AUTHORITY

- 40855_4: loose, bare, mid point, upper channel bank; soil consisted of very weak, dark greyish brown sandy clay loam overlying weak, very dark grey, loamy sand and clay loam.
- 40855_5: soft, bare, low point, subaqueous; soil consisted of very weak, dark grey sandy loam overlying weak, dark grey to bluish grey sandy clay loam.
- 40855_6: loose, salt bush, high point, upper bank slope; soil consisted of loose, black sand and loamy sand overlying firm, dark grey, silty clay loam.
- 40855_7: soft, bare, low point, subaqueous; soil consisted of very soft, dark grey silty loam overlying weak, dark grey silty clay loam.
- 40855_8: soft, decomposed rushes, reeds and salt bush, mid point, upper bank; soil consisted of very soft, very dark grey, silty clay loam overlying firm, very dark grey, sandy clay loam.

Table 1 – Soil Identification, subtype and general location description for Wimmera River Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40855_1	48304	5988472	Hydrosol - sandy or loamy	Low point, subaqueous sediments, middle of oxbow section.
40855_2	48313	5988461	Hydrosol - sandy or loamy	High point, bare, upper bank of oxbow section.
40855_3	48306	5988360	Subaqueous soil	Low point, subaqueous sediments, edge of Wimmera River channel.
40855_4	48309	5988360	Hydrosol - sandy or loamy	Mid point, bare, upper channel bank of Wimmera River.
40855_5	46835	5988859	Subaqueous soil	Low point, subaqueous sediments, edge of Wimmera River channel.
40855_6	46841	5988850	Hydrosol - sandy or loamy	Mid point, salt bush, upper steep sloping channel bank of Wimmera River.
40855_7	47625	5989083	Subaqueous soil	Low point, bare, subaqueous sediments, flat shallow section of channel.
40855_8	47635	5989081	Hydrosol - sandy or loamy	Mid point, decomposed rushes, reeds and salt bush, upper bank.

Figure 3 – Photographs of site 40855_1, showing the water surface (water column of 10cm), and the laid out soil profile of very soft, dark greyish brown silty clay loam overlying very weak, dark greyish brown and very dark greenish grey silty clay loam and clay.

Figure 4 – Photographs of site 40855_2, showing the surface condition and the soil profile of very weak, very dark grey silty clay loam overlying firm, greyish brown, silty clayey sand.

Figure 5 – Photographs of site 40855_3, showing the water surface (water column of 70cm), and the laid out soil profile of very soft, greyish brown clayey sand overlying weak, dark grey clayey sand and sandy clay.

Figure 6 – Photographs of site 40855_4, showing the surface condition and the laid out soil profile of very weak, dark greyish brown sandy clay loam overlying weak, very dark grey, loamy sand and clay loam.

Figure 7 – Photographs of site 40855_5, showing the water surface (water column of 40cm), and the laid out soil profile of very weak, dark grey sandy loam overlying weak, dark grey to bluish grey sandy clay loam.

Figure 8 – Photographs of site 40855_6, showing the surface condition and the soil profile of loose, black sand and loamy sand overlying firm, dark grey, silty clay loam.

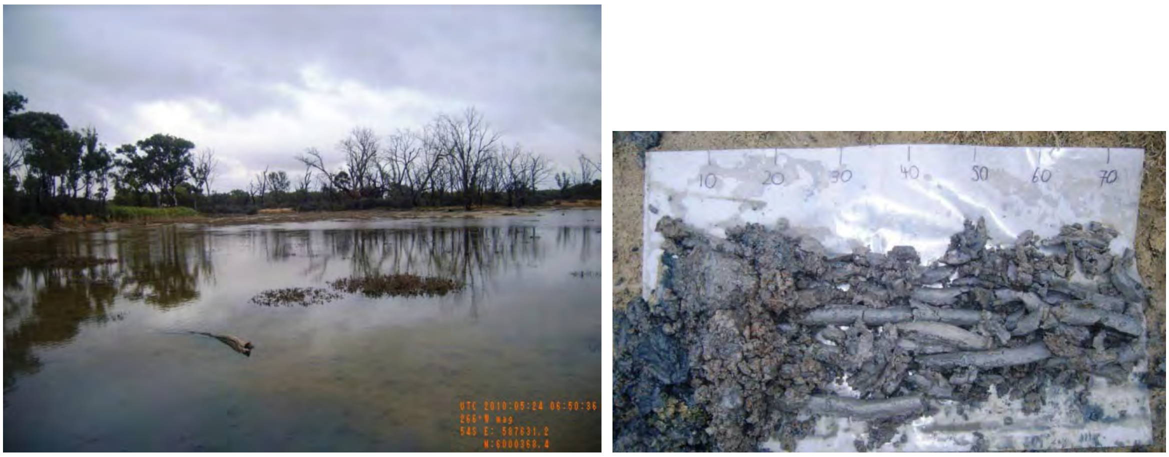


Figure 9 – Photographs of site 40855_7, showing the water surface (water column of 18cm), and the laid out soil profile of very soft, dark grey silty loam overlying weak, dark grey silty clay loam.

Figure 10 – Photographs of site 40855_8, showing the surface condition and the soil profile of very soft, very dark grey, silty clay loam overlying firm, very dark grey, sandy clay loam.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figures 11 and 12** on the following pages. Summary soil pH profile results indicate:

- 40855_1: all samples have $pH_w < 7.5$. Surface soils (0 - 25cm) have pH_w 4.88 – 7.21 with subsoils (25 – 95cm) ranging 5.46 – 6.75. Surface soils $pH_{incubation}$ ranged 4.75 – 5.41 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 6.09 – 6.42 indicating hyposulfidic conditions.
- 40855_2: all samples have $pH_w < 8.0$. Surface soils (0 - 10cm) have pH_w 7.01 – 7.44 with subsoils (10 – 75cm) ranging 7.49 – 7.91. Surface soils $pH_{incubation}$ ranged 6.10 – 6.20 indicating hyposulfidic and other soil conditions. Subsoils $pH_{incubation}$ ranged 6.67 – 7.07 indicating other soil conditions.
- 40855_3: all samples have $pH_w < 9.0$. Surface soils (0 - 20cm) have pH_w 7.51 – 8.67 with subsoils (20 – 75cm) ranging 6.29 – 6.77. Surface soils $pH_{incubation}$ ranged 6.46 – 7.10 indicating hyposulfidic and other soil conditions. Subsoils $pH_{incubation}$ ranged 5.65 – 5.75 indicating other soil conditions.
- 40855_4: all samples have $pH_w < 8.0$. Surface soils (0 - 15cm) have pH_w 6.27 – 7.88 with subsoils (15 – 110cm) ranging 5.59 – 7.56. Surface soils $pH_{incubation}$ ranged 4.90 – 7.10 indicating other acidic and other soil conditions. Subsoils $pH_{incubation}$ ranged 4.58 – 5.09 indicating hyposulfidic and other soil conditions.
- 40855_5: all samples have $pH_w < 9.0$. Surface soils (0 - 25cm) have pH_w 7.79 – 8.81 with subsoils (25 – 100cm) ranging 7.76 – 8.01. Surface soils $pH_{incubation}$ ranged 6.48 – 7.03 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.60 – 6.99 indicating hyposulfidic conditions.
- 40855_6: all samples have $pH_w < 9.5$. Surface soils (0 - 10cm) have pH_w 9.03 – 9.10 with subsoils (10 – 95cm) ranging 7.28 – 7.44. Surface soils $pH_{incubation}$ ranged 7.56 – 8.10 indicating other soil conditions. Subsoils $pH_{incubation}$ ranged 6.29 – 6.77 indicating other soil conditions.
- 40855_7: all samples have $pH_w < 8.5$. Surface soils (0 - 15cm) have pH_w 7.20 – 8.04 with subsoils (15 – 75cm) ranging 6.02 – 6.40. Surface soils $pH_{incubation}$ ranged 6.48 – 6.55 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.39 – 6.31 indicating other acidic and other soil conditions.
- 40855_8: all samples have $pH_w < 8.0$. Surface soils (0 - 15cm) have pH_w 7.39 – 7.58 with subsoils (15 – 100cm) ranging 6.31 – 6.46. Surface soils $pH_{incubation}$ ranged 6.42 – 6.63 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.48 – 5.78 indicating hyposulfidic, other acidic and other soil conditions.

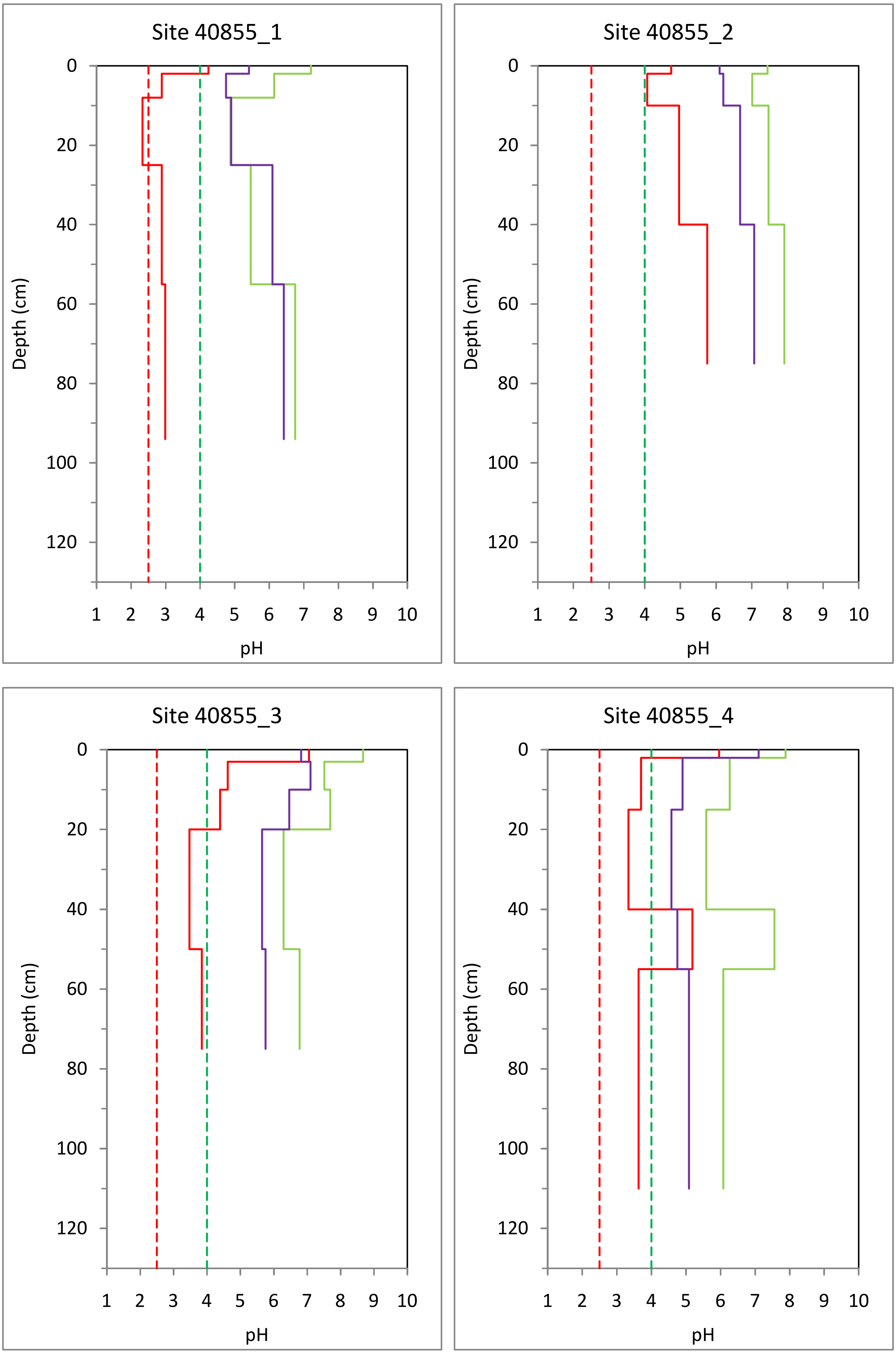


Figure 11 – Depth profiles of soil pH for Wimmera River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

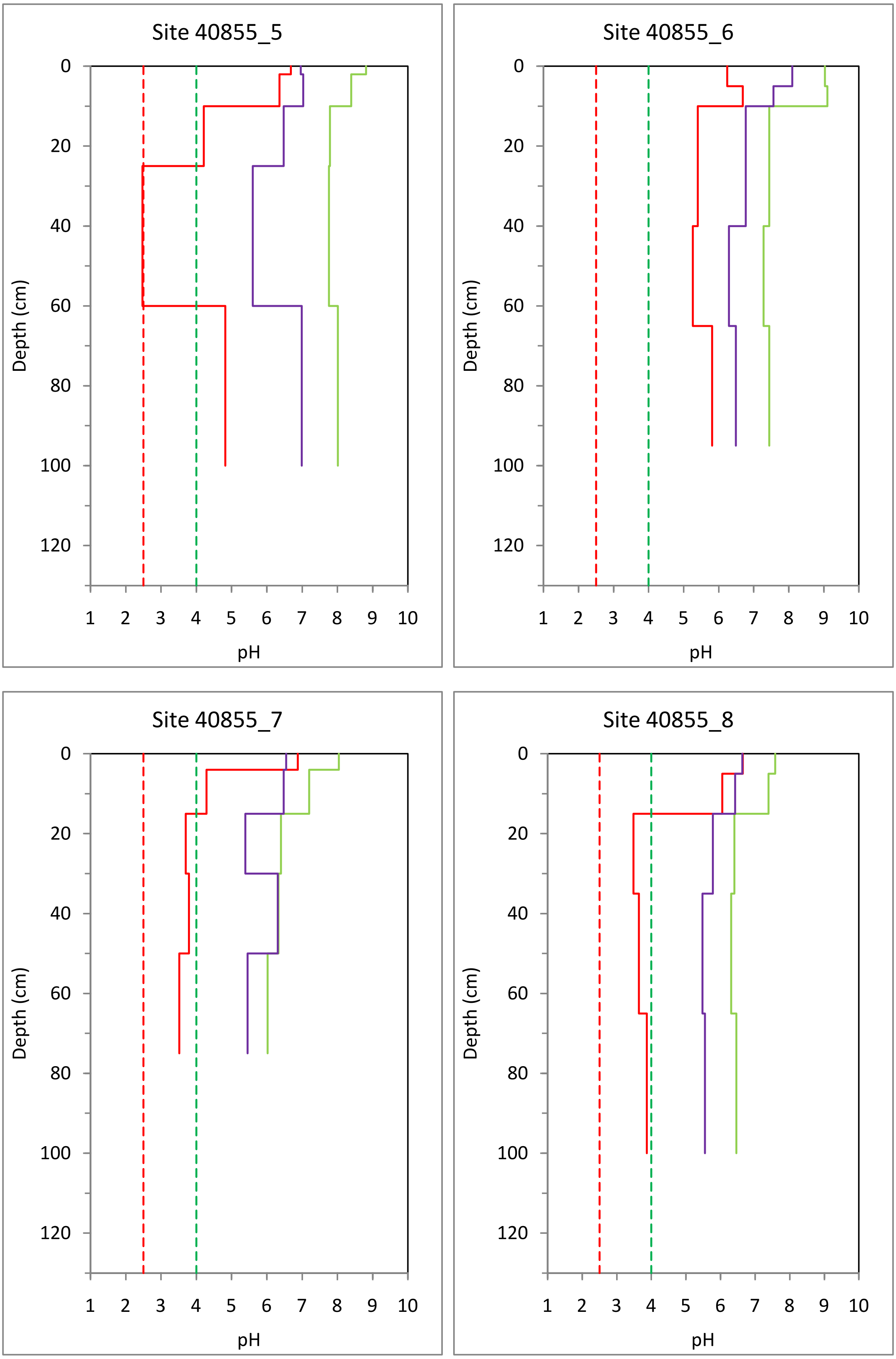


Figure 12 – Depth profiles of soil pH for Wimmera River, showing soil pH (pH$_w$ as green line), peroxide treated pH (pH$_{peroxide}$ as red line) and ageing pH (pH$_{incubation}$ after 8 weeks as purple line). Critical pH$_w$ and pH$_{incubation}$ value of 4.0 (green dashed line) and critical pH$_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 13 and 14** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 39 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 0 – 37 mole H+/tonne for samples analysed. The actual acidity values are supported by the pH profiles for the wetland indicating typically near neutral to alkaline conditions throughout the soil profile.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 39 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where S_{CR} ≥ 0.01% S. Results ranged from <0.01 (limit of laboratory detection) to 0.31% S. 21 out of the 39 collected samples (54%) had S_{CR} <0.01% S with 5 out of the 39 soil samples (13%) having S_{CR} >0.10% S. The highest results were typically encountered within surface, subaqueous materials from within the river channel and low points.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Wimmera River.

1.3.6 Retained Acidity (RA)

No pH_{KCL} results were below the threshold of 4.50 for retained acidity analysis. Therefore, no samples were analysed for Retained Acidity (RA).

1.3.7 Acid Neutralising Capacity (ANC)

5 out of the 39 soil samples collected were analysed for Acid Neutralising Capacity (ANC). Results ranged from 0.36 – 2.01 %$CaCO_3$ (equivalent in acidity units to 72 – 402 mole H+/tonne). Typically, buffering capacity occurred within surface soils within subaqueous and low point environments with the exception of 40855_5 occurring within subsoils.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between -187 to 130 mol H+/tonne. 34 out of the 39 samples (87%) have a low net acidity, 4 samples have moderate net acidity with one sample from site 40855_1 having high net acidity.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 42 to 10,260 mg/L for surface soil samples collected (i.e. 0 – 10cm). Eight surface soil samples were analysed for water soluble sulfate in total. All surface samples exceeded the trigger criterion of 100 mg/L for MBO formation potential with the exception of site 40855_6.

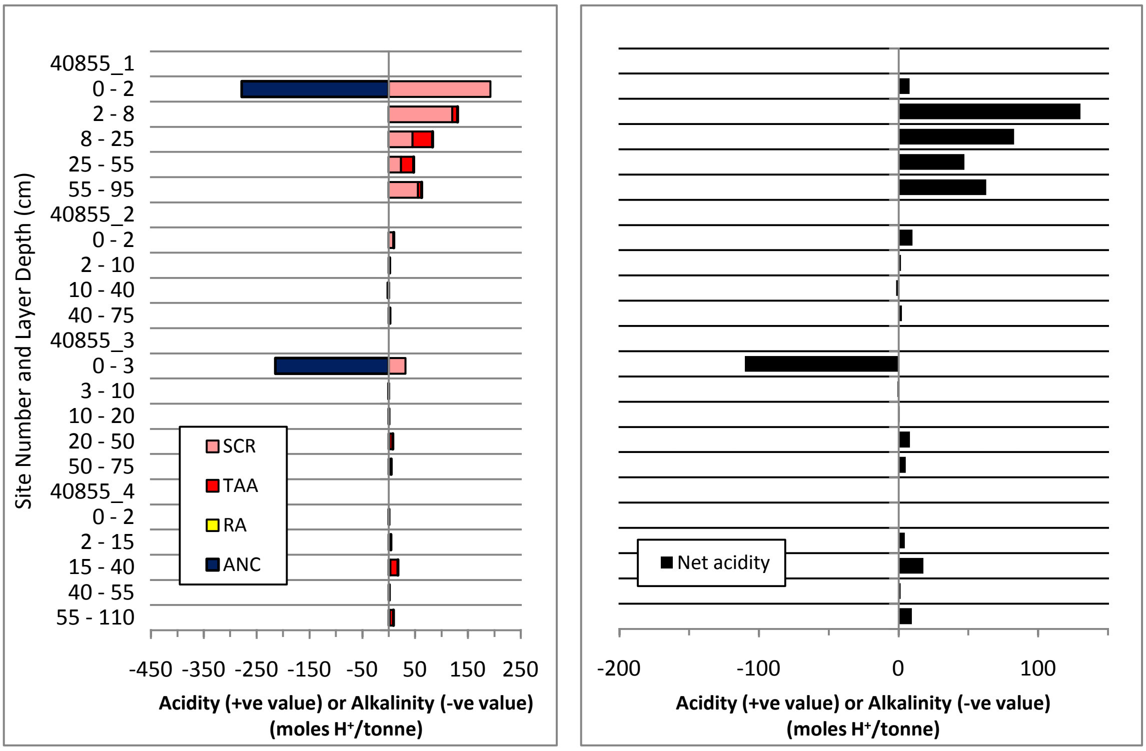


Figure 13 – Acid base accounting depth profiles for Wimmera River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

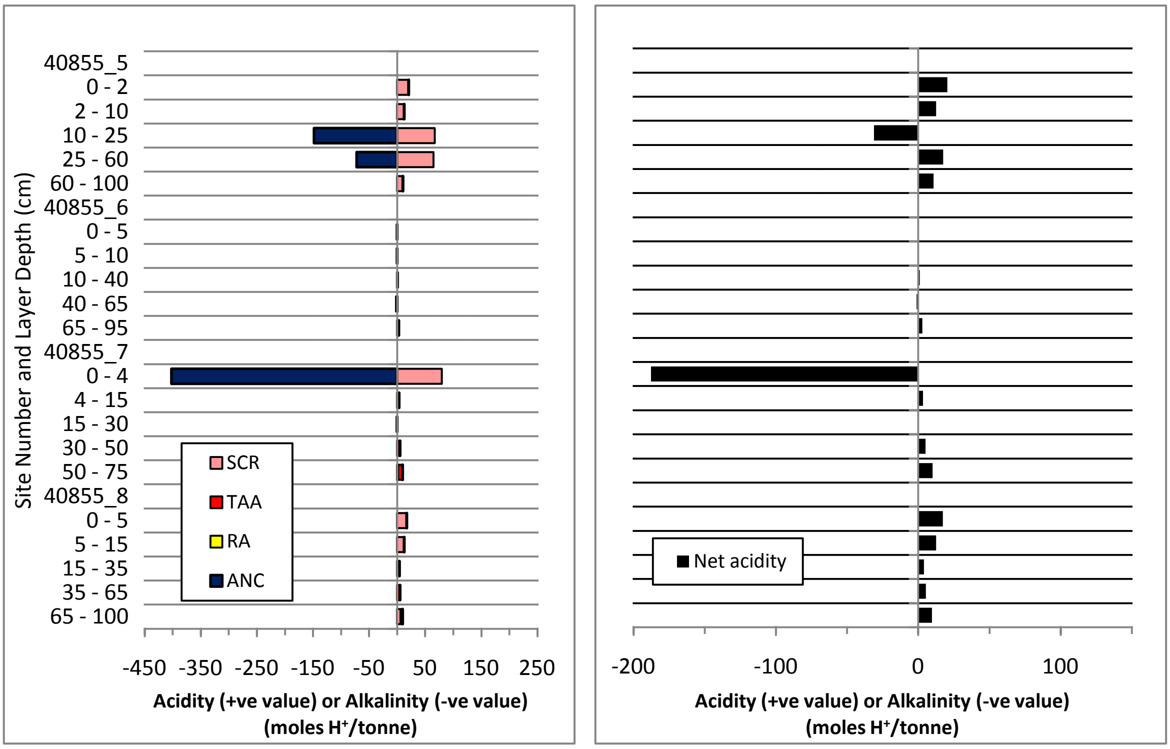


Figure 14 – Acid base accounting depth profiles for Wimmera River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at six out of the eight sites from Wimmera River. Measurements were taken from both pit inflow waters (2) and surface waters (4). Four water samples were collected for laboratory analysis from sites 40855_1 (SW), 40855_2 (PW), 40855_3 (SW) and 40855_8 (PW).

The surface waters within Wimmera River channel were alkaline (pH 8.40 – 8.49) and outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems pH range of 6.5 – 8.0. Surface water from site 40855_1 was slightly acidic (pH 6.29) with noticeable iron floc on the surface of the shallow channel. Pit inflow waters were acidic to slightly acidic at sites 40855_2 (pH 5.99) and 40855_8 (pH 6.48).

SEC values for surface water ranged 22,050 – 39,900µS/cm which was outside the ANZECC 2000 Lowland River criterion values of 125 – 2,200µS/cm. SEC values for pit inflow water was higher and ranged 44,100 – 78,600µS/cm which was outside the ANZECC 2000 Lowland River criterion values. All sites were outside the ANZECC 2000 Freshwater Lakes criterion values of 20 – 30µS/cm.

Alkalinity (as HCO_3) ranged between 20 – 40mg/L for pit water inflow and was higher for Wimmera River channel water (>240 mg/L) with the exception of the shallow water within the shallow channel (40588_1) with a value of 40 mg/L. All sites had oxidising conditions ranging 60 – 170 Eh with the exception of site 40855_1 with a value of -22 Eh. Surface water within the Wimmera River channel had DO concentration ranging 10.64 – 11.60mg/L with a lower concentration from pit inflow water and the shallow surface water from site 40855_1 ranging 1.43 – 2.45 mg/L.

Surface and pit inflow water exceeded the most relevant ANZECC 2000 trigger values for some nutrients (NO_3 and NH_4) and some dissolved metals (Al, Cd, Co, Fe, MN, Ni and Zn).

The water data indicates that the Wimmera River channel surface water has not been affected by acidification with pH values >8.00. Pit inflow water and shallow waters within the shallow circular channel system (40855_1 and 40855_2) indicate pH values <6.50 that have been affected slightly by acidification. The Wimmera River channel has high alkalinity and SEC values for surface waters providing buffering capacity.

1.5 Discussion

Acid sulfate soils within Wimmera River occurred as hyposulfidic materials typically within low subaqueous areas (Wimmera River channel) and within occasional soil layers on the upper banks. The remaining soils were either other acidic or other soils at each site sampled.

Results ranged from <0.01 (limit of laboratory detection) to 0.31%S. 21 out of the 39 collected samples (54%) had S_{CR} <0.01% S with 5 out of the 39 soil samples (13%) having S_{CR} >0.10% S. The highest results were typically encountered surface subaqueous No monosulfidic or sulfuric materials were encountered at the wetland from sites sampled. Water soluble sulfate values ranged between 42 to 10,260 mg/L and exceeded the trigger criterion of 100 mg/L for MBO formation potential with the exception of site 40855_6.

Net acidity results for all sites and samples ranged between -187 to 130 mol H+/tonne. 34 out of the 39 samples (87%) have a low net acidity, 4 samples have moderate net acidity with one sample from site 40855_1 having high net acidity.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are five (5) high priority samples based on the presence of hyposulfidic materials (S_{CR} >0.10%) and seven (7) high priority samples based on water soluble sulfate results above the trigger criterion of 100 mg/L. There are thirteen (13) moderate priority samples based on the presence of hyposulfidic materials (S_{CR} <0.10%). Remaining soil materials sampled are classified as "no further assessment".

Due to the low net acidity values for samples collected (87% - low) the requirement for Phase 2 laboratory analysis may not be warranted for Wimmera River. In addition, there is high alkalinity and buffering capacity within the wetland channel waters. However, water soluble sulfate values ranged between 42 to 10,260 mg/L and exceeded the trigger criterion of 100 mg/L for MBO formation potential at the majority of sites. Phase 2 analysis for the "Monosulfidic Formation Potential Method" may be suitable for selected surface samples.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Wimmera River are:

- Acidification hazard: low level of concern based on the low net acidities and sulfidic results (from S_{CR}). The degree of acidification potential from sulfidic sources only appears to be low. In addition, the wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources.

- De-oxygenation hazard: medium to high level of concern as water soluble sulfate results for the majority of surface soil materials exceeded the trigger value for monosulfide formation, although no MBO materials were observed in subaqueous areas that were sampled. As the wetland has only recently been inundated (within the last 2 years, anecdotally) MBO may not have had sufficient time to form within subaqueous environments.

- Metal mobilisation: The low acidification hazard indicates that sulfidic sources of acidity may not be sufficient for metals mobilisation. The wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources and therefore reduce the risk of metals being liberated from sulfidic sources.

1.6 Summary of Key Findings for Wimmera River

The summary of key findings for Wimmera River is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Monosulfidic materials were not observed. • Hypersulfidic materials were not observed. • Sulfidic materials identified included hyposulfidic materials occurring in low subaqueous areas (Wimmera River channel) and within occasional soil layers on the upper banks of Wimmera River. • The remaining soils were either other acidic or other soils. • Net acidities ranged between -187 to 130 mol H+/tonne (moderate). • Water soluble sulfate values ranged between 42 to 10,260 mg/L and exceeded the trigger criterion of 100 mg/L for MBO formation potential at 7 out of the 8 sites.

Acid sulfate soil identification:	• Site 1: Hydrosol – sandy or loamy occurring within shallow subaqueous environment in shallow circular channel section. • Site 2: Hydrosol – sandy or loamy occurring at upper bank of shallow circular channel section. • Site 3: Subaqueous soil occurring within Wimmera River channel edge, subaqueous. • Site 4: Hydrosol – sandy or loamy occurring at upper bank of Wimmera River channel edge. • Site 5: Subaqueous soil occurring within Wimmera River channel edge, subaqueous. • Site 6: Hydrosol – sandy or loamy occurring at upper bank of Wimmera River channel edge. • Site 7: Subaqueous soil occurring within Wimmera River channel edge, subaqueous. • Site 8: Hydrosol – sandy or loamy occurring at upper bank of Wimmera River channel edge.
Hazard assessment:	• Acidification hazard – low level of concern. • De-oxygenation hazard – medium to high level of concern. • Metal mobilisation hazard – low level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Wimmera River.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40855_1.1	40855_1	0	2	0.1102	0.0590	46	7.21	4.24	5.41	8895
40855_1.2	40855_1	2	8	0.1206	0.0716	41	6.14	2.89	4.75	-
40855_1.3	40855_1	8	25	0.1062	0.0609	43	4.88	2.33	4.90	-
40855_1.4	40855_1	25	55	0.1084	0.0649	40	5.46	2.89	6.09	-
40855_1.5	40855_1	55	95	0.1049	0.0697	34	6.75	2.99	6.42	-
40855_2.1	40855_2	0	2	0.1322	0.1006	24	7.44	4.74	6.10	10260
40855_2.2	40855_2	2	10	0.1316	0.0992	25	7.01	4.07	6.20	-
40855_2.3	40855_2	10	40	0.1417	0.1100	22	7.47	4.96	6.67	-
40855_2.4	40855_2	40	75	0.1536	0.1271	17	7.91	5.75	7.07	-
40855_3.1	40855_3	0	3	0.1425	0.1095	23	8.67	7.05	6.82	429
40855_3.2	40855_3	3	10	0.1455	0.1166	20	7.51	4.62	7.10	-
40855_3.3	40855_3	10	20	0.1441	0.1135	21	7.69	4.39	6.46	-
40855_3.4	40855_3	20	50	0.1479	0.1175	21	6.29	3.47	5.65	-
40855_3.5	40855_3	50	75	0.1335	0.1043	22	6.77	3.84	5.75	-
40855_4.1	40855_4	0	2	0.1387	0.1126	19	7.88	5.96	7.10	4035
40855_4.2	40855_4	2	15	0.1300	0.0977	25	6.27	3.70	4.90	-
40855_4.3	40855_4	15	40	0.1283	0.0946	26	5.59	3.34	4.58	-
40855_4.4	40855_4	40	55	0.1337	0.1115	17	7.56	5.19	4.75	-
40855_4.5	40855_4	55	110	0.1352	0.1050	22	6.08	3.63	5.09	-
40855_5.1	40855_5	0	2	0.1545	0.1236	20	8.81	6.68	6.96	315
40855_5.2	40855_5	2	10	0.1366	0.1017	26	8.39	6.36	7.03	-
40855_5.3	40855_5	10	25	0.1354	0.0942	30	7.79	4.21	6.48	-
40855_5.4	40855_5	25	60	0.1368	0.1001	27	7.76	2.47	5.60	-
40855_5.5	40855_5	60	100	0.1369	0.1091	20	8.01	4.82	6.99	-
40855_6.1	40855_6	0	5	0.1281	0.1190	7	9.03	6.24	8.10	42
40855_6.2	40855_6	5	10	0.1103	0.1012	8	9.10	6.69	7.56	-
40855_6.3	40855_6	10	40	0.0982	0.0822	16	7.44	5.40	6.77	-
40855_6.4	40855_6	40	65	0.1113	0.0938	16	7.28	5.26	6.29	-
40855_6.5	40855_6	65	95	0.1146	0.0958	16	7.44	5.81	6.49	-
40855_7.1	40855_7	0	4	0.1210	0.0773	36	8.04	6.88	6.55	1350
40855_7.2	40855_7	4	15	0.1197	0.0842	30	7.20	4.29	6.48	-

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40855_7.3	40855_7	15	30	0.1130	0.0790	30	6.40	3.70	5.39	-
40855_7.4	40855_7	30	50	0.1236	0.0892	28	6.33	3.79	6.31	-
40855_7.5	40855_7	50	75	0.1318	0.1003	24	6.02	3.52	5.45	-
40855_8.1	40855_8	0	5	0.1100	0.0744	32	7.58	6.64	6.63	2745
40855_8.2	40855_8	5	15	0.1273	0.0878	31	7.39	6.05	6.42	-
40855_8.3	40855_8	15	35	0.1242	0.0899	28	6.40	3.48	5.78	-
40855_8.4	40855_8	35	65	0.1201	0.0927	23	6.31	3.64	5.48	-
40855_8.5	40855_8	65	100	0.1261	0.0995	21	6.46	3.87	5.55	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Wimmera River

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40855_1.1	40855_1	0	2	7.16	0	0.31	0	1	8	-	Hyposulfidic
40855_1.2	40855_1	2	8	6.20	10	0.19	0	-	130	-	Hyposulfidic
40855_1.3	40855_1	8	25	4.69	37	0.07	0	-	83	-	Hyposulfidic
40855_1.4	40855_1	25	55	5.32	24	0.04	0	-	47	-	Hyposulfidic
40855_1.5	40855_1	55	95	6.26	7	0.09	0	-	63	-	Hyposulfidic
40855_2.1	40855_2	0	2	6.96	0	0.02	0	-	10	-	Hyposulfidic
40855_2.2	40855_2	2	10	6.63	0	<0.01	0	-	2	-	Other soil
40855_2.3	40855_2	10	40	6.56	0	<0.01	0	-	-2	-	Other soil
40855_2.4	40855_2	40	75	6.68	0	<0.01	0	-	2	-	Other soil
40855_3.1	40855_3	0	3	8.79	0	0.05	0	1	-110	-	Hyposulfidic
40855_3.2	40855_3	3	10	7.74	0	<0.01	0	-	-1	-	Other soil
40855_3.3	40855_3	10	20	7.27	0	<0.01	0	-	1	-	Other soil
40855_3.4	40855_3	20	50	6.07	6	<0.01	0	-	8	-	Other soil
40855_3.5	40855_3	50	75	6.35	2	<0.01	0	-	5	-	Other soil
40855_4.1	40855_4	0	2	8.08	0	<0.01	0	-	0	-	Other soil
40855_4.2	40855_4	2	15	6.44	3	<0.01	0	-	4	-	Other acidic
40855_4.3	40855_4	15	40	5.52	14	0.01	0	-	18	-	Hyposulfidic
40855_4.4	40855_4	40	55	6.56	0	<0.01	0	-	1	-	Other acidic

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol H^+ t^{-1}	%	mol H^+ t^{-1}	$\%CaCO_3$	mol H^+ t^{-1}	%Sav DW	class
40855_4.5	40855_4	55	110	5.95	7	<0.01	0	-	9	-	Other acidic
40855_5.1	40855_5	0	2	9.04	0	0.03	0	-	20	-	Hyposulfidic
40855_5.2	40855_5	2	10	8.64	0	0.02	0	-	13	-	Hyposulfidic
40855_5.3	40855_5	10	25	7.93	0	0.11	0	1	-31	-	Hyposulfidic
40855_5.4	40855_5	25	60	7.66	0	0.10	0	0	17	-	Hyposulfidic
40855_5.5	40855_5	60	100	7.64	0	0.02	0	-	11	-	Hyposulfidic
40855_6.1	40855_6	0	5	9.16	0	<0.01	0	-	0	-	Other soil
40855_6.2	40855_6	5	10	9.16	0	<0.01	0	-	0	-	Other soil
40855_6.3	40855_6	10	40	7.85	0	<0.01	0	-	1	-	Other soil
40855_6.4	40855_6	40	65	7.44	0	<0.01	0	-	-1	-	Other soil
40855_6.5	40855_6	65	95	7.32	0	<0.01	0	-	3	-	Other soil
40855_7.1	40855_7	0	4	8.18	0	0.13	0	2	-188	-	Hyposulfidic
40855_7.2	40855_7	4	15	7.45	0	0.01	0	-	3	-	Hyposulfidic
40855_7.3	40855_7	15	30	6.55	0	<0.01	0	-	0	-	Other acidic
40855_7.4	40855_7	30	50	6.36	4	<0.01	0	-	5	-	Other soil
40855_7.5	40855_7	50	75	6.02	8	<0.01	0	-	10	-	Other acidic
40855_8.1	40855_8	0	5	7.88	0	0.03	0	-	17	-	Hyposulfidic
40855_8.2	40855_8	5	15	7.87	0	0.02	0	-	12	-	Hyposulfidic
40855_8.3	40855_8	15	35	6.38	4	<0.01	0	-	4	-	Other soil
40855_8.4	40855_8	35	65	6.26	5	<0.01	0	-	5	-	Other acidic
40855_8.5	40855_8	65	100	6.30	3	0.01	0	-	10	-	Hyposulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Wimmera River.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40855_1.W1	40855_2.W1	40855_3.W1	-	-	40855_8.W1
Site ID	(number)	-	-	40855_1	40855_2	40855_3	40855_5	40855_7	40855_8
Wetland ID	(code)	-	-	40855	40855	40855	40855	40855	40855
Site Number	(number)	-	-	1	2	3	5	7	8
Upper depth	cm	-	-	-10	32	-30	-30	-18	25
Lower depth	cm	-	-	0	42	0	0	0	35
Temperature	(deg C)	-	-	13.4	14.7	13.4	13.2	14.4	15.4
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	39900	78600	22700	22100	22050	44100
Dissolved Oxygen	(%)	-	-	19.9	25.5	108.4	107.6	105.6	14.2
Dissolved Oxygen	(mg/l)	-	-	2.36	2.45	11.6	11.2	10.64	1.43
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	6.29	5.99	8.40	8.44	8.49	6.48
Redox potential	Eh	-	-	-22	170	72	60	90	145
Turbidity	(NTU)	*6 - 50*	*1 - 20*	25	356	3.2	3.1	9.1	992
HCO_3	(mg/l)	-	-	40	20	>240	>240	>240	40
Comment	-	-	-	SW	PW	SW	SW, no sample collected	SW, no sample collected	PW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Wimmera River.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	24-05-10	24-05-10	24-05-10	24-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201593	2201594	2201595	2201596
Sample ID	(number)	-	40855_1.W1 (SW)	40855_2.W1 (PW)	40855_3.W1(SW)	40855_8.W1 (PW)
Site ID	(number)	-	40855_1	40855_2	40855_3	40855_8
Wetland ID	(code)	-	40855	40855	40855	40855
Site Number	(number)	-	1	2	3	8
Upper depth	cm	-	-10	32	-30	25
Lower depth	cm	-	0	42	0	35
Na	$mg\ l^{-1}$	-	6900	16000	3200	6900
K	$mg\ l^{-1}$	-	79	260	76	75
Ca	$mg\ l^{-1}$	-	820	510	220	1100
Mg	$mg\ l^{-1}$	-	910	1800	420	1300
Si	$mg\ l^{-1}$	-	9.8	32	0.9	46
Br	$mg\ l^{-1}$	-	<5	<5	<5	<5
Cl	$mg\ l^{-1}$	-	15000	36000	8000	17000
NO_3	$mg\ l^{-1}$	0.7	0.9	1.8	0.07	0.49
NH_4-N[K]	$mg\ l^{-1}$	0.01	3.8	1.4	0.1	3.8
PO_4-P[E]	$mg\ l^{-1}$	0.005	<0.01	0.02	<0.01	<0.01
SO_4	$mg\ l^{-1}$	-	3700	4900	1200	2600
Ag	$\mu g\ l^{-1}$	0.05	<1	<1	<1	<1
Al[A]	$\mu g\ l^{-1}$	55	70	60	50	30
As[B]	$\mu g\ l^{-1}$	13	3	5	4	3
Cd	$\mu g\ l^{-1}$	0.2	<0.2	0.4	<0.2	0.8
Co	$\mu g\ l^{-1}$	2.8	69	5	<1	48
Cr[C]	$\mu g\ l^{-1}$	1	<1	<1	<1	<1
Cu[H]	$\mu g\ l^{-1}$	1.4	<1	<1	<1	<1
Fe	$\mu g\ l^{-1}$	300	72000	<20	<20	1400
Mn	$\mu g\ l^{-1}$	1700	1900	250	4	3900
Ni[H]	$\mu g\ l^{-1}$	11	27	8	2	22
Pb[H]	$\mu g\ l^{-1}$	3.4	<1	<1	<1	1
Se	$\mu g\ l^{-1}$	11	3	11	2	3
Zn[H]	$\mu g\ l^{-1}$	8	13	4	<1	10
DOC	$mg\ l^{-1}$	-	26	11	16	8

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A] *Trigger value for Aluminium in freshwater where pH > 6.5.*

[B] *Trigger value assumes As in solution as Arsenic (AsV).*

[C] *Trigger value for Chromium is applicable to Chromium (CrVI)*

[E] *Guideline is for filterable reactive phosphorous (FRP).*

[H] *Hardness affected (refer to Guidelines).*

[K] *Guideline for South-east Australia-Freshwater Lakes and res*

Table 6 - Site description data for acid sulfate soil assessment of Wimmera River.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40855_1	40855	1	24-05-10	54	48304	5988472
40855_2	40855	2	24-05-10	54	48313	5988461
40855_3	40855	3	24-05-10	54	48306	5988360
40855_4	40855	4	24-05-10	54	48309	5988360
40855_5	40855	5	24-05-10	54	46835	5988859
40855_6	40855	6	24-05-10	54	46841	5988850
40855_7	40855	7	24-05-10	54	47625	5989083
40855_8	40855	8	24-05-10	54	47635	5989081

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40855_1	-10	soft	salt bush	low point, subaqueous	Subaqueous sediment samples, iron staining, cut off lagoon	5	Hydrosol - sandy or loamy	part of a cut off stream/oxbow channel form from Wimmera River
40855_2	32	soft	bare	high point	dry point in hydro toposequence, cut off lagoon	5	Hydrosol - sandy or loamy	part of a cut off stream/oxbow channel form from Wimmera River
40855_3	-70	soft	bare	low point, subaqueous	Subaqueous sediment samples, river channel landform	30	Subaqueous soil	within Wimmera River channel
40855_4		loose	bare	mid point	upper channel edge, dryer, river channel landform	10	Hydrosol - sandy or loamy	No water evident
40855_5	-40	soft	bare	low point, subaqueous	Subaqueous sediment samples, river channel landform	30	Subaqueous soil	within Wimmera River channel
40855_6		loose	salt bush	high point	dry point in hydro toposequence, river channel landform	10	Hydrosol - sandy or loamy	No water evident

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40855_7	-18	soft	bare	low point, subaqueous	Subaqueous sediment samples, shallow wide channel	5	Subaqueous soil	-
40855_8	25	soft	decomposed rush matting, reeds salt bush	mid point	dry point in hydro toposequence, shallow wide channel	5	Hydrosol - sandy or loamy	-

Table 7 - Profile description data for acid sulfate soil assessment of Wimmera River.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40855_1.1	SS	0	2	10YR34	Silty clay loam	Loamy	Wet	6.89	1:1
40855_1.2	SS	2	8	GLEY22.510G	Silty clay loam	Loamy	Wet	6.88	1:1
40855_1.3	SS	8	25	2.5Y42	Silty clay loam	Clayey	Wet	6.00	1:1
40855_1.4	PT	25	55	2.5Y42	Silty clay loam	Clayey	Wet	5.21	1:1
40855_1.5	PT	55	95	GLEY135GY	Clay	Clayey	Wet	7.10	1:1
40855_2.1	SS	0	2	2.5Y31	Clay loam sandy	Loamy	Moist	7.15	1:1
40855_2.2	SS	2	10	2.5Y41	Silty clay loam	Loamy	Moist	6.86	1:1
40855_2.3	SS	10	40	2.5Y31	Clay loam sandy	Sandy	Moist	7.09	1:1
40855_2.4	PT	40	75	2.5Y52	Clayey sand	Sandy	Wet	7.23	1:1
40855_3.1	SS	0	3	GLEY12.510Y	Clayey sand	Sandy	Wet	7.08	1:1
40855_3.2	SS	3	10	2.5Y52	Clayey sand	Sandy	Wet	6.69	1:1
40855_3.3	SS	10	20	2.5Y52	Clayey sand	Sandy	Wet	7.17	1:1
40855_3.4	PT	20	50	2.5Y41	Clayey sand	Sandy	Wet	5.88	1:1
40855_3.5	PT	50	75	2.5Y41	Sandy clay	Clayey	Wet	6.51	1:1
40855_4.1	SS	0	2	2.5Y53	Loamy sand	Sandy	Moist	7.17	1:1
40855_4.2	SS	2	15	2.5Y42	Sandy clay loam	Sandy	Moist	5.55	1:1
40855_4.3	SS	15	40	2.5Y42	Sandy clay loam	Sandy	Moist	5.24	1:1
40855_4.4	PT	40	55	2.5Y53	Loamy sand	Sandy	Wet	5.42	1:1
40855_4.5	PT	55	110	2.5Y31	Clay loam	Clayey	Wet	5.75	1:1
40855_5.1	PT	0	2	GLEY1410Y	Sandy loam	Sandy	Wet	8.09	1:1
40855_5.2	PT	2	10	2.5Y41	Sandy loam	Sandy	Wet	7.41	1:1
40855_5.3	PT	10	25	2.5Y41	Sandy loam	Sandy	Wet	7.42	1:1
40855_5.4	PT	25	60	2.5Y41	Sandy clay loam	Clayey	Wet	7.23	1:1
40855_5.5	PT	60	100	GLEY2.55PB	Sandy clay loam	Clayey	Wet	7.83	1:1
40855_6.1	SS	0	5	2.5Y62	Sand	Sandy	Moist	8.74	1:1
40855_6.2	SS	5	10	2.5Y2.51	Loamy sand	Sandy	Moist	8.18	1:1
40855_6.3	SS	10	40	2.5Y2.51	Silty clay loam	Loamy	Moist	7.42	1:1
40855_6.4	PT	40	65	5Y41.	Silty clay loam	Loamy	Moist	7.11	1:1
40855_6.5	PT	65	95	5Y451	Silty clay loam	Clayey	Moist	7.15	1:1
40855_7.1	SS	0	4	GLEY1310Y	Silty loam	Loamy	Wet	7.63	1:1
40855_7.2	SS	4	15	2.5Y41	Silty loam	Clayey	Wet	7.52	1:1

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40855_7.3	PT	15	30	2.5Y41	Silty loam	Clayey	Wet	6.69	1:1
40855_7.4	PT	30	50	2.5Y41	Silty clay loam	Clayey	Wet	6.58	1:1
40855_7.5	PT	50	75	2.5Y41	Silty clay loam	Clayey	Wet	6.28	1:1
40855_8.1	SS	0	5	2.5Y32	Clay loam	Loamy	Moist	7.34	1:1
40855_8.2	SS	5	15	2.5Y31	Silty clay loam	Loamy	Moist	6.84	1:1
40855_8.3	PT	15	35	2.5Y31	Silty clay loam	Clayey	Moist	6.86	1:1
40855_8.4	PT	35	65	2.5Y31	Silty clay loam	Clayey	Moist	6.02	1:1
40855_8.5	PT	65	100	2.5Y31	Sandy clay loam	Sandy	Moist	6.26	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Wimmera River

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40855_1.1	50	FM	5YR58	TOH	MA	1	VS	ferric iron surface coating, organic odour, organic materials, rootlets
40855_1.2	0				MA	1	VS	organic odour, organic materials
40855_1.3	10	FM	5YR58	MAT	MA	1	VS	organic materials
40855_1.4	10	FM	5YR58	MAT	-	0	VW	minor organics
40855_1.5	0	-	-	-	-	0	VW	minor organics
40855_2.1	0	-	-	-	MA	1	VW	organic odour, organic materials
40855_2.2	0	-	-	-	MA	1	VW	minor organics
40855_2.3	0	-	-	-	MA	1	W	minor organics
40855_2.4	0	-	-	-	-	0	F	minor organics
40855_3.1	0	-	-	-	MA	1	VS	decomposed organic materials, H_2S odour
40855_3.2	0	-	-	-	MA	1	VW	slight organic odour
40855_3.3	0	-	-	-	MA	1	W	-
40855_3.4	0	-	-	-	-	0	W	-
40855_3.5	0	-	-	-	-	0	W	-
40855_4.1	2	FM	5YR58	MAT	MA	1	VS	rootlets
40855_4.2	5	FM	5YR58	MAT	MA	1	VW	organic odour, rootlets

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40855_4.3	15	FM	5YR58	MAT	MA	1	VW	slight organic odour
40855_4.4	2	FM	5YR58	MAT	L	1	L	-
40855_4.5	2	FM	5YR58	MAT		0	W	-
40855_5.1	0	-	-	-		0	VS	decomposed organic materials, H_2S odour
40855_5.2	0	-	-	-		0	VW	minor organic matter, rootlets
40855_5.3	0	-	-	-		0	W	minor organic matter, rootlets
40855_5.4	0	-	-	-		0	W	-
40855_5.5	0	-	-	-		0	W	-
40855_6.1	0	-	-	-	SG	1	L	minor shell fragments
40855_6.2	0	-	-	-	GR	1	L	minor organic matter, rootlets
40855_6.3	0	-	-	-	MA	1	VF	organic matter, rootlets
40855_6.4	0	-	-	-		0	F	minor organic matter
40855_6.5	0	-	-	-		0	F	minor decomposed organic matter
40855_7.1	0	-	-	-	MA	1	VS	organic materials
40855_7.2	0	-	-	-	MA	1	VS	decomposed organic materials, H_2S odour
40855_7.3	10	FM	5YR58	MAT	MA	1	W	organic materials
40855_7.4	2	FM	5YR58	MAT		0	W	minor organic matter
40855_7.5	2	FM	5YR58	MAT		0	W	minor organic matter
40855_8.1	0	-	-	-	MA	1	VS	organic matter, rootlets, matting, organic odour, trace sub rounded gravels,
40855_8.2	10	FM	5YR58	MAT	MA	1	VS	organic matter, rootlets
40855_8.3	15	FM	5YR58	MAT		0	W	organic matter, rootlets
40855_8.4	15	FM	5YR58	MAT		0	F	organic matter
40855_8.5	5	FM	5YR58	MAT		0	F	organic matter

APPENDIX 12: RICHARDSON RIVER (40858 - 40859) SUMMARY REPORT

APPENDIX 12:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40858 and 40859

Wetland Name: Richardson River

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 RICHARDSON RIVER 3
1.1 Location and Setting Description 3
1.2 Soil Profile Description and Distribution 3
1.3 Summary of Field and Laboratory Results 6
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 6
1.3.2 Acid Base Accounting 8
1.3.3 Titratable Actual Acidity (TAA) 8
1.3.4 Chromium Reducible Sulfur (S_{CR}) 8
1.3.5 Acid Volatile Sulfur (AVS) 8
1.3.6 Retained Acidity (RA) 8
1.3.7 Acid Neutralising Capacity (ANC) 8
1.3.8 Net Acidity 8
1.3.9 Water soluble SO_4 8
1.4 Hydrochemistry 10
1.5 Discussion 10
1.6 Summary of Key Findings for Richardson River 11

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Richardson River Sites. 4
Table 2 – Summary Of Key Findings 11
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Richardson River. 12
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Richardson River. 14
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Richardson River. 15
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Richardson River. 16
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Richardson River. 17
Table 8 – Additional Data: Water Watch Water Quality Data For Richardson River Collected By The NCCMA. 19

LIST OF FIGURES

Figure 1a – Richardson River 40858 Site Plan.

Figure 1b – Richardson River 40859 Site Plan.

Figure 2a – Richardson River Conceptual Hydrotoposequence Cross Section – 40858.

Figure 2b – Richardson River Conceptual Hydrotoposequence Cross Section – 40859.

Figure 3 – Photographs of site 40858_1, showing the water surface (water column of 30cm), and the laid out soil profile of very soft, dark greyish brown to black (MBO) sandy clay loam and silty clay loam overlying very soft to firm, dark greenish grey silty clay loam.

Figure 4 – Photographs of site 40858_2, showing the surface condition and the soil profile of salt crust and very soft, dark greyish brown sandy clay loam overlying very soft to firm, greenish black silty clay loam and sandy clay loam.

Figure 5 – Photographs of site 40859_1, showing the surface condition (no soil materials were collected here, only one water sample).

Figure 6 – Photographs of site 40859_2, showing the surface condition and soil profile of loose, dark greyish brown clay loam overlying soft, greenish black silty clay loam.

Figure 7 – Photographs of site 40859_3, showing the surface condition and the soil profile of durri crust and weak, dark greyish brown clayey sand overlying very firm, grey clay loam sandy.

Figure 8 – Depth profiles of soil pH for Richardson River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 9 (continued) – Depth profiles of soil pH for Richardson River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 10 – Acid base accounting depth profiles for Richardson River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

Figure 11 – Acid base accounting depth profiles for Richardson River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 RICHARDSON RIVER

1.1 Location and Setting Description

Richardson River is situated in western Victoria, approximately 2km South West of the township of Donald VIC. The wetland is accessed from Donald South Road off the Sunraysia Highway. The wetland is short, curved and linear in shape and approximately 30m wide and 300m in length. The wetland has a total area of approximately 1 hectare.

The wetland is an incised channel with minor, steep banks and batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had minimal surface water covering the wetland within the channel (approximately 30%). Site 40858 had a strong metallic odour with noticeable iron staining, floc and sulphurous odours within the mid channel (low points).

Water within the wetland was generally clear to slight brown and orange and the bottom or lowest point could be seen visually through the water column (30 – 65cm). The channel for site 40859 contained some minor reeds and low salt tolerant bush. Site 40858 was typically devoid of vegetation with the exception of woody debris and large dead trees along some edges of the upper edge of the channel and floodplain. Five sites were sampled as shown in **Figure 1** on the following page with site 40859_1 for water sampling purposes only.

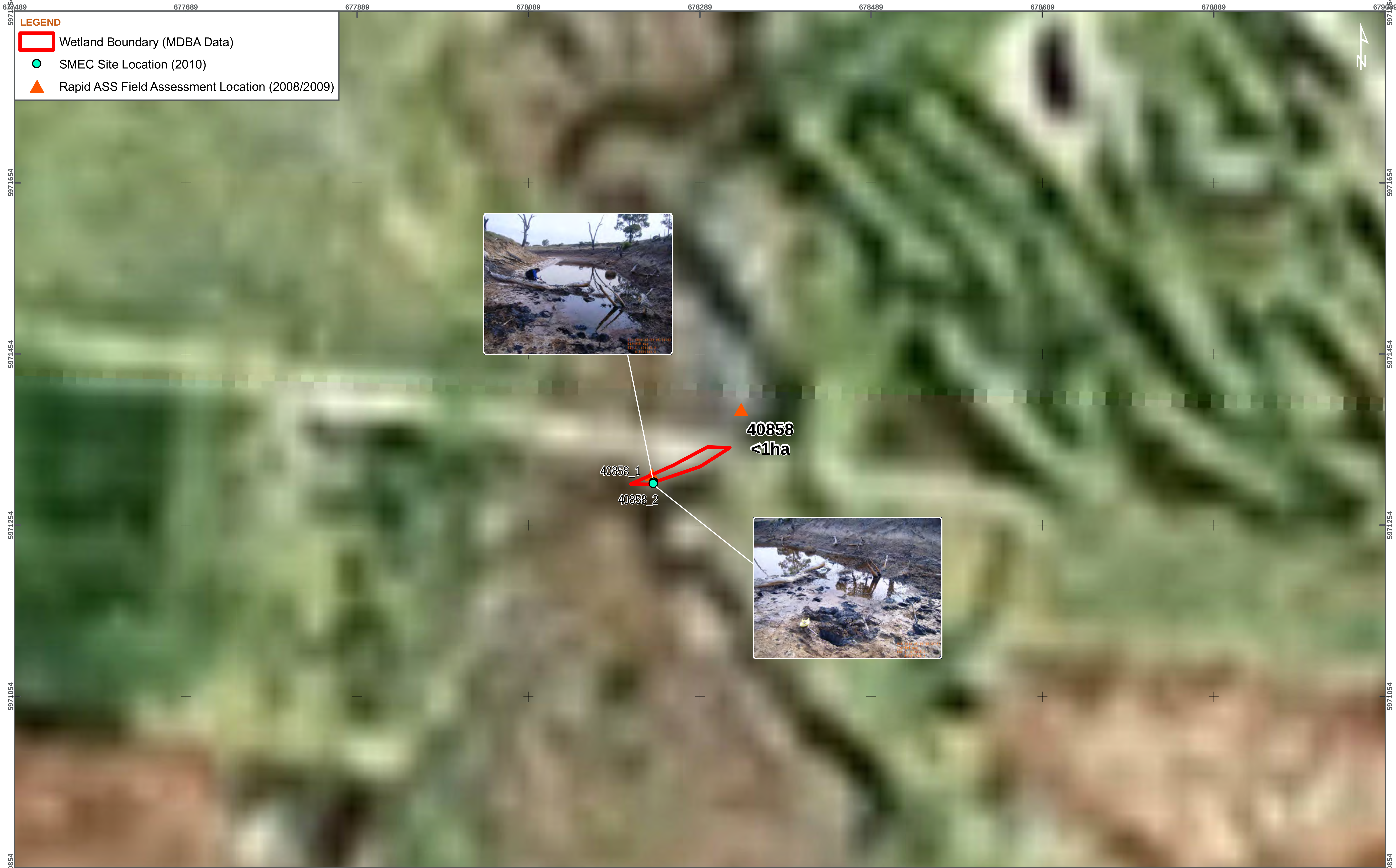
The two wetlands within this report have separate sequence numbers but are adjoining each other and are part of the same complex. Therefore, they have been combined for this summary report.

1.2 Soil Profile Description and Distribution

Five sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at two different areas of the wetland with two sites chosen for each soil transect. **Figures 1a and 1b** on the following page provides an aerial view of the wetland, site locations and surface condition. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figures 2a and 2b** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 7** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40858_1: soft, bare, woody debris in channel, low point, subaqueous; soil consisted of very soft, dark greyish brown to black sandy clay loam and silty clay loam overlying very soft to firm, dark greenish grey silty clay loam.
- 40858_2: loose, bare, mid point, upper bank of channel; soil consisted of salt crust and very soft, dark greyish brown sandy clay loam overlying very soft to firm, greenish black silty clay loam and sandy clay loam.
- 40859_1: water surface, low point, no soil sampling, only water samples collected.
- 40859_2: loose, bare, low point; soil consisted of loose, dark greyish brown clay loam overlying soft, greenish black silty clay loam.



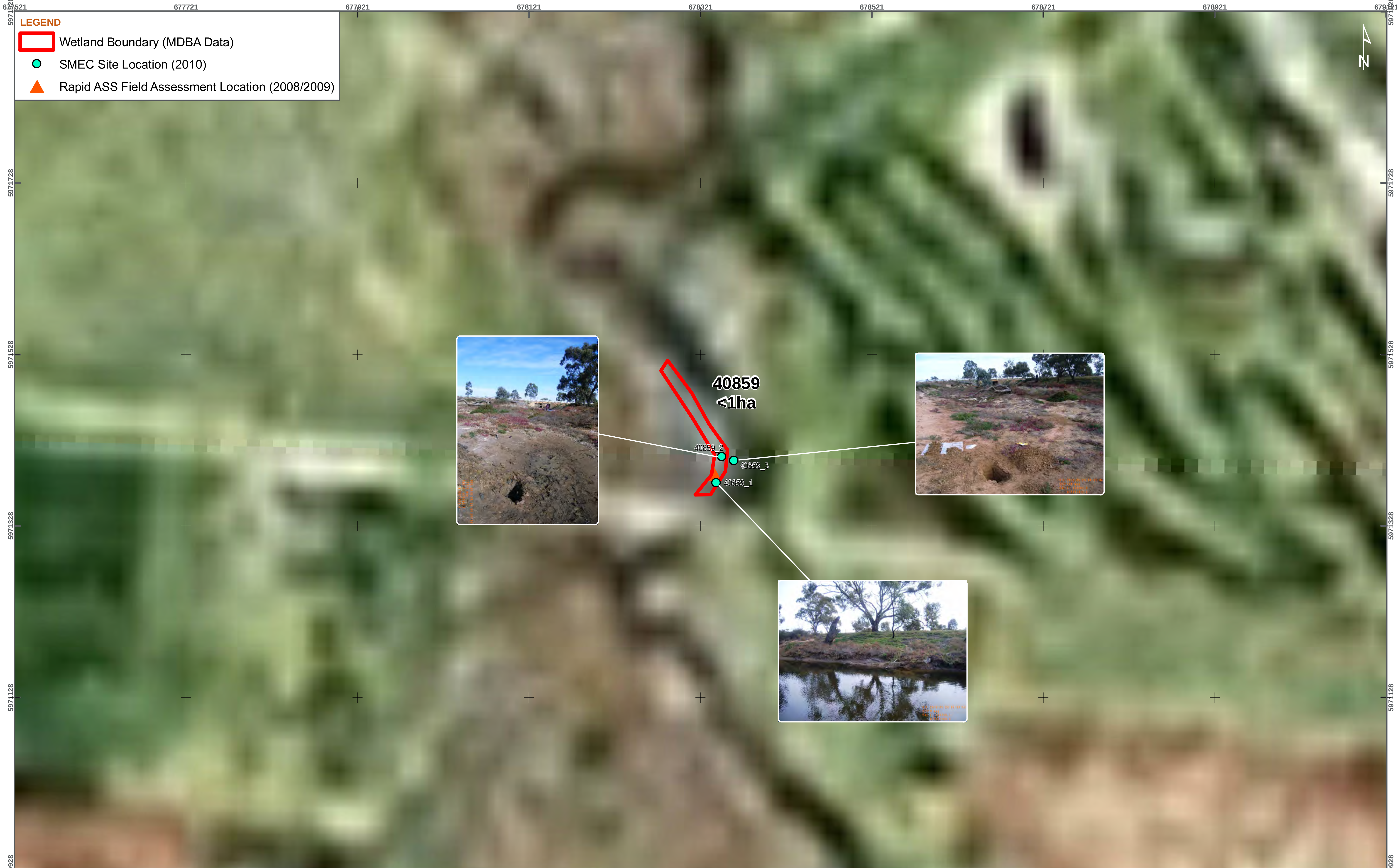
Note: Inset Photos show Surface Condition of Site

DATE 09/07/2010	SCALE 1:4,000 (0 50 100 200 Meters)	PAGE SIZE A3	COORDINATE SYSTEM MGA Zone 54
CREATED BY B. Stewart	LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\ 009DATA\GIS		

FIG NO. 1a PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 FIGURE TITLE Richardson River 40858 CMA:NCCMA

SMEC



DATE 09/07/2010	**SCALE** 1:4,000 (0 – 50 – 100 – 200 Meters)	**PAGE SIZE** A3	**COORDINATE SYSTEM** MGA Zone 54
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS		

FIG NO. 1b

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 **FIGURE TITLE** Richardson River :40859 CMA:NCCMA

Note: Inset Photos show Surface Condition of Site

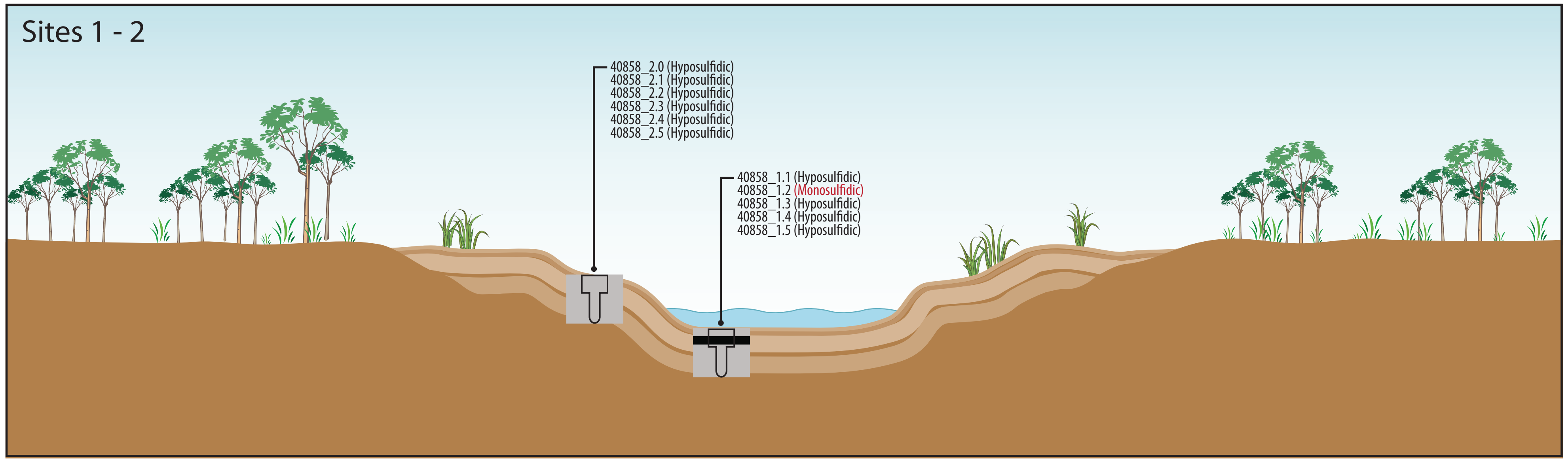
SMEC

LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

Sites 1 - 2



40858_1

40858_2

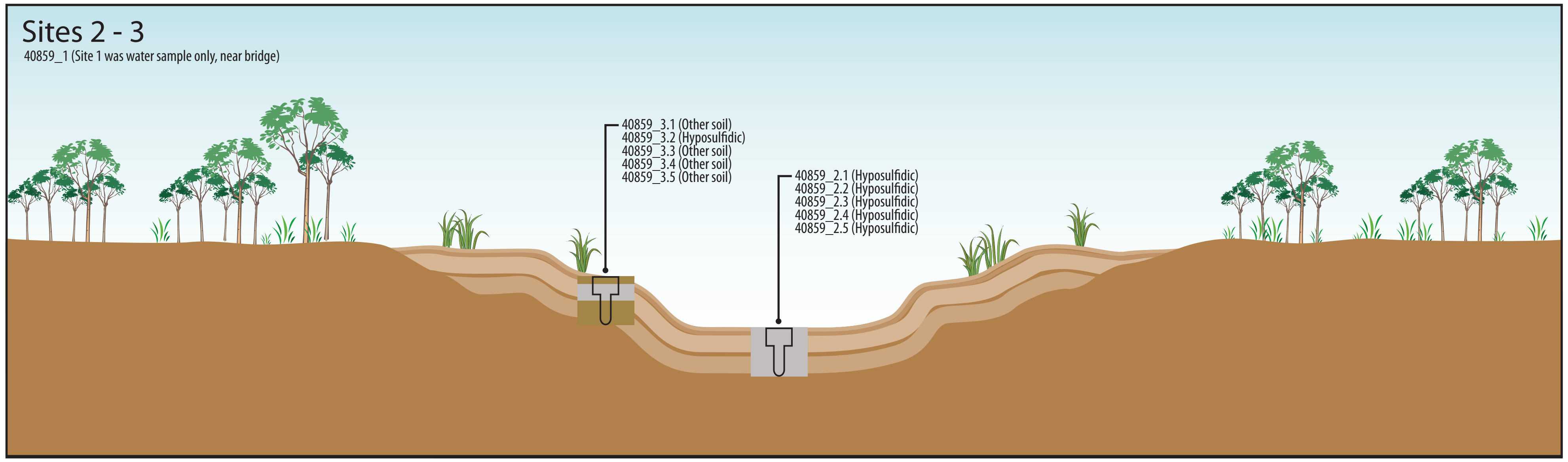
40858_2

DATE 15/07/2010	**SCALE** Not to Scale
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

FIG NO. 2a **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Richardson River 40858

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.



LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

40859_2

40859_2

40859_3

40859_3

DATE 15/07/2010	**SCALE** Not to Scale	**FIG NO.** 2b	**PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS	**PROJECT NO.** 3001801	**FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Richardson River 40859

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

- 40859_3: loose, bare, high point, upper bank of channel; soil consisted of durri crust and weak, dark greyish brown clayey sand overlying very firm, grey clay loam sandy.

Table 1 – Soil Identification, subtype and general location description for Richardson River Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40858_1	140024	5965653	Subaqueous soil	Low point, subaqueous sediments, middle of channel.
40858_2	140024	5965651	Hydrosol - sandy or loamy	Mid point, upper bank of channel, salt crust.
40859_1	140124	5965734	Water sample collected only	Low point, subaqueous, middle of channel.
40859_2	140129	5965765	Hydrosol - sandy or loamy	Low point, middle of channel.
40859_3	140143	5965761	Hydrosol - sandy or loamy	High point, upper bank of channel, durri crust.

Figure 3 – Photographs of site 40858_1, showing the water surface (water column of 30cm), and the laid out soil profile of very soft, dark greyish brown to black (MBO) sandy clay loam and silty clay loam overlying very soft to firm, dark greenish grey silty clay loam.

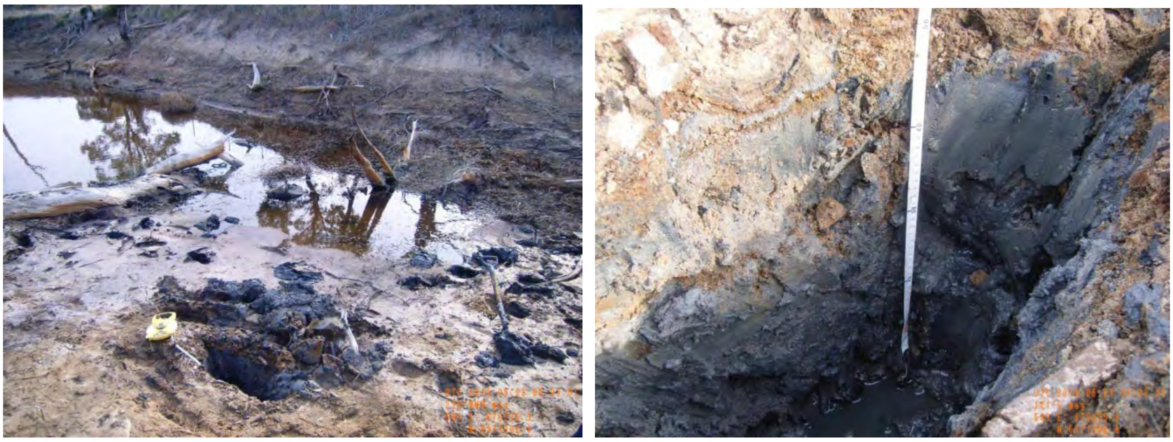


Figure 4 – Photographs of site 40858_2, showing the surface condition and the soil profile of salt crust and very soft, dark greyish brown sandy clay loam overlying very soft to firm, greenish black silty clay loam and sandy clay loam.

Figure 5 – Photographs of site 40859_1, showing the surface condition (no soil materials were collected here, only one water sample).

Figure 6 – Photographs of site 40859_2, showing the surface condition and soil profile of loose, dark greyish brown clay loam overlying soft, greenish black silty clay loam.

Figure 7 – Photographs of site 40859_3, showing the surface condition and the soil profile of durri crust and weak, dark greyish brown clayey sand overlying very firm, grey clay loam sandy.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figures 8 and 9** on the following pages. Summary soil pH profile results indicate:

- 40858_1: all samples have $pH_w < 8.0$. Surface soils (0 - 15cm) have pH_w 7.07 – 7.57 with subsoils (15 – 110cm) ranging 7.51 – 7.90. Surface soils $pH_{incubation}$ ranged 5.55 – 6.77 indicating hyposulfidic and monosulfidic conditions. Subsoils $pH_{incubation}$ ranged 6.64 – 6.76 indicating hyposulfidic conditions.
- 40858_2: all samples have $pH_w < 8.0$. Surface soils (0 - 15cm) have pH_w 6.53 – 7.93 with subsoils (15 – 100cm) ranging 6.74 – 7.23. Surface soils $pH_{incubation}$ ranged 5.25 – 6.88 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.15 – 6.17 indicating hyposulfidic conditions.
- 40859_1: Only water samples were collected at this site.
- 40859_2: all samples have $pH_w < 9.0$. Surface soils (0 - 25cm) have pH_w 7.66 – 8.66 with subsoils (25 – 110cm) ranging 7.53 – 7.73. Surface soils $pH_{incubation}$ ranged 6.39 – 6.96 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 7.02 – 7.11 indicating hyposulfidic conditions.
- 40859_3: all samples have $pH_w < 8.5$. Surface soils (0 - 15cm) have pH_w 8.03 – 8.24 with subsoils (15 – 100cm) ranging 8.10 – 8.24. Surface soils $pH_{incubation}$ ranged 6.83 – 7.31 indicating hyposulfidic and other soil conditions. Subsoils $pH_{incubation}$ ranged 7.13 – 7.19 indicating other soil conditions.

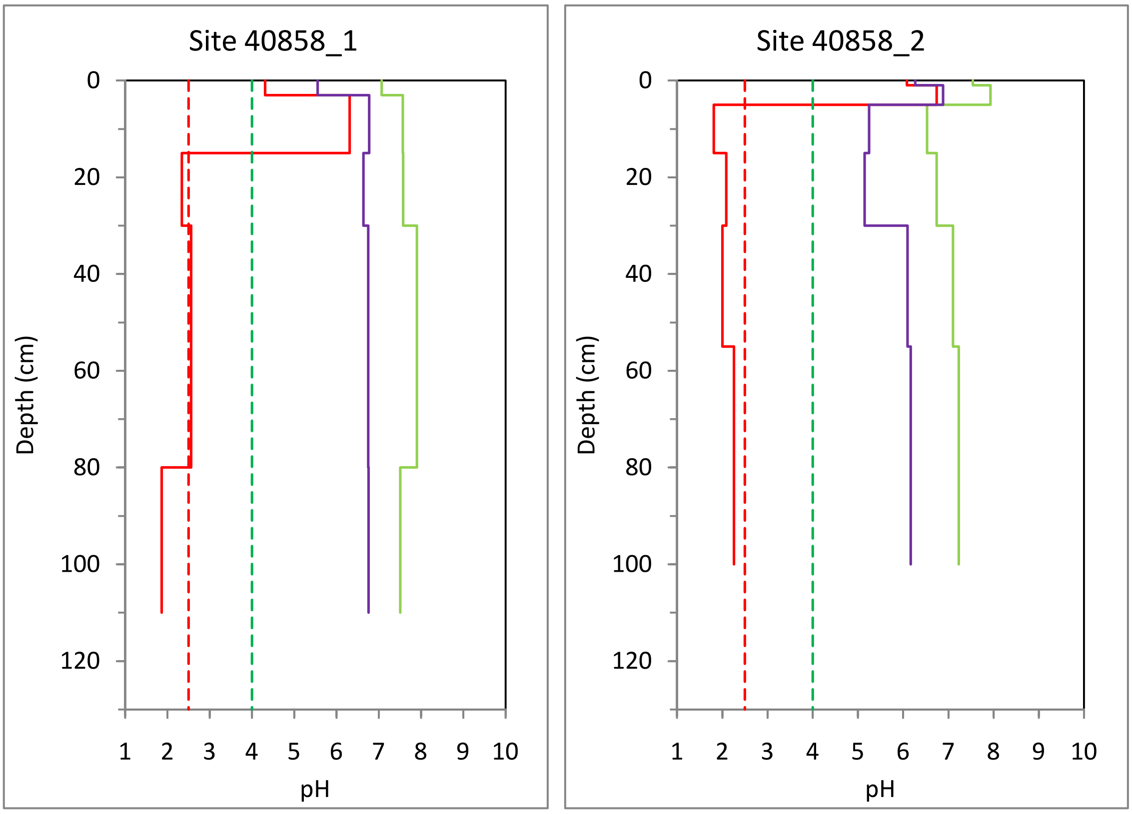


Figure 8 – Depth profiles of soil pH for Richardson River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

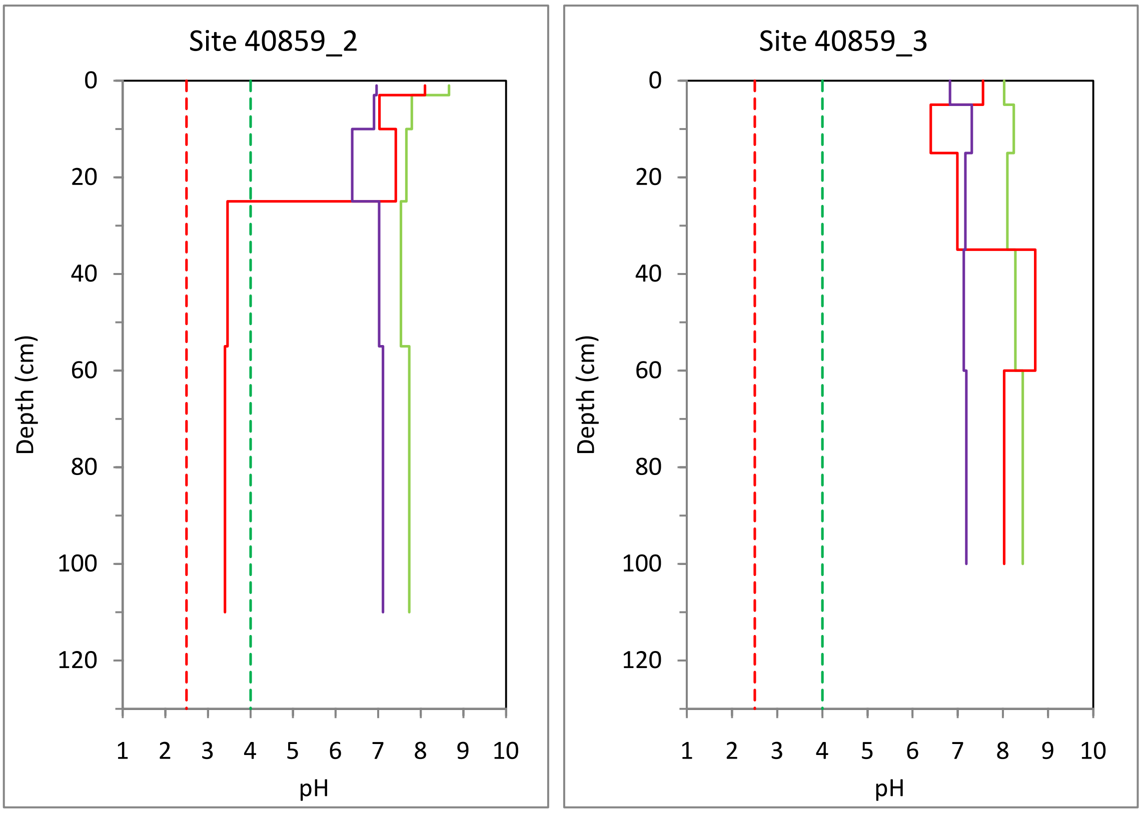


Figure 9 – Depth profiles of soil pH for Richardson River, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 10 and 11** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 21 soil samples collected were analysed for titratable actual acidity (TAA). All TAA results were reported as 0 mol H+/tonne for samples analysed. This is likely due to the high pH_W values (all >6.50) and high water alkalinity and salinity of the wetland.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 21 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01% S (limit of laboratory detection) to 1.02% S. Of the 21 samples analysed 13 (62%) were >0.10% S with the majority and highest results coming from site 40858_1 and 40858_2. Site 40859_3 only had one sample exceed the threshold (0.01% S) with remaining samples all <0.01% S.

1.3.5 Acid Volatile Sulfur (AVS)

One sample was analysed for S_{AV} from the subaqueous site (40858_2). The sample matrix was made up of highly decomposed organic matter with a buttery texture and value of 0.2518 %S_{AV} dry weight. The layer was 12cm thick and visually identified as likely MBO at the time of sampling. This material occurred throughout site 40858 channel and was not identified at sites within 40859.

1.3.6 Retained Acidity (RA)

No pH_{KCL} results were below the threshold of 4.50 for retained acidity analysis. Therefore, no samples were analysed for Retained Acidity (RA).

1.3.7 Acid Neutralising Capacity (ANC)

14 out of the 21 soil samples collected were analysed for Acid Neutralising Capacity (ANC). Results ranged from 0.38 – 11.06 % $CaCO_3$. Spatially and vertically, results were variable throughout the sites. There appears to be a higher concentration of ANC at sites within the channel low points (sites 40858_1 and 40859_2).

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between -937 to 556 mol H+/tonne. 11 out of the 21 samples (52%) have a low net acidity, 3 (14%) samples have moderate net acidity with 7 samples (33%) having a high net acidity.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 1,072.5 to 26,250 mg/L for surface soil samples collected (i.e. 0 – 10cm). Seven surface soil samples were analysed for water soluble sulfate in total. All samples collected exceed the trigger criterion of 100 mg/L for MBO formation potential.

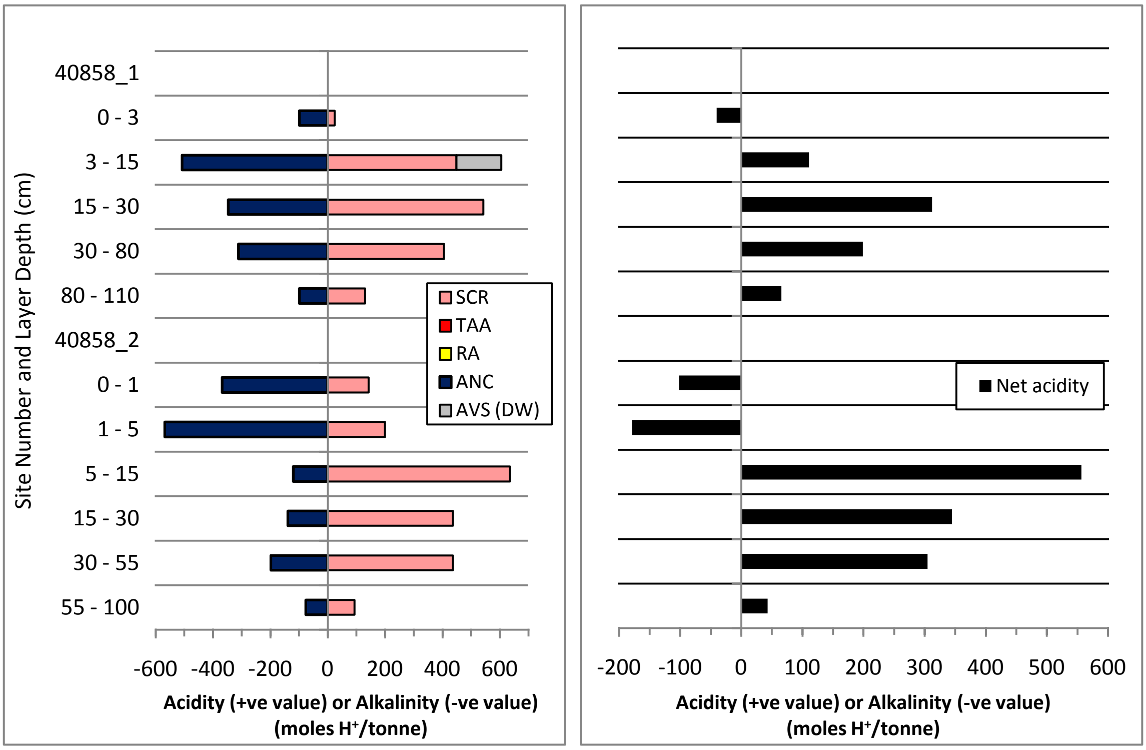


Figure 10 – Acid base accounting depth profiles for Richardson River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

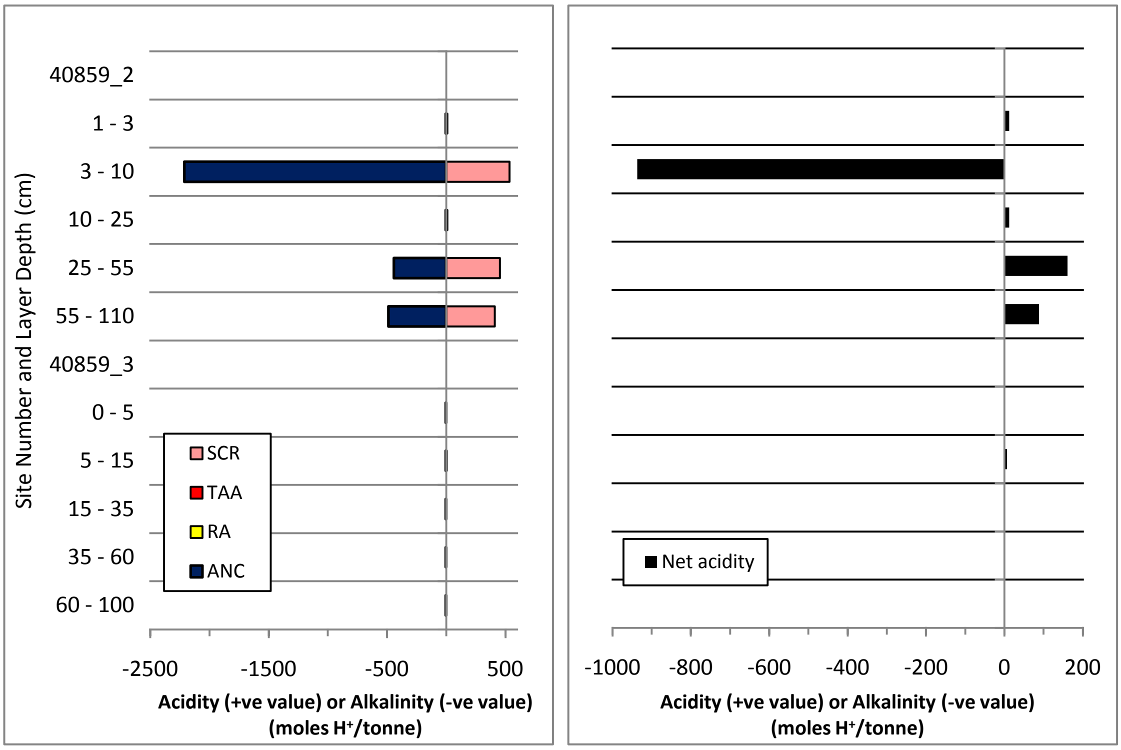


Figure 11 – Acid base accounting depth profiles for Richardson River. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at two out of the five sites from Richardson River. All measurements were from surface waters with insufficient pit inflow water to measure and sample conditions at all sites. Two water samples were collected for laboratory analysis from wetland surface waters from sites 40858_1 and 40859_1 (water only). **Table 8** provides water watch data for the Richardson River collected by the NCCMA between 2007 – 2010.

The wetland surface waters were near neutral and slightly alkaline (pH 6.95 – 8.20). Surface waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 – 8.0 for site 40859_1.

All sites had high SEC values greater than the Lowland River trigger values of 125 – 2,200µS/cm. SEC ranged between 12,730 – 199,700µS/cm with the higher value from site 40858_1 which was hyper saline. Alkalinity (as HCO_3) was high at both sites >240 HCO_3. Both sites had oxidising conditions ranging 103 – 153 Eh and high DO ranging 7.79 – 12.53 mg/L.

Surface water exceeded the most relevant ANZECC 2000 trigger values for some nutrients (NH_4 at site 40858_1) and some dissolved metals at site 40858_1 (Al, As, Cd, Co, Mn, Ni, Pb and Se) and site 40859_1 (Al only).

The water data indicates that the Richardson River channel surface water has not been significantly affected by acidification with pH values ranging 6.50 – 8.20. The Richardson River channel has high alkalinity and SEC values (hyper saline) for surface waters providing buffering capacity to sulfidic acidification inputs.

1.5 Discussion

Acid sulfate soils within Richardson River occurred as areas of hyposulfidic and monosulfidic soil material forming within the channel low points. Monosulfidic materials were encountered within site 40858_1 and were confined to subaqueous areas within the channel. Hyposulfidic materials were encountered within the channel low points at both mid channel sites and half way up the bank at site 40858_2 and to a lesser extent at site 40859_3.

Of the 21 samples analysed 13 (62%) were >0.10% S with the majority and highest results coming from site 40858_1 and 40858_2. Site 40859_3 only had one sample exceed the threshold (0.01% S) with remaining samples all <0.01% S. No sulfuric materials were encountered at the wetland. Typically, deeper soil materials at site 40859_3 were classified as “other soil” (non acidic).

Seven surface soil samples were analysed for water soluble sulfate in total. All samples collected exceed the trigger criterion of 100 mg/L for MBO formation potential. Net acidity results for all sites and samples ranged between -937 to 556 mol H+/tonne. 11 out of the 21 samples (52%) have a low net acidity, 3 (14%) samples have moderate net acidity with 7 samples (33%) having a high net acidity.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are twelve (12) high priority sites based on the presence of hyposulfidic materials with S_{CR} >0.10% S, one (1) high priority sample that is monosulfidic and four (4) high priority samples with water soluble sulfate results above the trigger criterion of 100 mg/L. There are four (4) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10% S. The remaining four (4) samples are classified as “no further assessment”.

Due to the size of the wetland (1 ha) the requirement for Phase 2 laboratory analysis may not be warranted. The wetland also has a high buffering capacity with surface water currently hyper saline. MBO has already formed at site 40858_1 and throughout the channel extent at 40858 which does present a hazard for downstream flows.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Richardson River are:

- Acidification hazard: medium level of concern based on the high (7 samples) net acidities and sulfidic results (from S_{CR}). The MBO formed at site 40858 may also provide an acidity source. The degree of acidification potential from sulfidic sources is lower however as the wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources.

- De-oxygenation hazard: high level of concern as water soluble sulfate results for all surface soil materials exceeded the trigger value for monosulfide formation. In addition, MBO materials were observed (12cm layer) in subaqueous areas that were sampled at site 40858_1 and throughout the channel. Currently however, dissolved oxygen levels within the surface water are high.

- Metal mobilisation: The medium acidification hazard indicates that sulfidic sources of acidity may be sufficient for metals mobilisation; however the wetland has high alkalinity and buffering capacity that would act to buffer acidity from sulfidic sources and therefore reduce the risk of metals being liberated from sulfidic sources.

1.6 Summary of Key Findings for Richardson River

The summary of key findings for Richardson River is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Sulfuric materials were not observed. • Hypersulfidic materials were not observed. • Monosulfidic materials were encountered within site 40858_1 and were confined to subaqueous areas within the channel. • Hyposulfidic materials were encountered within the channel low points at both mid channel sites and half way up the bank at site 40858_2 and to a lesser extent at site 40859_3. • Net acidities ranged between -937 to 556 mol H+/tonne.
Acid sulfate soil identification:	• Site 40858_1: Subaqueous soil (with MBO) occurring under current standing water level in the wetland, middle of channel. • Site 40858_2: Hydrosol – sandy or loamy occurring at middle bank of river channel. • Site 40859_1: Only water sampled. • Site 40859_2: Hydrosol – sandy or loamy occurring at middle of channel. • Site 40859_3: Hydrosol – sandy or loamy occurring at middle bank of river channel.
Hazard assessment:	• Acidification hazard – medium level of concern. • De-oxygenation hazard – high level of concern. • Metal mobilisation hazard – medium level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Richardson River.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40858_1.1	40858_1	0	3	0.1158	0.0892	23	7.07	4.31	5.55	21600
40858_1.2	40858_1	3	15	0.1107	0.0620	44	7.57	6.31	6.77	-
40858_1.3	40858_1	15	30	0.1090	0.0606	44	7.58	2.34	6.64	-
40858_1.4	40858_1	30	80	0.1093	0.0640	41	7.90	2.56	6.75	-
40858_1.5	40858_1	80	110	0.1478	0.1174	21	7.51	1.86	6.76	-
40858_2.0	40858_2	0	1	0.1272	0.0945	26	7.54	6.08	6.27	-
40858_2.1	40858_2	1	5	0.1229	0.0830	32	7.93	6.74	6.88	20850
40858_2.2	40858_2	5	15	0.1189	0.0715	40	6.53	1.81	5.25	16650
40858_2.3	40858_2	15	30	0.1229	0.0817	34	6.74	2.09	5.15	-
40858_2.4	40858_2	30	55	0.1214	0.0873	28	7.10	2.00	6.10	-
40858_2.5	40858_2	55	100	0.1411	0.1126	20	7.23	2.26	6.17	-
40859_1.1	40859_1	-	-	-	-	-	-	-	-	-
40859_2.1	40859_2	1	3	0.1349	0.1120	17	8.66	8.10	6.96	20850
40859_2.2	40859_2	3	10	0.1101	0.0585	47	7.79	7.03	6.90	26250
40859_2.3	40859_2	10	25	0.1281	0.0991	23	7.66	7.41	6.39	-
40859_2.4	40859_2	25	55	0.1208	0.0820	32	7.53	3.46	7.02	-
40859_2.5	40859_2	55	110	0.1228	0.0808	34	7.73	3.40	7.11	-
40859_3.1	40859_1	0	5	0.1055	0.1018	4	8.03	7.56	6.83	1072.5
40859_3.2	40859_2	5	15	0.0841	0.0741	12	8.24	6.40	7.31	1740
40859_3.3	40859_3	15	35	0.1093	0.0918	16	8.10	6.99	7.17	-
40859_3.4	40859_4	35	60	0.0959	0.0801	16	8.28	8.72	7.13	-
40859_3.5	40859_5	60	100	0.1191	0.0975	18	8.44	8.03	7.19	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Richardson River.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	$\%CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40858_1.1	40858_1	0	3	6.85	0	0.04	0	0	-40	-	Hyposulfidic
40858_1.2	40858_1	3	15	7.60	0	0.72	0	3	111	0.2518	Monosulfidic
40858_1.3	40858_1	15	30	8.00	0	0.87	0	2	312	-	Hyposulfidic
40858_1.4	40858_1	30	80	8.22	0	0.65	0	2	199	-	Hyposulfidic
40858_1.5	40858_1	80	110	7.86	0	0.21	0	0	66	-	Hyposulfidic
40858_2.0	40858_2	0	1	8.07	0	0.23	0	2	-102	-	Hyposulfidic
40858_2.1	40858_2	1	5	8.00	0	0.32	0	3	-179	-	Hyposulfidic
40858_2.2	40858_2	5	15	7.38	0	1.02	0	1	556	-	Hyposulfidic
40858_2.3	40858_2	15	30	7.30	0	0.70	0	1	345	-	Hyposulfidic
40858_2.4	40858_2	30	55	7.70	0	0.70	0	1	305	-	Hyposulfidic
40858_2.5	40858_2	55	100	7.53	0	0.15	0	0	43	-	Hyposulfidic
40859_1.1	40859_1	-	-	-	-	-	-	-	-	-	*Water Only*
40859_2.1	40859_2	1	3	8.58	0	0.02	0	-	12	-	Hyposulfidic
40859_2.2	40859_2	3	10	8.32	0	0.86	0	11	-937	-	Hyposulfidic
40859_2.3	40859_2	10	25	8.41	0	0.02	0	-	12	-	Hyposulfidic
40859_2.4	40859_2	25	55	8.20	0	0.73	0	2	161	-	Hyposulfidic
40859_2.5	40859_2	55	110	8.30	0	0.66	0	2	88	-	Hyposulfidic
40859_3.1	40859_1	0	5	8.60	0	<0.01	0	-	0	-	Other soil
40859_3.2	40859_2	5	15	8.68	0	0.01	0	-	6	-	Hyposulfidic
40859_3.3	40859_3	15	35	8.14	0	<0.01	0	-	0	-	Other soil
40859_3.4	40859_4	35	60	8.47	0	<0.01	0	-	0	-	Other soil
40859_3.5	40859_5	60	100	8.45	0	<0.01	0	-	0	-	Other soil

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Richardson River.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40858_1.W1	40859_1.W1
Site ID	(number)	-	-	40858_1	40859_1
Wetland ID	(code)	-	-	40858	40859
Site Number	(number)	-	-	1	1
Upper depth	cm	-	-	-30	-30
Lower depth	cm	-	-	0	0
Temperature	(deg C)	-	-	12.1	11.3
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	199700	12730
Dissolved Oxygen	(%)	-	-	36.4	111.6
Dissolved Oxygen	(mg/l)	-	-	7.79	12.53
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	6.95	8.20
Redox potential	Eh	-	-	103	153
Turbidity	(NTU)	*6 - 50*	*1 - 20*	45	9.9
HCO_3	(mg/l)	-	-	>240	>240
Comment	-	-	-	SW	SW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Richardson River.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	23-05-10	23-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201599	2201600
Sample ID	(number)	-	40858_1.W1	40859_1.W1
Site ID	(number)	-	40858_1	40859_1
Wetland ID	(code)	-	40858	40859
Site Number	(number)	-	1	1
Upper depth	cm	-	-30	-30
Lower depth	cm	-	0	0
Na	mg l^{-1}	-	99000	2300
K	mg l^{-1}	-	860	24
Ca	mg l^{-1}	-	530	230
Mg	mg l^{-1}	-	16000	280
Si	mg l^{-1}	-	1.2	0.1
Br	mg l^{-1}	-	NR INT	<5
Cl	mg l^{-1}	-	150000	4400
NO_3	mg l^{-1}	0.7	0.03	0.03
NH_4-N[K]	mg l^{-1}	0.01	8.9	<0.1
PO_4-P[E]	mg l^{-1}	0.005	<0.01	<0.01
SO_4	mg l^{-1}	-	23000	800
Ag	µg l^{-1}	0.05	<1	<1
Al[A]	µg l^{-1}	55	140	90
As[B]	µg l^{-1}	13	22	2
Cd	µg l^{-1}	0.2	0.8	<0.2
Co	µg l^{-1}	2.8	4	<1
Cr[C]	µg l^{-1}	1	<1	<1
Cu[H]	µg l^{-1}	1.4	<1	<1
Fe	µg l^{-1}	300	<20	<20
Mn	µg l^{-1}	1700	1700	61
Ni[H]	µg l^{-1}	11	19	3
Pb[H]	µg l^{-1}	3.4	14	<1
Se	µg l^{-1}	11	17	2
Zn[H]	µg l^{-1}	8	8	3
DOC	mg l^{-1}	-	24	6

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]Trigger value for Aluminium in freshwater where pH > 6.5.

[B]Trigger value assumes As in solution as Arsenic (AsV).

[C]Trigger value for Chromium is applicable to Chromium (CrVI) only.

[E]Guideline is for filterable reactive phosphorous (FRP).

[H]Hardness affected (refer to Guidelines).

[K]Guideline for South-east Australia-Freshwater Lakes and reservoirs.

Table 6 - Site description data for acid sulfate soil assessment of Richardson River.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40858_1	40858	1	23-05-10	54	140024	5965653
40858_2	40858	2	23-05-10	54	140024	5965651
40859_1	40859	1	23-05-10	54	140124	5965734
40859_2	40859	2	23-05-10	54	140129	5965765
40859_3	40859	3	23-05-10	54	140143	5965761

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40858_1	-30	soft	bare, woody debris in channel	low point, subaqueous	likely MBO site, hyper saline condition, subaqueous	70	Subaqueous soil	Middle of channel form, hyper saline ponded water
40858_2		loose	bare	mid point	dry point in hydro toposequence	30	Hydrosol - sandy or loamy	No water evident
40859_1	-65	water	water	low point	collect water sample from ponded water in wetland, no soil collected	10	Water sample collected only	water sample collected only, no soil sample collected
40859_2		surface crust, soft under foot	bare	low point	depression and moist surface appearance	60	Hydrosol - sandy or loamy	No water evident
40859_3		surface durri crust	bare	high point	dry point in hydro toposequence, nearing channel bank	30	Hydrosol - sandy or loamy	No water evident

Table 7 - Profile description data for acid sulfate soil assessment of Richardson River.

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40858_1.1	SS	0	3	2.5Y42	Sandy clay loam	Sandy	Wet	6.73	1:1
40858_1.2	PT	3	15	GLEY14N	Silty clay loam	Loamy	Wet	7.46	1:1
40858_1.3	PT	15	30	GLEY1410Y	Silty clay loam	Clayey	Wet	7.66	1:1
40858_1.4	PT	30	80	GLEY1410Y	Silty clay loam	Clayey	Wet	7.83	1:1
40858_1.5	PT	80	110	GLEY145GY	Sandy clay loam	Sandy	Wet	7.72	1:1
40858_2.0	SS	0	1	10YR32	Salt crust	Salty	Dry	7.14	1:1
40858_2.1	SS	1	5	10YR42	Sandy clay loam	Sandy	Moist	7.31	1:1
40858_2.2	SS	5	15	GLEY1410Y	Silty clay loam	Clayey	Moist	7.12	1:1
40858_2.3	SS	15	30	GLEY1410Y	Silty clay loam	Clayey	Moist	7.10	1:1
40858_2.4	SS	30	55	GLEY1310Y	Clay loam sandy	Sandy	Moist	7.46	1:1
40858_2.5	PT	55	100	GLEY1310Y	Sandy clay loam	Sandy	Wet	7.33	1:1
40859_1.1	WA	-	-	-	-	-	-	-	1:1
40859_2.1	SS	0	3	2.5Y53	Loamy sand	Sandy	Moist	8.12	1:1
40859_2.2	SS	3	10	2.5Y42	Clay loam	Clayey	Moist	7.80	1:1
40859_2.3	SS	10	25	2.5Y52	Sandy clay loam	Sandy	Moist	7.02	1:1
40859_2.4	SS	25	55	GLEY145GY	Silty clay loam	Clayey	Wet	7.60	1:1
40859_2.5	PT	55	110	GLEY145GY	Silty clay loam	Clayey	Wet	7.80	1:1
40859_3.1	SS	0	5	10YR56	Clayey sand	Sandy	Moist	7.58	1:1
40859_3.2	SS	5	15	2.5Y42	Clayey sand	Sandy	Moist	7.64	1:1
40859_3.3	SS	15	35	2.5Y52	Clayey sand	Sandy	Moist	7.63	1:1
40859_3.4	SA	35	60	2.5Y51	Clay loam sandy	Sandy	Moist	7.74	1:1
40859_3.5	SA	60	100	2.5Y61	Clay loam sandy	Sandy	Moist	8.51	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Richardson River.

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40858_1.1	0	-	-	-	MA	1	VS	highly decomposed organic matter, metallic odour, H_2S odour
40858_1.2	0	-	-	-	MA	1	VS	highly decomposed organic matter, metallic odour, H_2S odour, buttery texture, very soft, MBO
40858_1.3	0	-	-	-	MA	1	VS	highly decomposed organic matter, metallic odour, H_2S odour
40858_1.4	0	-	-	-	MA	1	VS	highly decomposed organic matter, metallic odour, H_2S odour
40858_1.5	0	-	-	-	-	0	VW	minor lenses of highly decomposed organic matter
40858_2.0	SALT	-	-	-	-	0	VS	salt crust, lenses
40858_2.1	0	-	-	-	MA	1	VS	highly decomposed organic matter in lenses, plant matter with salt
40858_2.2	0	-	-	-	MA	1	VS	highly decomposed organic matter
40858_2.3	0	-	-	-	MA	1	VS	highly decomposed organic matter
40858_2.4	0	-	-	-	MA	1	VS	highly decomposed organic matter
40858_2.5	0	-	-	-	-	0	VW	highly decomposed organic matter
40859_1.1		-	-	-	-			Water sample collected only
40859_2.1	0	-	-	-	MA	1	L	minor organics
40859_2.2	0	-	-		MA	1	S	highly decomposed organic matter, organic odour, larger organic fragments
40859_2.3	10	FM	5YR58	MAT	MA	1	S	organic matter, rootlets
40859_2.4	0	-	-	-	MA	1		organic matter, rootlets
40859_2.5	0	-	-	-	-	0	S	minor organics, slight H_2S odour
40859_3.1	0	-	-	-	MA	1	L	durri crust, 1mm lenses, powdery
40859_3.2	5	FM	5YR58	MAT	MA	1	W	-
40859_3.3	10	FM	5YR58	MAT	MA	1	VF	-
40859_3.4	10	FM	5YR58	MAT	-	0	VF	-
40859_3.5	10	FM	5YR58	MAT	-	0	VF	-

Table 8 – Additional Data: Water watch Water Quality Data for Richardson River Collected by the NCCMA.

RNR520 - Richardson River Wastewater Treatment Plant Road Donald			
Date and (notes)	**Electrical Conductivity (µS/cm)**	**pH (pH Units)**	**Turbidity (NTU)**
16/01/2007 (Stagnant (pool))	195200	7.30	68
23/01/2007 (Stagnant (pool))	220000	-	-
20/02/2007 (Stagnant (pool))	184000	7.40	98
17/03/2007 (Stagnant (pool))	183300	7.30	87
15/04/2007 (Stagnant (pool))	179900	7.60	91
16/05/2007 (Stagnant (pool))	142800	8.60	94
16/06/2007 (Stagnant (pool))	175700	8.90	46
15/07/2007 (Stagnant (pool))	173200	8.80	49
12/08/2007 (Stagnant (pool))	96600	8.60	21
14/09/2007 (Stagnant (pool))	136300	8.00	16
13/10/2007 (Stagnant (pool))	139900	7.90	18
09/11/2007 (Stagnant (pool))	155100	7.70	19
31/12/2007 (Stagnant (pool))	22500	8.30	13
23/01/2008 (Stagnant (pool))	39500	8.70	15
20/02/2008 (Stagnant (pool))	70100	8.20	15
26/03/2008 (Dry (no water))	77300	8.10	14
08/04/2008 ()	120100	7.70	19
05/05/2008 ()	132700	7.60	29
16/06/2008 ()	139100	7.80	32
11/07/2008 ()	161500	7.70	26
14/08/2008 ()	163400	7.70	19
12/09/2008 ()	169700	7.60	16
23/10/2008 ()	164000	7.80	19
14/11/2008 ()	167000	7.70	33
09/12/2008 ()	175000	7.20	42
24/01/2009 (Stagnant (pool))	174880	6.60	61
14/02/2009 (Stagnant (pool))	172800	6.80	21
13/03/2009 (Stagnant (pool))	183100	6.70	20
13/04/2009 (Stagnant (pool))	191210	6.60	23
03/05/2009 (Stagnant (pool))	196100	6.80	9

RNR520 - Richardson River Wastewater Treatment Plant Road Donald			
Date and (notes)	**Electrical Conductivity (µS/cm)**	**pH (pH Units)**	**Turbidity (NTU)**
26/06/2009 (Stagnant (pool))	134200	7.60	4
18/07/2009 (Stagnant (pool))	15240	7.90	40
20/08/2009 (Stagnant (pool))	8100	8.30	21
08/09/2009 (Stagnant (pool))	7990	8.20	12
18/10/2009 (Stagnant (pool))	9,700	9.20	5
12/11/2009 (Stagnant (pool))	11,800	9.00	9
18/12/2009 (Stagnant (pool))	12,700	8.70	11
16/01/2010 ()	14,790	8.60	10
17/02/2010 ()	36,000	8.00	5
15/03/2010 ()	34,900	7.90	<10

APPENDIX 13: BET BET CREEK (40860 - 40863) SUMMARY REPORT

APPENDIX 13:

Priority Region: Victorian Northern Flowing Rivers

Sequence Number: 40860 – 40863

Wetland Name: Bet Bet Creek

Phase 1 Inland Acid Sulfate Soil Detailed Assessment within the Victorian Northern Flowing Rivers Region

TABLE OF CONTENTS

1 BET BET CREEK 3
1.1 Location and Setting Description 3
1.2 Soil Profile Description and Distribution 3
1.3 Summary of Field and Laboratory Results 9
1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$) 9
1.3.2 Acid Base Accounting 14
1.3.3 Titratable Actual Acidity (TAA) 14
1.3.4 Chromium Reducible Sulfur (S_{CR}) 14
1.3.5 Acid Volatile Sulfur (AVS) 14
1.3.6 Retained Acidity (RA) 14
1.3.7 Acid Neutralising Capacity (ANC) 14
1.3.8 Net Acidity 14
1.3.9 Water soluble SO_4 15
1.4 Hydrochemistry 17
1.5 Discussion 18
1.6 Summary of Key Findings for Bet Bet Creek 19

LIST OF TABLES

Table 1 – Soil Identification, Subtype And General Location Description For Bet Bet Creek Sites. 4
Table 2 – Summary Of Key Findings 19
Table 3 – Laboratory Analytical Data For Acid Sulfate Soil Assessment Of Bet Bet Creek. 20
Table 4 - Field Hydrochemistry Data For Acid Sulfate Soil Assessment Of Bet Bet Creek. 24
Table 5 - Laboratory Hydrochemistry Data For Acid Sulfate Soil Assessment Of Bet Bet Creek. 25
Table 6 - Site Description Data For Acid Sulfate Soil Assessment Of Bet Bet Creek. 27
Table 7 - Profile Description Data For Acid Sulfate Soil Assessment Of Bet Bet Creek 29
Table 8 – Additional Data: Water Watch Water Quality Data For Bet Bet Creek Collected By The NCCMA. 34

LIST OF FIGURES

Figure 1a – Bet Bet Creek 40860 Site Plan.
Figure 1b – Bet Bet Creek 40861 Site Plan.
Figure 1c – Bet Bet Creek 40862 Site Plan.
Figure 1d – Bet Bet Creek 40863 Site Plan.
Figure 1e – Bet Bet Creek Channel Complex Overview.
Figure 2a – Bet Bet Creek Conceptual Hydrotoposequence Cross Section – 40860.
Figure 2b – Bet Bet Creek Conceptual Hydrotoposequence Cross Section – 40861.
Figure 2c – Bet Bet Creek Conceptual Hydrotoposequence Cross Section – 40862.
Figure 2d – Bet Bet Creek Conceptual Hydrotoposequence Cross Section – 40863.
Figure 3 – Photographs of site 40860_1, showing the water surface (water column of 40cm), and the laid out soil profile of soft, dark yellowish brown silty clay loam overlying very weak, black silty clay loam.
Figure 4 – Photographs of site 40860_2, showing the water surface condition and the soil profile of loose, greyish brown sandy clay loam and silty clay loam overlying soft, dark grey clay.

Figure 5 – Photographs of site 40860_3, showing the water surface (water column of 45cm), and the laid out soil profile of loose to weak, brown silty loam and clay overlying soft, very dark bluish grey silty clay loam.

Figure 6 – Photographs of site 40860_4, showing the surface condition and the soil profile of soft, dark brown silty clay loam overlying very weak, dark greyish brown clay.

Figure 7 – Photographs of site 40861_1, showing the surface condition and the soil profile of weak, dark grayish brown silty clay loam overlying soft, dark grey clay.

Figure 8 – Photographs of site 40861_2, showing the surface condition and the soil profile of very soft, yellowish brown clay loam and clay overlying very weak, very dark greyish brown silty clay loam.

Figure 9 – Photographs of site 40861_3, showing the surface condition and the soil profile of loose to very weak, very dark greyish brown clay loam and silty clay loam overlying very weak, dark. yellowish brown sandy clay loam

Figure 10 – Photographs of site 40861_4, showing the surface condition and the soil profile of very weak, brown silty clay loam overlying weak, brown some grey brown clay.

Figure 11 – Photographs of site 40862_1, showing the surface condition and the soil profile of loose, dark brown loam overlying loose, brown clayey sand.

Figure 12 – Photographs of site 40862_2, showing the surface condition and the soil profile of very dark brown sandy loam overlying soft, bluish black silty clay loam.

Figure 13 – Photographs of site 40863_1, showing the water surface (water column of 35cm) and the laid out soil profile of very soft, black silty clay loam overlying very soft, bluish black silty clay loam.

Figure 14 – Photographs of site 40863_2, showing the surface condition and the soil profile very soft, dark grey to dark brown clay loam overlying soft, dark greenish grey clay.

Figure 15 – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 16 (continued) – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 17(continued) – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 18 (continued) – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

Figure 19 – Acid base accounting depth profiles for Bet Bet Creek (40860) wetland. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars)

Figure 20 – Acid base accounting depth profiles for Bet Bet Creek (40861) wetland. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

Figure 21 – Acid base accounting depth profiles for Bet Bet Creek (40862) wetland. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

Figure 22 – Acid base accounting depth profiles for Bet Bet Creek (40863) wetland. Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1 BET BET CREEK

1.1 Location and Setting Description

Bet Bet Creek is situated in north central Victoria, approximately 9.5km west of the township of Dunolly VIC. The wetland is accessed from Dunolly Eddington Road and Bendigo Maryborough Road. The wetland is a creek channel with meander bends and approximately 100m wide and 3km in length. The Bet Bet Creek assessment relates to four sections that were selected with separate sequence numbers along the creek channel. The wetlands are approximately 30 hectares in total area for the combined sections along the creek.

The wetland is an incised creek channel with minor, steep sided banks and batters leading up onto the floodplain. At the time when the soil survey was conducted in May 2010, the wetland had shallow surface water covering the channel (approximately 60%). Along much of the creek iron floc was noted in the shallow ponded areas of the channel on top of the subaqueous surface sediments.

Water within the wetland was generally clear to slight brown and orange and the bottom or lowest point could be seen visually through the water column (typically 10 – 45cm depth). The creek channel contained some minor reeds and large woody debris and low grasses and medium sized trees along the upper banks and on the floodplain. Twelve sites were sampled as shown in **Figures 1a – 1d** on the following pages.

1.2 Soil Profile Description and Distribution

Twelve sites were described and sampled. The soil subtype and general location description is presented in **Table 1**. Sites were selected throughout the wetland based on different surface features and locations in the wetland. A transect approach was used at six different areas of the wetland with sites chosen for each transect within the creek channel. **Figures 1a to 1d** on the following pages provide an aerial view of the wetland, site locations and surface condition. A site overview map indicating the Bet Bet Creek channel is shown in **Figure 1e** on the following pages. Samples collected and distribution of acid sulfate soil subtype class are shown in the wetland conceptual cross section shown in **Figures 2a to 2d** on the following pages. Photographs of soil profiles and surface condition are presented in **Figures 3 – 10** on the following pages. Additional site and profile description data is presented in **Tables 6** and **7** respectively at the end of this appendix.

Summary soil profile descriptions for each site include:

- 40860_1: water, bare, woody debris in channel, low point, subaqueous; soil consisted of soft, dark yellowish brown silty clay loam overlying very weak, black silty clay loam.
- 40860_2: soft, bare to minor grasses, mid point; soil consisted of loose, greyish brown sandy clay loam and silty clay loam overlying soft, dark grey clay.
- 40860_3: water, low point, subaqueous; soil consisted of loose to weak, brown silty loam and clay overlying soft, very dark bluish grey silty clay loam.
- 40860_4: soft, bare to minor reeds and twig litter, mid point; soil consisted of soft, dark brown silty clay loam overlying very weak, dark greyish brown clay.

DATE 09/07/2010	**SCALE** 1:2,750 (0 25 50 100 Meters)	**PAGE SIZE** A3	**COORDINATE SYSTEM** MGA Zone 54
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS		

FIG NO. 1a **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

PROJECT NO. 3001801 **FIGURE TITLE** Bet Bet Creek 40860 - CMA: NCCMA

Note: Inset Photos show Surface Condition of Site

SMEC

DATE 09/07/2010

SCALE 1:3,500 (0, 37.5, 75, 150 Meters)

PAGE SIZE A3

COORDINATE SYSTEM MGA Zone 54

FIG NO. 1b

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: Inset Photos show Surface Condition of Site

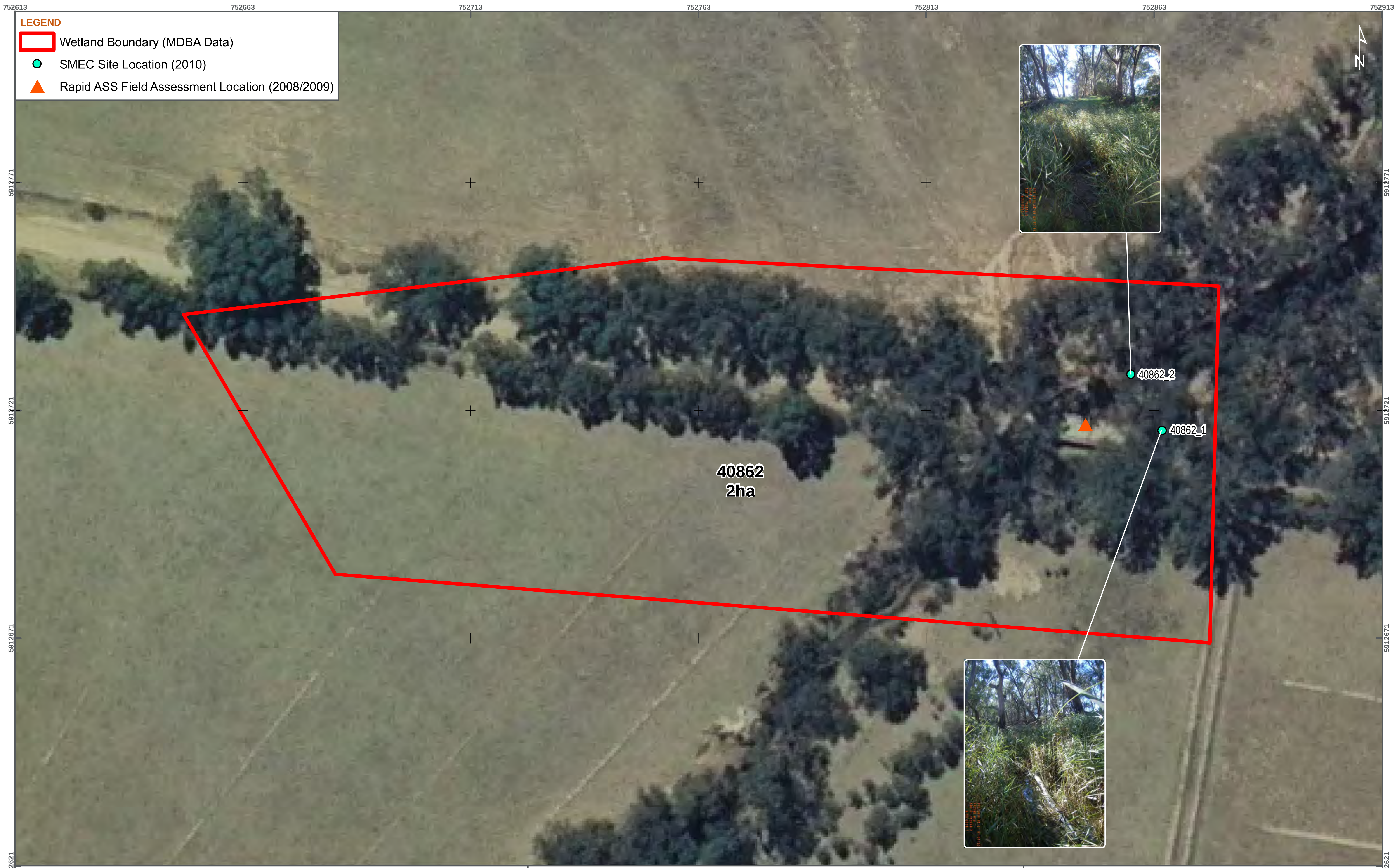
CREATED BY B. Stewart

LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801

FIGURE TITLE Bet Bet Creek 40861 - CMA: NCCMA

SMEC



DATE 09/07/2010

SCALE 1:750

0 10 20 40 Meters

PAGE SIZE A3

COORDINATE SYSTEM MGA Zone 54

FIG NO. 1c

PROJECT TITLE Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: Inset Photos show Surface Condition of Site

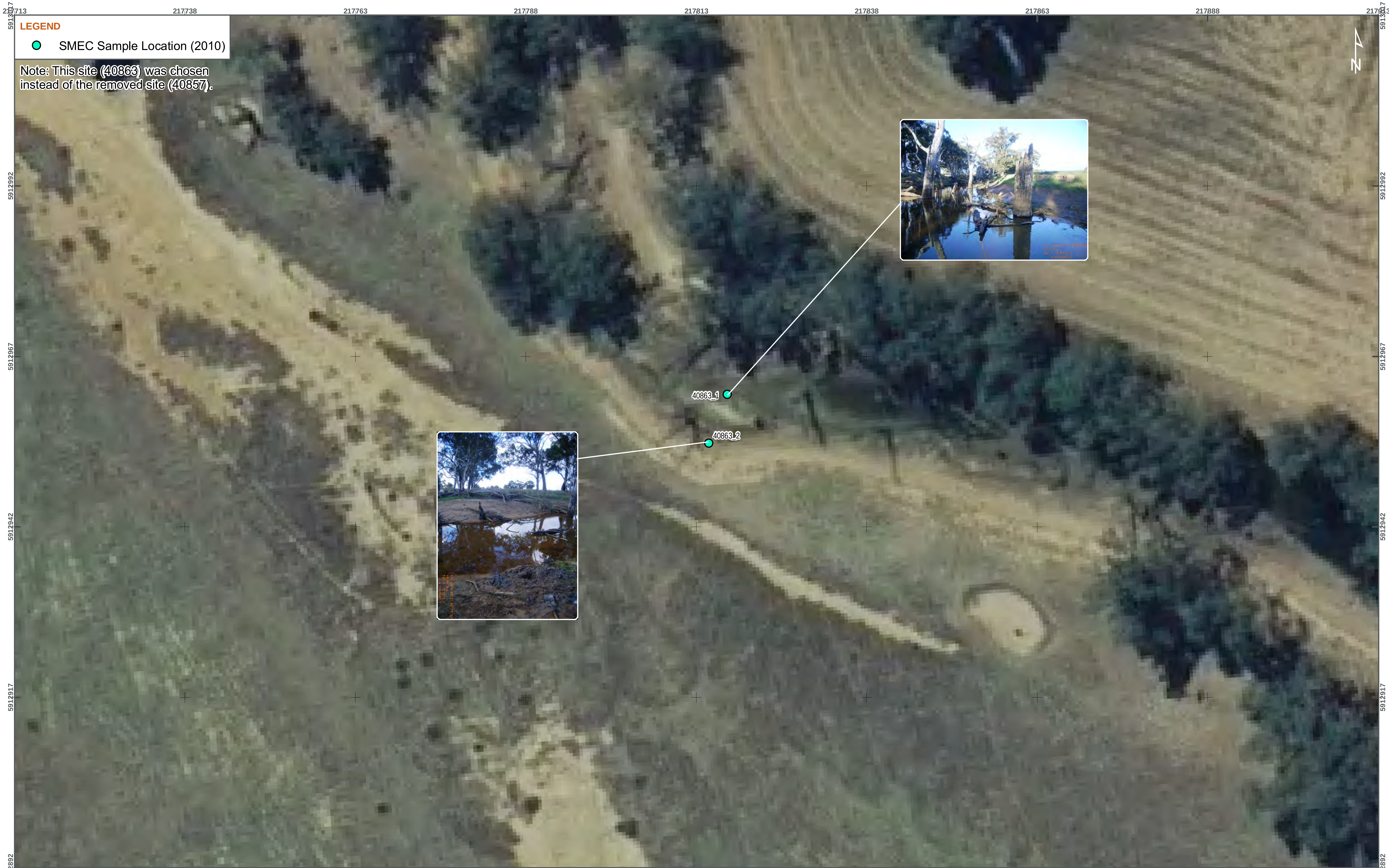
CREATED BY B. Stewart

LOCATION I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801

FIGURE TITLE Bet Bet Creek 40862 - CMA: NCCMA

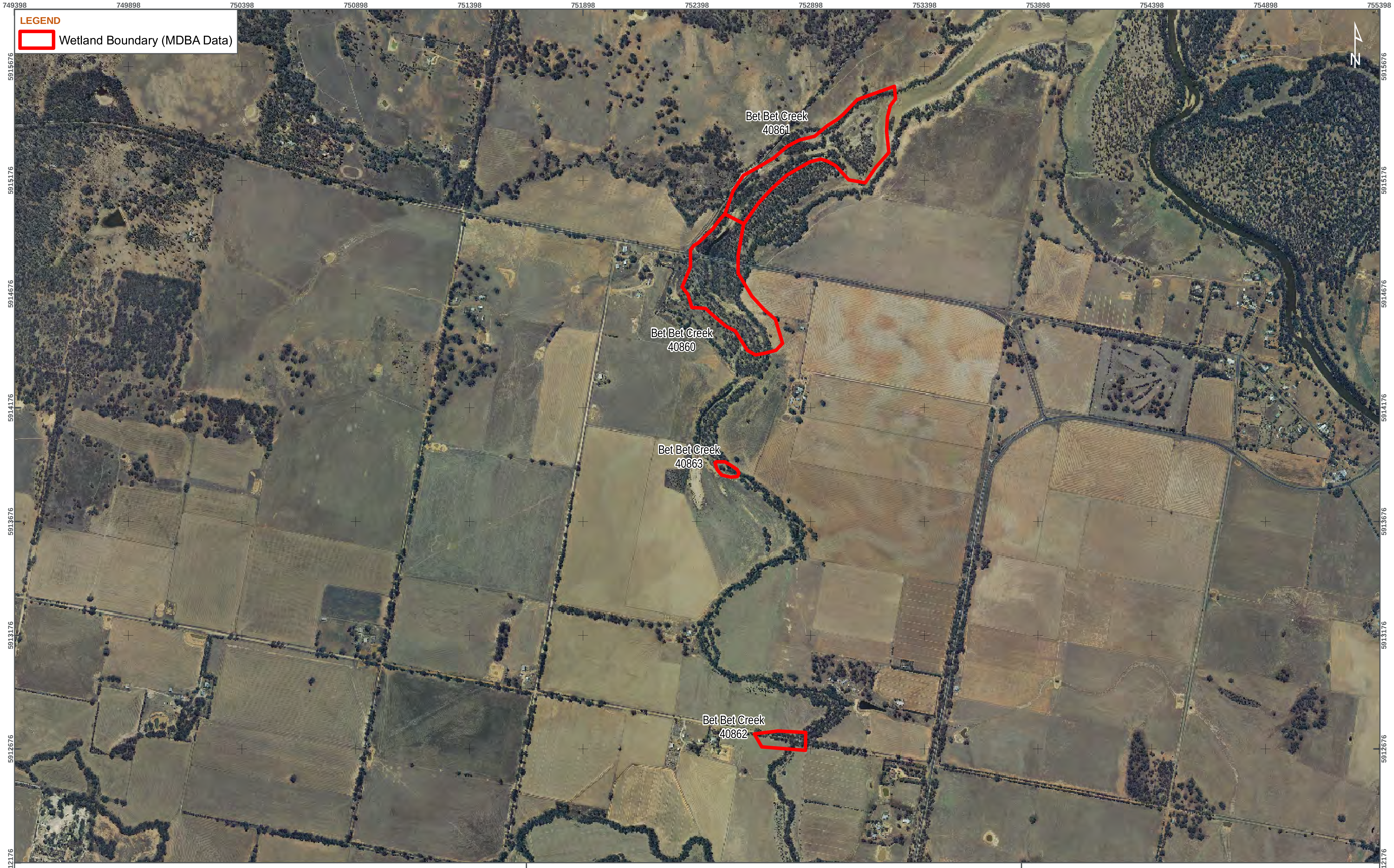
SMEC



DATE 09/07/2010	**SCALE** 1:500	0 5 10 20 Meters	**PAGE SIZE** A3	**COORDINATE SYSTEM** MGA Zone 55	**FIG NO.** 1d **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS				**PROJECT NO.** 3001801 **FIGURE TITLE** Bet Bet Creek 40863 CMA:NCCMA

Note: Inset Photos show Surface Condition of Site

SMEC



DATE 19/08/2010	**SCALE** 1:15,000 (0 125 250 500 Meters)	**PAGE SIZE** A3	**COORDINATE SYSTEM** MGA Zone 54	**FIG NO.** 1e **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions
CREATED BY B. Stewart	**LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS			**PROJECT NO.** 3001801 **FIGURE TITLE** Bet Bet Creek 40860 - 40863 Site Overview

Note: Inset Photos show Surface Condition of Site

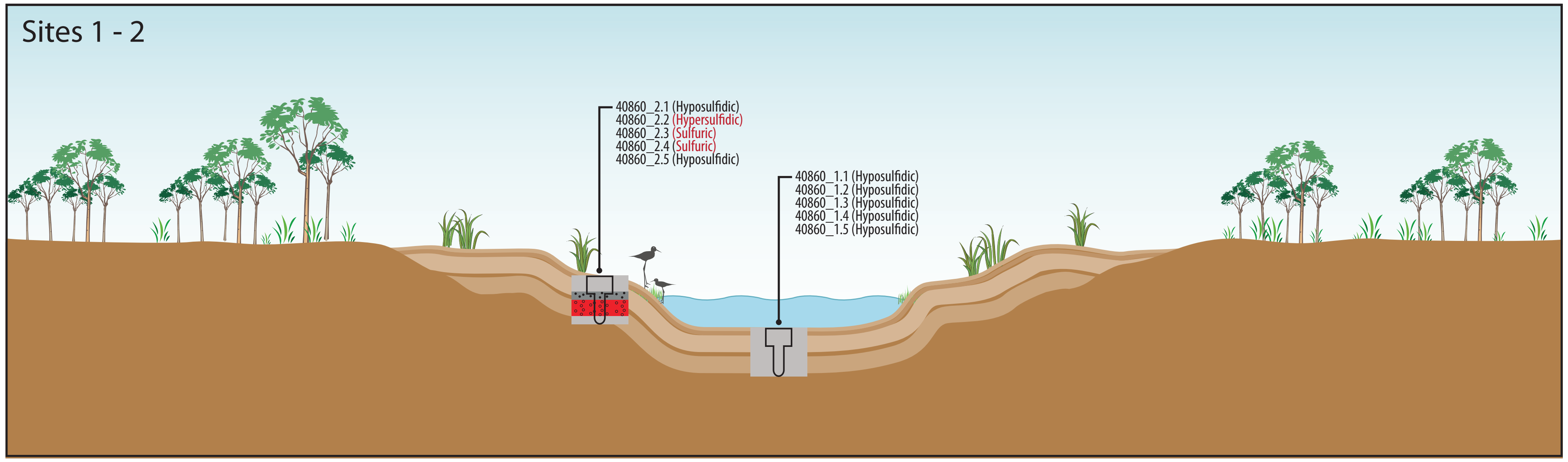
SMEC

LEGEND

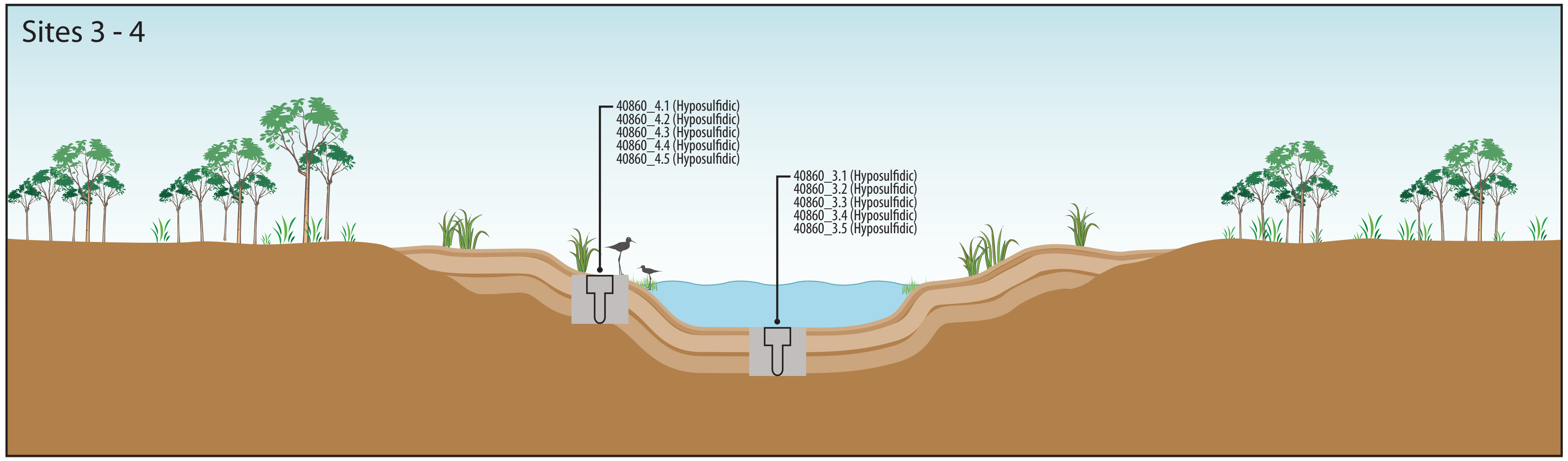
Soil Types

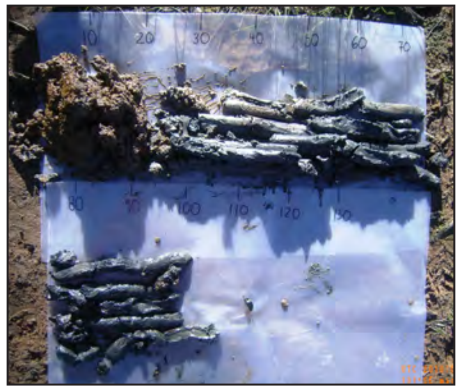
- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils

Sites 1 - 2



Sites 3 - 4





40860_1

40860_2

40860_2

40860_3

40860_4

40860_4

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2a **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

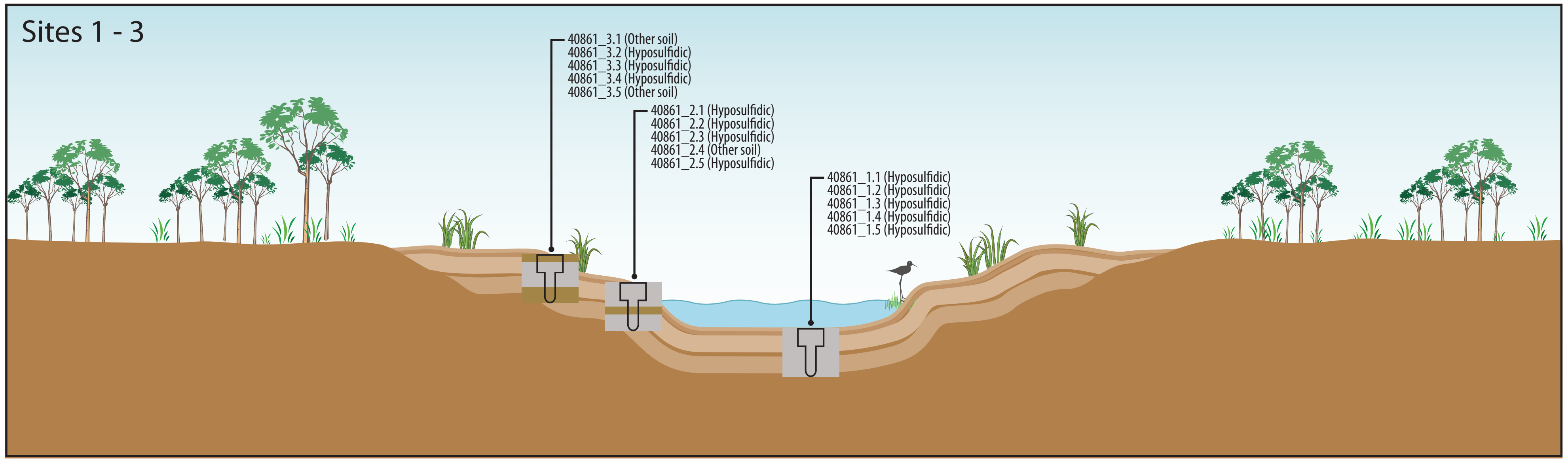
CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

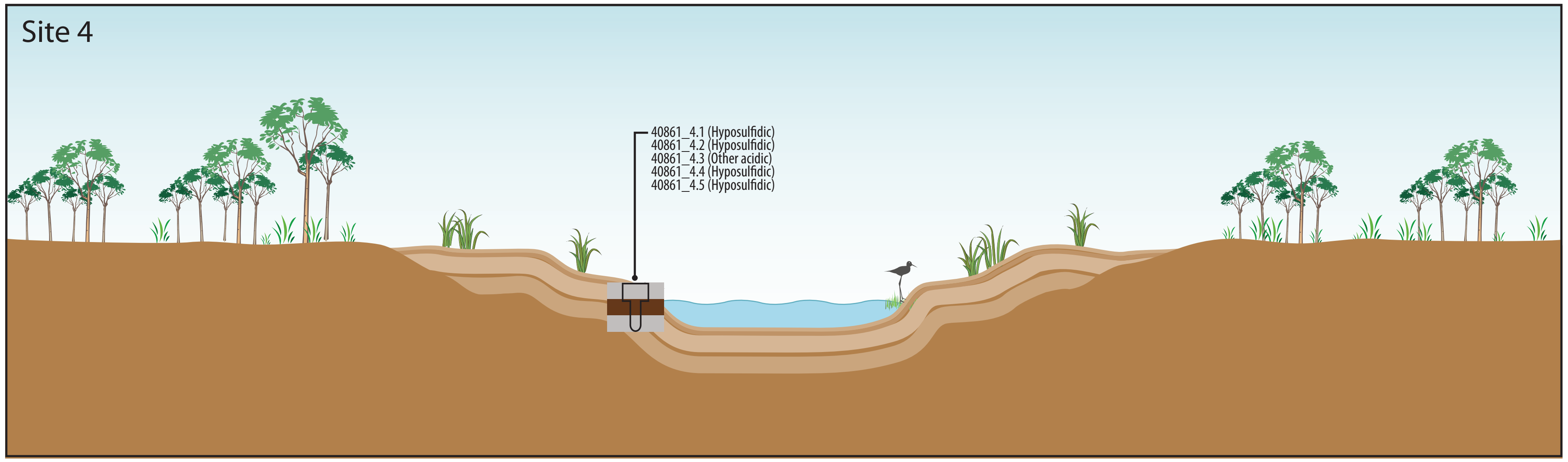
PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Bet Bet Creek 40860

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

LEGEND
Soil Types

Sulfuric	Hyposulfidic
Monosulfidic	Other acidic
Hypersulfidic	Other soils






40861_1


40861_2


40861_2


40861_3


40861_3


40861_4

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2b **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

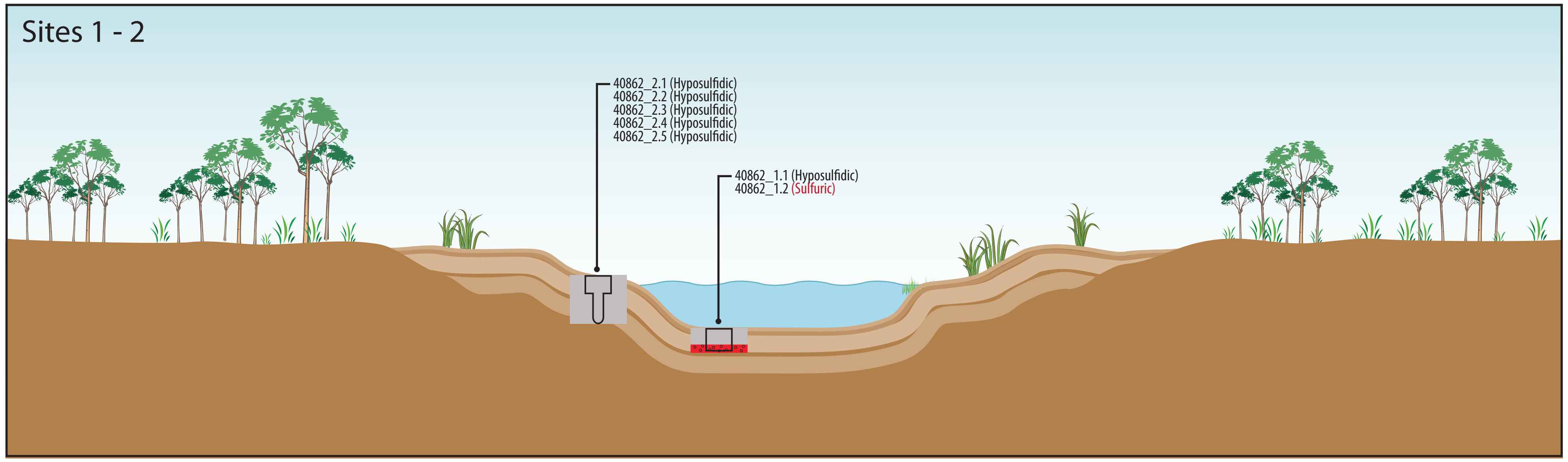
Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Bet Bet Creek 40861

LEGEND
Soil Types

Sulfuric	Hyposulfidic
Monosulfidic	Other acidic
Hypersulfidic	Other soils



40862_1

40862_2

40862_2

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2c **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

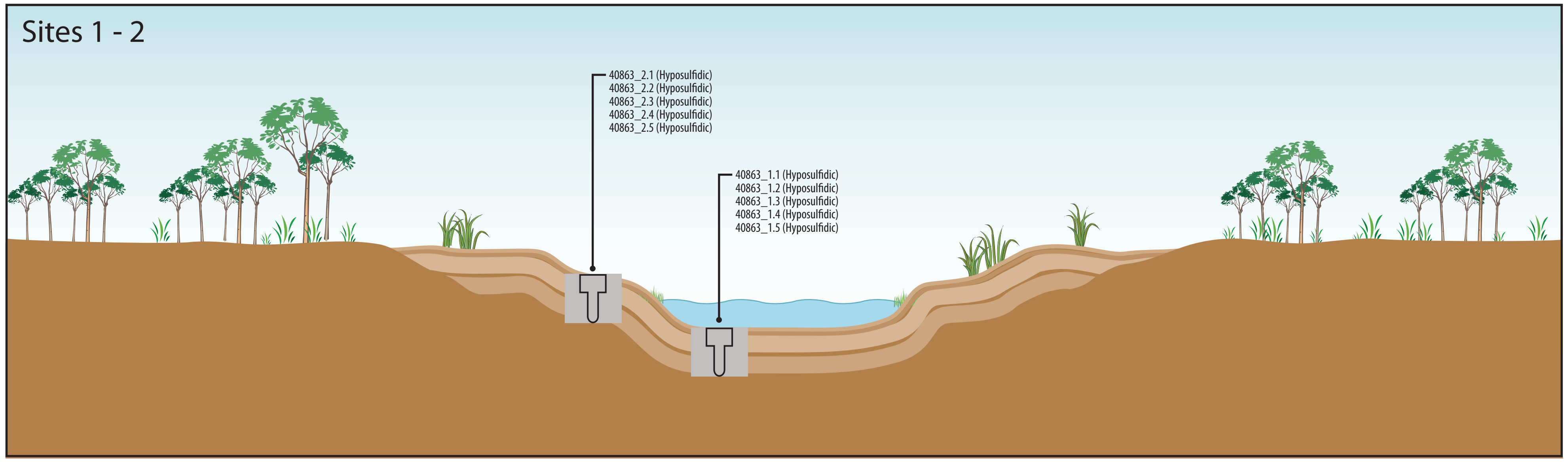
CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

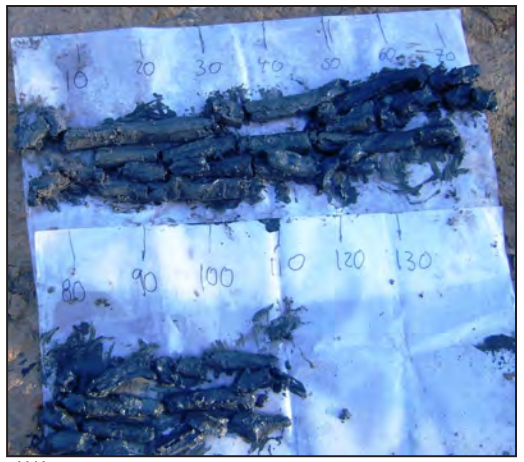
PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Bet Bet Creek 40862

LEGEND

Soil Types

- Sulfuric
- Monosulfidic
- Hypersulfidic
- Hyposulfidic
- Other acidic
- Other soils





40863_1

40863_2

40863_2

DATE 15/07/2010 **SCALE** Not to Scale

FIG NO. 2d **PROJECT TITLE** Detailed Assessment of Acid Sulfate Soils: MD1513-17 Wetlands within the Victorian Northern Flowing Rivers Regions

Note: This is a conceptual cross section of wetlands surveyed and provides an inferred assessment of soil materials and site features at sites sampled. Changes in environmental conditions can occur due to seasonal and temporal factors and therefore the data collected represents only a snapshot of soil and site conditions.

CREATED BY B. Stewart **LOCATION** I:\projects\3001801 – MDBA Detailed Inland ASS\009DATA\GIS

PROJECT NO. 3001801 **FIGURE TITLE** Conceptual Hydrotoposequence Cross Section, Bet Bet Creek 40863

- 40861_1: water, reeds, low point, subaqueous; soil consisted of weak, dark grayish brown silty clay loam overlying soft, dark grey clay.
- 40861_2: soft, reed surface matting, mid point; soil consisted of very soft, yellowish brown clay loam and clay overlying very weak, very dark greyish brown silty clay loam.
- 40861_3: soft, low grasses, high point; soil consisted of loose to very weak, very dark greyish brown clay loam and silty clay loam overlying very weak, dark yellowish brown sandy clay loam.
- 40861_4: cracking, minor low grasses, mid point; soil consisted of very weak, brown silty clay loam overlying weak, brown some grey brown clay.
- 40862_1: water, long reeds, low point, subaqueous; soil consisted of loose, dark brown loam overlying loose, brown clayey sand.
- 40862_2: firm, long reeds, mid point; soil consisted of soft, very dark brown sandy loam overlying soft, bluish black silty clay loam.
- 40863_1: water, bare, woody debris in channel, low point, subaqueous; soil consisted of very soft, black silty clay loam overlying very soft, bluish black silty clay loam.
- 40863_2: soft, bare to minor grasses, mid point; soil consisted of very soft, dark grey to dark brown clay loam overlying soft, dark greenish grey clay.

Table 1 – Soil Identification, subtype and general location description for Bet Bet Creek Sites.

Site ID	Easting UTM Zone 54	Northing UTM Zone 54	Acid sulfate soil subtype class	General location description
40860_1	217857	5913648	Subaqueous soil	Low point, subaqueous sediments, middle of channel.
40860_2	217860	5913649	Sulfuric soil	Mid point, upper bank of channel.
40860_3	217666	5913942	Subaqueous soil	Low point, subaqueous sediments, middle of channel.
40860_4	217662	5913939	Hydrosol - sandy or loamy	Mid point, upper bank of channel.
40861_1	217985	5914350	Subaqueous soil	Low point, subaqueous sediments, middle of channel.
40861_2	217980	5914355	Hydrosol - sandy or loamy	Mid point, edge of water line in flatter/wider channel section.
40861_3	217972	5914365	Hydrosol - sandy or loamy	High point, upper bank of channel.
40861_4	218394	5914553	Hydrosol - sandy or loamy	Mid point, edge of water line in large cracking surface channel section.
40862_1	218225	5911807	Sulfuric soil	Low point, subaqueous sediments, middle of channel.
40862_2	218217	5911819	Hydrosol - sandy or loamy	Mid point, upper bank of channel.
40863_1	217817	5912962	Subaqueous soil	Low point, subaqueous sediments, middle of channel.
40863_2	217815	5912955	Hydrosol - sandy or loamy	Mid point, upper bank of channel.

Figure 3 – Photographs of site 40860_1, showing the water surface (water column of 40cm), and the laid out soil profile of soft, dark yellowish brown silty clay loam overlying very weak, black silty clay loam.

Figure 4 – Photographs of site 40860_2, showing the water surface condition and the soil profile of loose, greyish brown sandy clay loam and silty clay loam overlying soft, dark grey clay.

Figure 5 – Photographs of site 40860_3, showing the water surface (water column of 45cm), and the laid out soil profile of loose to weak, brown silty loam and clay overlying soft, very dark bluish grey silty clay loam.

Figure 6 – Photographs of site 40860_4, showing the surface condition and the soil profile of soft, dark brown silty clay loam overlying very weak, dark greyish brown clay.

Figure 7 – Photographs of site 40861_1, showing the surface condition and the soil profile of weak, dark grayish brown silty clay loam overlying soft, dark grey clay.


Figure 8 – Photographs of site 40861_2, showing the surface condition and the soil profile of very soft, yellowish brown clay loam and clay overlying very weak, very dark greyish brown silty clay loam.


Figure 9 – Photographs of site 40861_3, showing the surface condition and the soil profile of loose to very weak, very dark greyish brown clay loam and silty clay loam overlying very weak, dark. yellowish brown sandy clay loam.

Figure 10 – Photographs of site 40861_4, showing the surface condition and the soil profile of very weak, brown silty clay loam overlying weak, brown some grey brown clay.

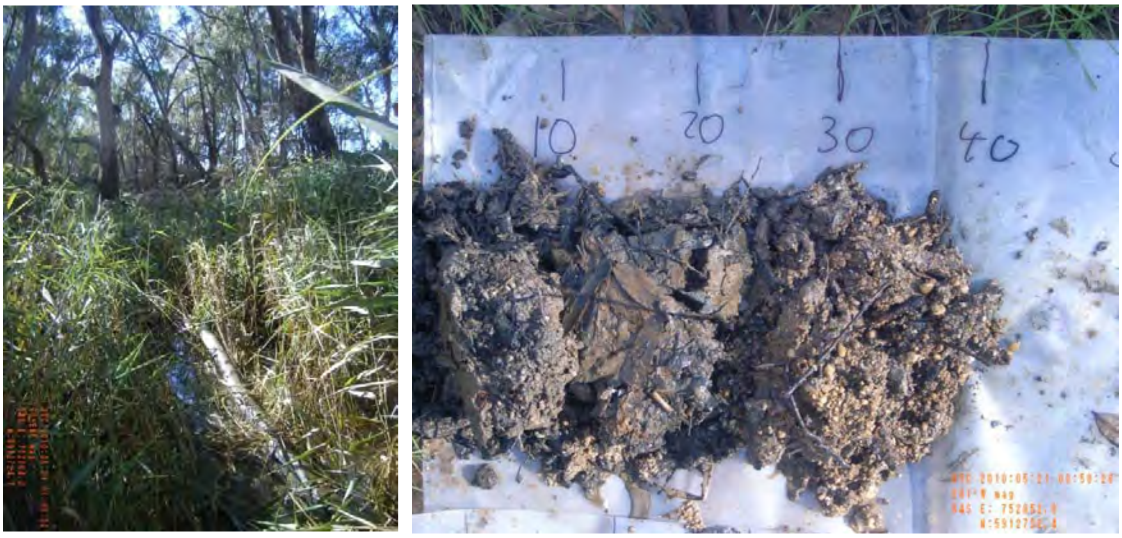


Figure 11 – Photographs of site 40862_1, showing the surface condition and the soil profile of loose, dark brown loam overlying loose, brown clayey sand.

Figure 12 – Photographs of site 40862_2, showing the surface condition and the soil profile of very dark brown sandy loam overlying soft, bluish black silty clay loam.

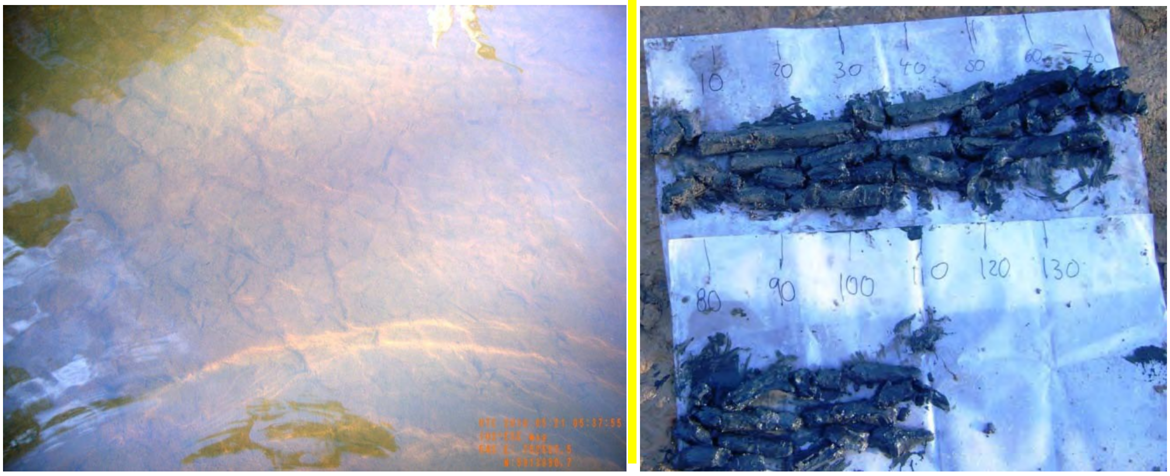


Figure 13 – Photographs of site 40863_1, showing the water surface (water column of 35cm) and the laid out soil profile of very soft, black silty clay loam overlying very soft, bluish black silty clay loam.

Figure 14 – Photographs of site 40863_2, showing the surface condition and the soil profile very soft, dark grey to dark brown clay loam overlying soft, dark greenish grey clay.

1.3 Summary of Field and Laboratory Results

The tabulated soil field and laboratory data is provided in **Table 3** at the end of this appendix. The subheadings below provide short summaries of the results obtained.

1.3.1 Soil pH Testing (pH_w, $pH_{peroxide}$ and $pH_{incubation}$)

Soil pH profiles for the eight sites are presented in **Figures 15 to 18** on the following pages. Summary soil pH profile results indicate:

- 40860_1: all samples have $pH_w < 7.0$. Surface soils (0 - 20cm) have pH_w 4.80 – 5.59 with subsoils (20 – 105cm) ranging 6.25 – 6.99. Surface soils $pH_{incubation}$ ranged 4.25 – 4.50 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.00 – 5.44 indicating hyposulfidic conditions.
- 40860_2: all samples have $pH_w < 7.5$. Surface soils (0 - 20cm) have pH_w 4.07 – 4.24 with subsoils (20 – 110cm) ranging 3.63 – 7.18. Surface soils $pH_{incubation}$

ranged 3.51 – 4.45 indicating hypersulfidic and hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 3.21 – 5.64 indicating sulfuric and hyposulfidic conditions.

- 40860_3: all samples have pH_w < 7.5. Surface soils (0 - 30cm) have pH_w 4.89 – 6.02 with subsoils (30 – 100cm) ranging 5.59 – 7.24. Surface soils $pH_{incubation}$ ranged 4.03 – 4.16 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.76 – 5.30 indicating hyposulfidic conditions.
- 40860_4: all samples have pH_w < 8.0. Surface soils (0 - 20cm) have pH_w 6.83 – 6.95 with subsoils (20 – 110cm) ranging 7.26 – 7.72. Surface soils $pH_{incubation}$ ranged 6.20 – 6.34 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 6.47 – 6.77 indicating hyposulfidic conditions.
- 40861_1: all samples have pH_w < 6.5. Surface soils (0 - 15cm) have pH_w 5.33 – 6.07 with subsoils (15 – 110cm) ranging 4.97 – 6.03. Surface soils $pH_{incubation}$ ranged 4.56 – 4.76 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.35 – 4.81 indicating hyposulfidic conditions.
- 40861_2: all samples have pH_w < 7.0. Surface soils (0 - 15cm) have pH_w 6.13 – 6.73 with subsoils (15 – 75cm) ranging 6.48 – 6.99. Surface soils $pH_{incubation}$ ranged 5.02 – 5.65 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.59 – 6.01 indicating hyposulfidic and other soil conditions.
- 40861_3: all samples have pH_w < 7.5. Surface soils (0 - 20cm) have pH_w 6.65 – 6.84 with subsoils (20 – 100cm) ranging 6.34 – 7.16. Surface soils $pH_{incubation}$ ranged 5.61 – 5.85 indicating hyposulfidic and other soil conditions. Subsoils $pH_{incubation}$ ranged 5.62 – 6.22 indicating hyposulfidic and other soil conditions.
- 40861_4: all samples have pH_w < 7.0. Surface soils (0 - 20cm) have pH_w 5.38 – 6.63 with subsoils (20 – 110cm) ranging 4.85 – 6.33. Surface soils $pH_{incubation}$ ranged 4.73 – 5.69 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.45 – 5.86 indicating hyposulfidic and other soil conditions.
- 40862_1: all samples have pH_w < 5.0. Surface soils (0 - 35cm) have pH_w 3.85 – 4.69 with $pH_{incubation}$ ranging 2.55 – 4.20 indicating hyposulfidic and sulfuric conditions.
- 40862_2: all samples have pH_w < 7.5. Surface soils (0 - 20cm) have pH_w 6.43 – 6.55 with subsoils (20 – 110cm) ranging 6.65 – 7.16. Surface soils $pH_{incubation}$ ranged 4.60 – 4.85 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 5.02 – 6.62 indicating hyposulfidic conditions.
- 40863_1: all samples have pH_w < 7.5. Surface soils (0 - 20cm) have pH_w 6.03 – 6.64 with subsoils (20 – 110cm) ranging 6.83 – 7.20. Surface soils $pH_{incubation}$ ranged 4.55 – 4.92 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.09 – 6.19 indicating hyposulfidic conditions.
- 40863_2: all samples have pH_w < 7.5. Surface soils (0 - 15cm) have pH_w 4.70 – 5.11 with subsoils (20 – 100cm) ranging 6.16 – 7.16. Surface soils $pH_{incubation}$ ranged 4.06 – 4.44 indicating hyposulfidic conditions. Subsoils $pH_{incubation}$ ranged 4.36 – 5.81 indicating hyposulfidic conditions.

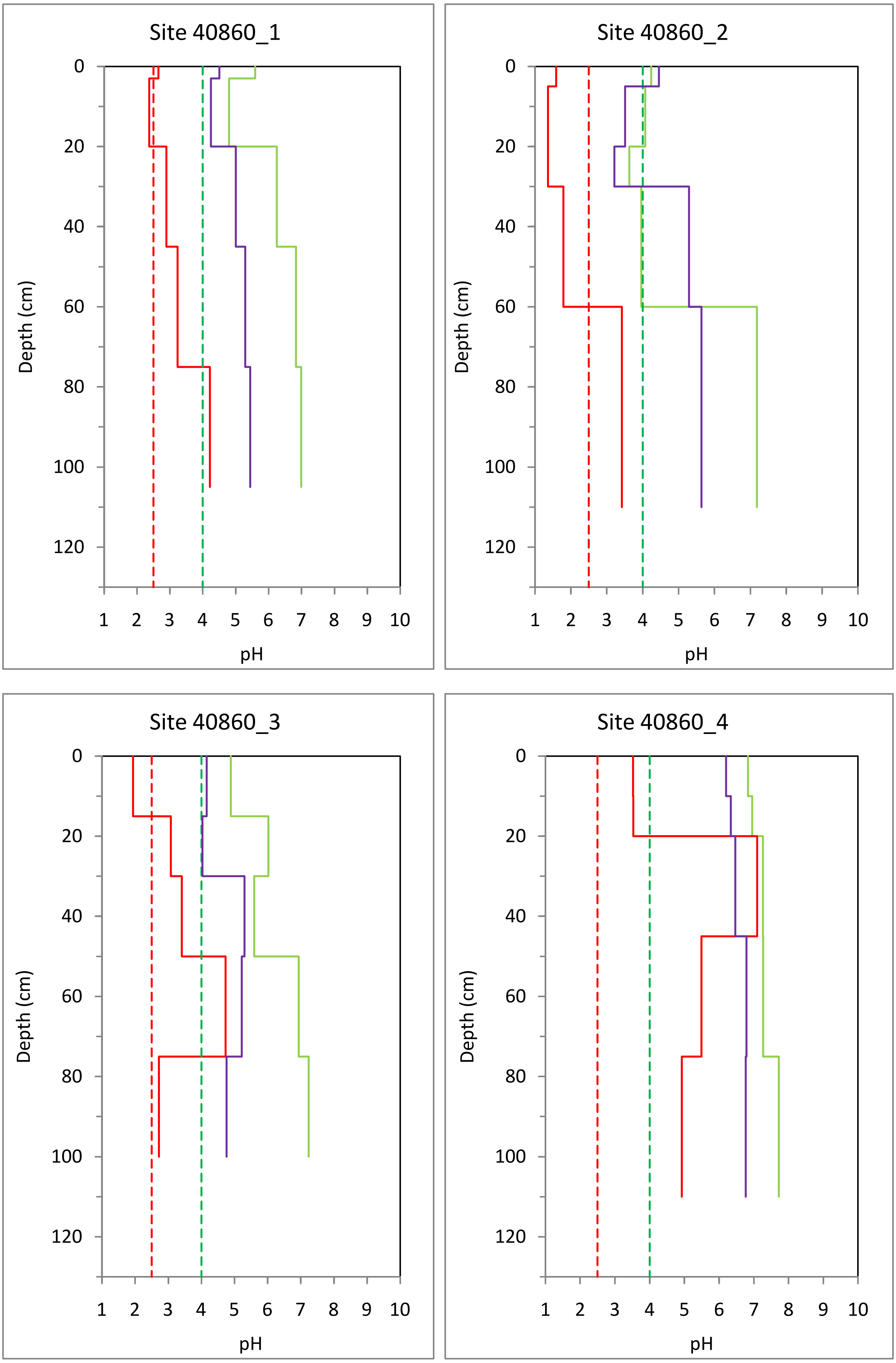


Figure 15 – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

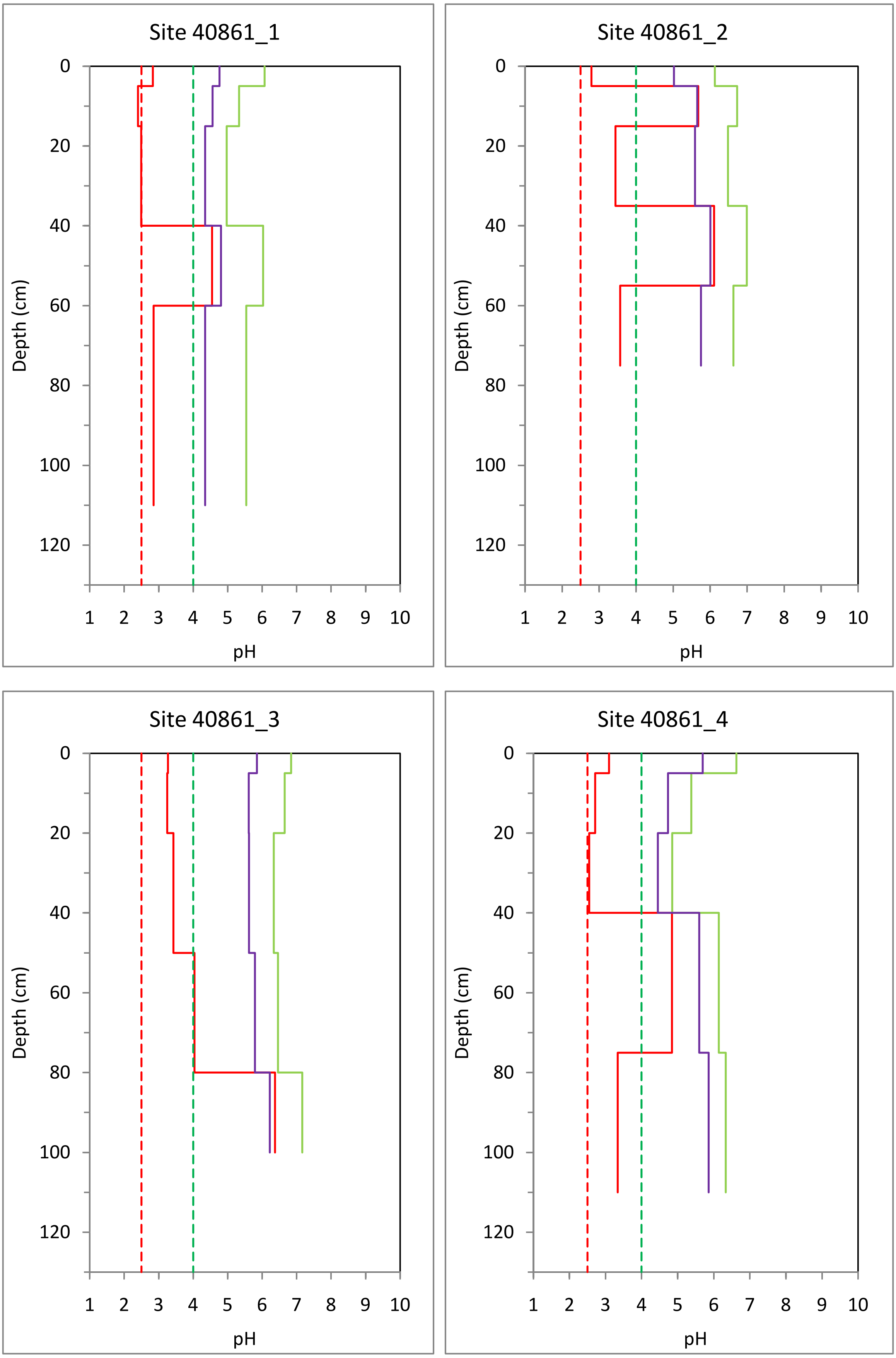


Figure 16 – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

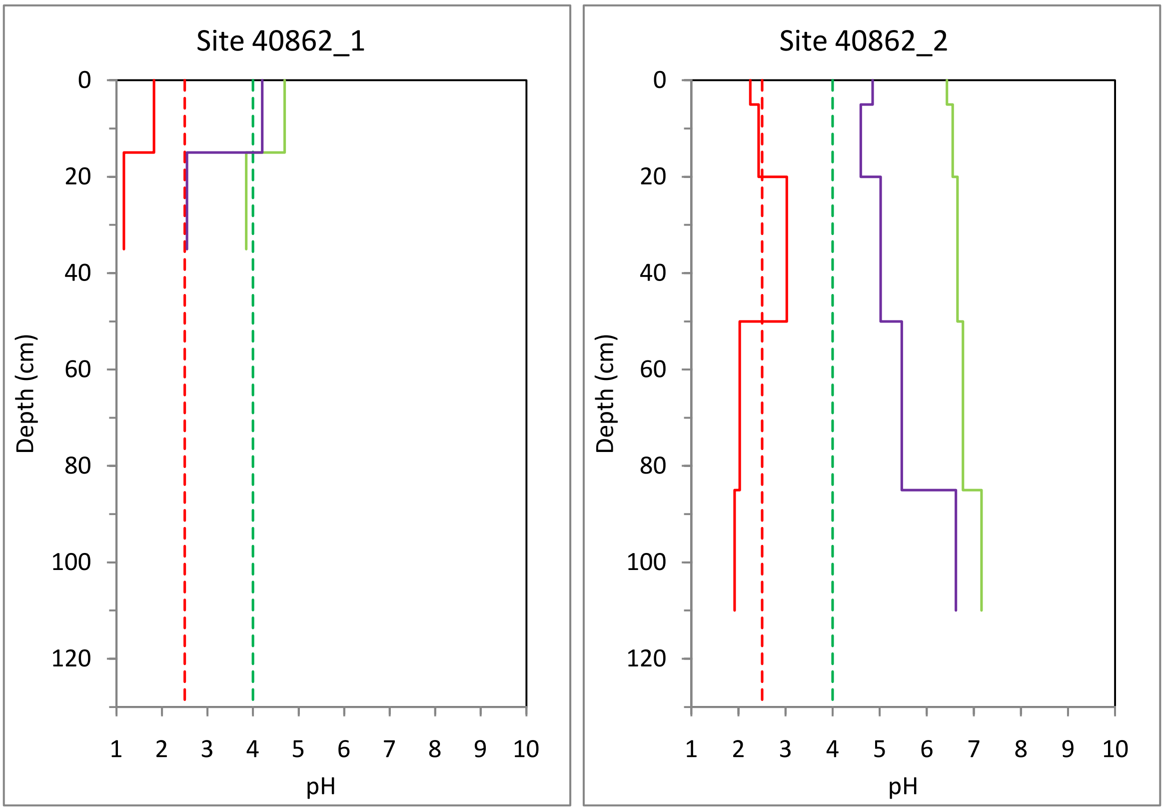


Figure 17 – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

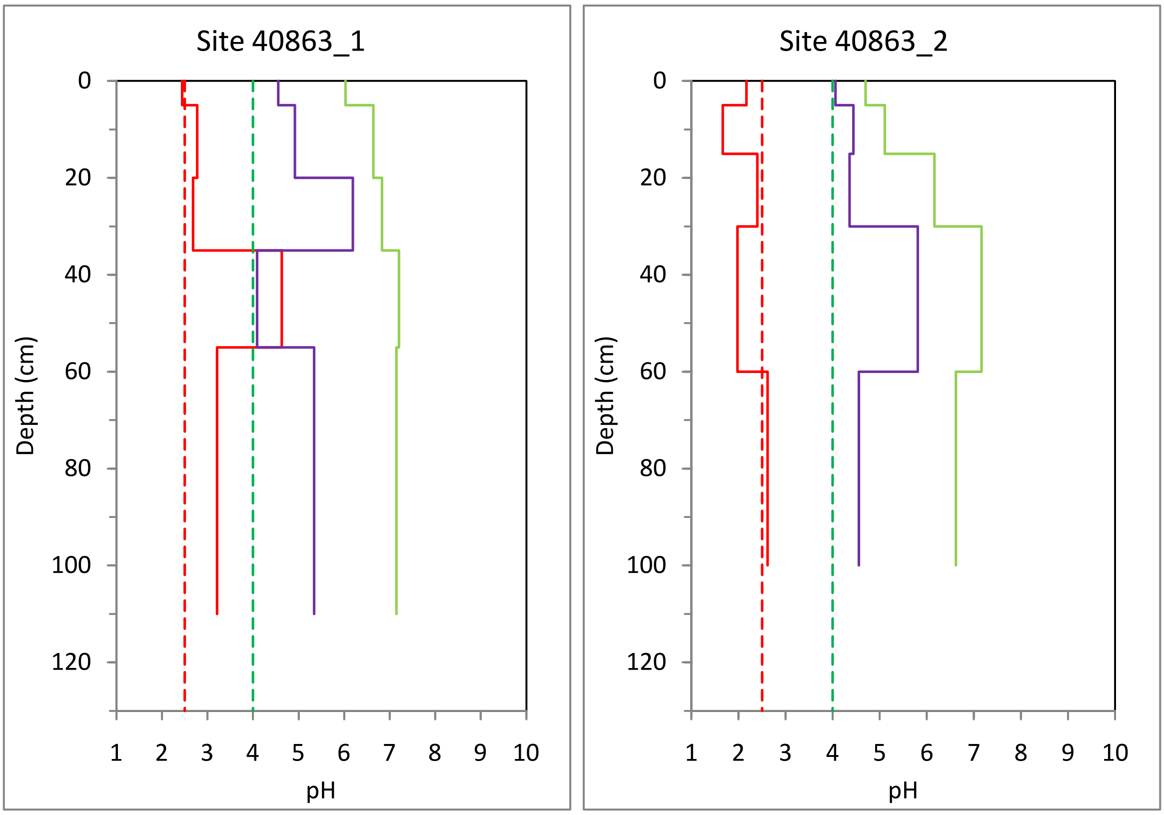


Figure 18 – Depth profiles of soil pH for Bet Bet Creek, showing soil pH (pH_w as green line), peroxide treated pH ($pH_{peroxide}$ as red line) and ageing pH ($pH_{incubation}$ after 8 weeks as purple line). Critical pH_w and $pH_{incubation}$ value of 4.0 (green dashed line) and critical $pH_{peroxide}$ value of 2.5 (red dashed line).

1.3.2 Acid Base Accounting

The acid base accounting tabulated data is provided in **Table 3** at the end of this appendix and summarised in **Figures 19 to 22** on the following pages.

1.3.3 Titratable Actual Acidity (TAA)

All 57 soil samples collected were analysed for titratable actual acidity (TAA). Results ranged between 0 – 166 mol H+/tonne for samples analysed. TAA results were typically higher in surface soils and decreasing in concentration within deeper subsoils. The highest results were from site 40860_2 from the edge of the channel. The results are supported by the pH profiles for the sites typically indicating increasing pH_W with depth of sample.

1.3.4 Chromium Reducible Sulfur (S_{CR})

All 57 soil samples collected were analysed for Chromium Reducible Sulfur (S_{CR}). Sulfidic soil materials are classified as such where $S_{CR} \geq 0.01\%$ S. Results ranged from <0.01% S (limit of laboratory detection) to 0.65% S. Of the 57 samples analysed 22 (39%) were >0.10% S with the majority and highest results coming typically from subsoils at the majority of sites sampled.

1.3.5 Acid Volatile Sulfur (AVS)

No monosulfidic black ooze (MBO) was noted to occur during sampling based on field observations. Therefore, no samples were analysed for Acid Volatile Sulfur (S_{AV}) from Bet Bet Creek sites.

1.3.6 Retained Acidity (RA)

Out of the 57 samples collected, 4 were analysed (7%) for Retained Acidity with a trigger value of pH_{KCL} <4.50. Results ranged between 14 – 122 mole H+/tonne. The highest results were from site 40860_2 from the edge of the channel.

1.3.7 Acid Neutralising Capacity (ANC)

8 out of the 57 soil samples collected (14%) were analysed for Acid Neutralising Capacity (ANC). Results ranged from 0.26 – 1.63 % $CaCO_3$. Soil materials with ANC were typically present in the deeper subsoils within subaqueous environments (mid channel). ANC was encountered within soils from sites 40860_1, 40860_3, 40862_2 and 40863_1.

1.3.8 Net Acidity

The following net acidity thresholds have been adopted for this assessment:

- low net acidity (<19 mole H+/tonne);
- moderate net acidity (19 - 100 mole H+/tonne); and
- high net acidity (> 100 mole H+/tonne).

Net acidity results for all sites and samples ranged between 0 to 544 mol H+/tonne. 14 out of the 57 samples (25%) have a high net acidity, 27 (47%) samples have moderate net acidity with 15 samples (26%) having a low net acidity. Typically, the highest net acidity values were encountered within subsoils.

1.3.9 Water soluble SO_4

Water soluble sulfate values ranged between 205.5 to 2,205 mg/L for surface soil samples collected (i.e. 0 – 10cm). Twelve surface soil samples were analysed for water soluble sulfate in total. All samples collected exceed the trigger criterion of 100 mg/L for MBO formation potential.

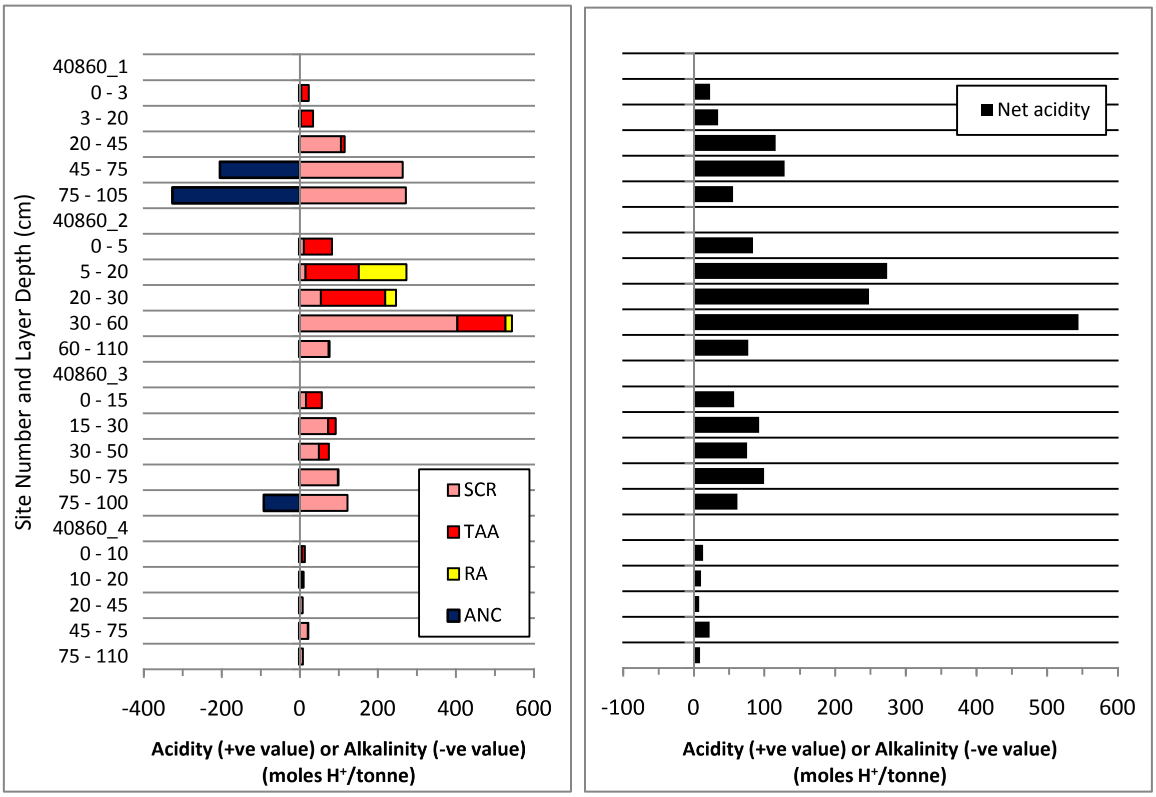


Figure 19 – Acid base accounting depth profiles for Bet Bet Creek (40860). Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

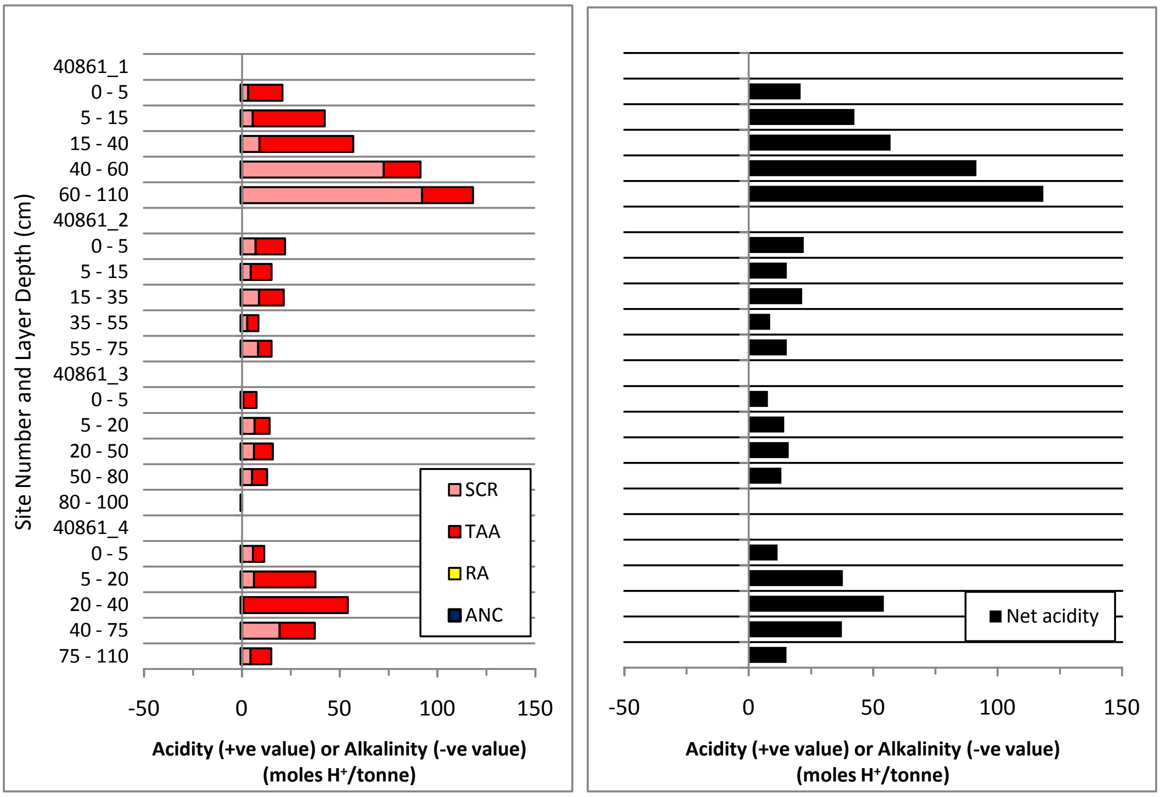


Figure 20 – Acid base accounting depth profiles for Bet Bet Creek (40861). Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

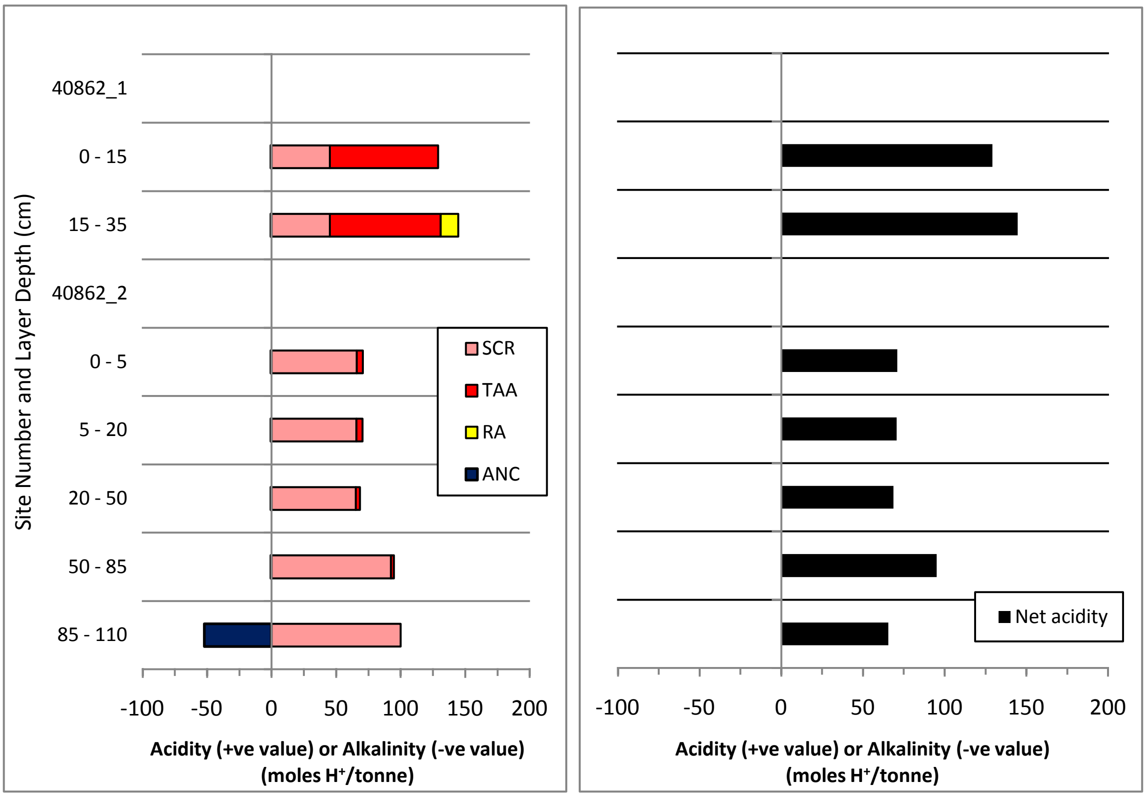


Figure 21 – Acid base accounting depth profiles for Bet Bet Creek (40862). Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

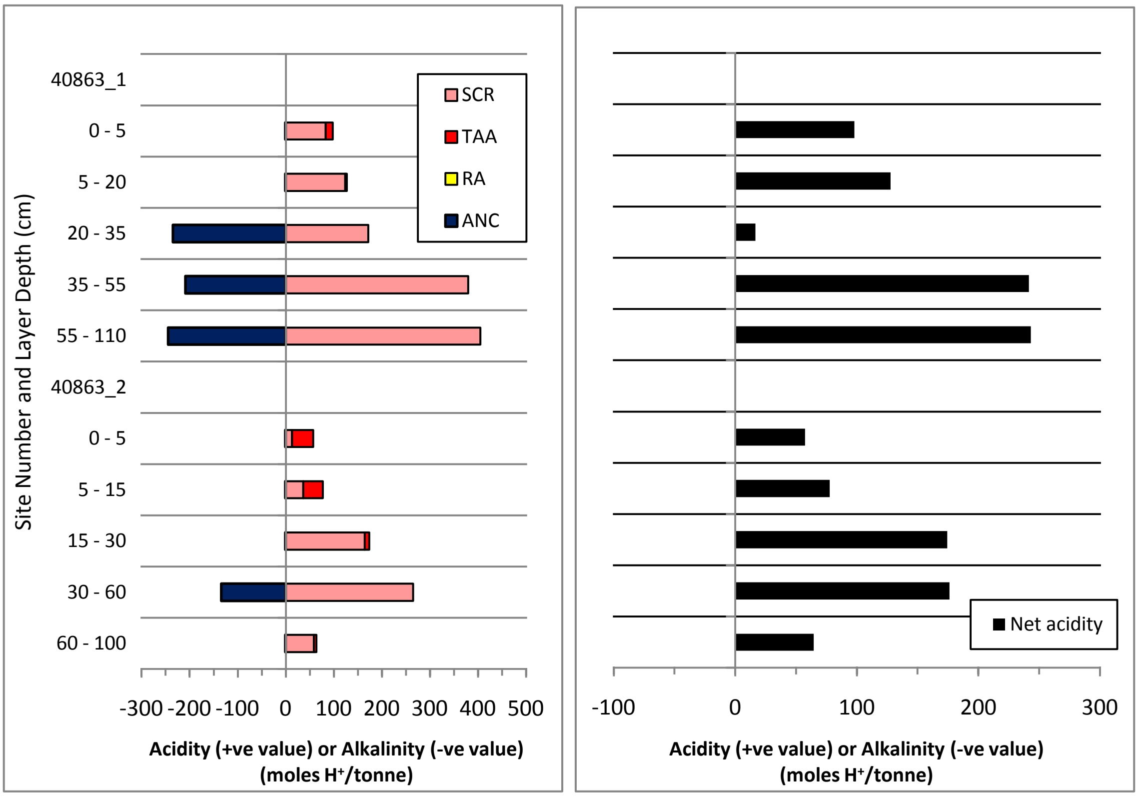


Figure 22 – Acid base accounting depth profiles for Bet Bet Creek (40863). Left side shows the components: titratable actual acidity (TAA – red bar), potential acidity (S_{CR} – pink bar), retained acidity (RA – yellow bar), Monosulfides (A_{VS} DW – purple bar) and acid neutralising capacity (ANC – dark blue bar), and right side shows net acidity (net acidity – black bars).

1.4 Hydrochemistry

The tabulated water field and laboratory analysis data is provided in **Table 4** and **Table 5** at the end of this appendix. Field water quality measurements were taken at ten out of the twelve sites from Bet Bet Creek. Four measurements were from pit inflow waters and six from wetland surface waters. Eight water samples were collected for laboratory analysis including four from pit inflow waters and four from wetland surface waters. **Table 8** provides water watch data for Bet Bet Creek collected by the NCCMA between 2007 – 2009.

The wetland surface waters were near neutral to slightly acidic (pH 5.70 – 7.48). Surface waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of pH 6.5 – 8.0 for sites 40860_1 and 40860_3 only. Pit inflow waters were all acidic to slightly acidic (pH 4.86 – 6.44). Pit inflow waters were outside the ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 – 8.0 for all sites (40860_2, 40861_2, 40862_2 and 40863_2).

The majority of surface water and pit infow waters had high SEC values greater than the ANZECC (2000) Lowland River trigger values of 125 – 2,200µS/cm. SEC ranged 1,853 – 18,570µS/cm. Only two sites had SEC results below the trigger values which were 40861_1 and 40861_2. Alkalinity (as HCO_3) ranged 0 – >240 HCO_3. All surface water sites had oxidising conditions ranging 10 – 138 Eh with pit water inflow ranging -24 to 120 Eh. DO for surface waters were between 4.46 – 14.60 mg/L.

Surface and pit inflow waters exceeded the most relevant ANZECC (2000) trigger values for some nutrients (NH_4, NO_3 and PO_4) and some dissolved metals at all sites (Al, As, Cd, Co, Cr, Fe, Mn, Ni, and Zn). Dissolved Fe and Mn concentrations were typically very high at pit inflow sampling sites 40860_2, 40862_2 and 40863_2.

The water data indicates that Bet Bet Creek channel surface water has not been significantly affected by acidification with pH values ranging 5.70 – 7.48. Pit inflow waters were acidic to slightly acidic pH 4.86 – 6.44 and with high levels of dissolved metals such as Fe and Mn. Flushing of the channel may reduce the concentrations of acidity present based on pit inflow data (higher acidity and dissolved metals) in comparison to surface water (neutral to slightly acidic).

1.5 Discussion

Acid sulfate soils within Bet Bet Creek occurred as hyposulfidic soil material forming within the channel low points and within the channel banks with some sulfuric and minor hypersulfidic materials also occurring within the channel.

Results ranged from <0.01% S (limit of laboratory detection) to 0.65% S. Of the 57 samples analysed 22 (39%) were >0.10% S with the majority and highest results coming typically from subsoils at the majority of sites sampled.Twelve surface soil samples were analysed for water soluble sulfate in total. All samples collected exceed the trigger criterion of 100 mg/L for MBO formation potential.

Net acidity results for all sites and samples ranged between 0 to 544 mol H+/tonne. 14 out of the 57 samples (25%) have a high net acidity, 27 (47%) samples have moderate net acidity with 15 samples (26%) having a low net acidity. Typically, the highest net acidity values were encountered within subsoils.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there are twenty one (21) high priority sites based on the presence of hyposulfidic materials with S_{CR} >0.10% S, one (1) high priority sample based on the presence of hypersulfidic materials, three (3) high priority samples based on the presence of sulfuric materials and twelve (12) high priority samples with water soluble sulfate results above the trigger criterion of 100 mg/L.

There are twenty eight (28) moderate priority samples based on the presence of hyposulfidic materials with S_{CR} <0.10% S. The remaining four (4) samples are classified as “no further assessment”.

Due to the number of high and moderate net acidities, high priority samples and extent of materials along the creek channel, Phase 2 laboratory analysis may be warranted for selected samples from Bet Bet Creek.

The potential hazards at a wetland scale posed by acid sulfate soil materials at the Bet Bet Creek are:

- Acidification hazard: high level of concern based on the high and moderate net acidity within soil materials at the wetland. Both sulfuric and hypersulfidic materials are present within the channel and may provide a sulfidic acidity source.

- De-oxygenation hazard: medium level of concern as water soluble sulfate results for all surface soil materials exceeded the trigger value for monosulfide formation, although no MBO materials were observed in the wetland during this survey.

- Metal mobilisation: The high acidification hazard indicates that sulfidic sources of acidity may be sufficient for additional and significant metals mobilisation. Dissolved Fe and Mn concentrations were typically very high pit inflow sampling sites. High level of concern.

1.6 Summary of Key Findings for Bet Bet Creek

The summary of key findings for Bet Bet Creek is detailed in Table 2.

Table 2 – Summary of Key Findings

Soil materials:	• Monosulfidic materials were not observed within the creek. • Sulfuric materials were observed within the creek channel. • Hypersulfidic materials were observed within the creek channel. • Hyposulfidic materials were encountered within the channel low points and within the channel banks. • Net acidities ranged between 0 to 544 mol H+/tonne.
Acid sulfate soil identification:	• Site 40860_1: Subaqueous soil occurring under current standing water level in the wetland. • Site 40860_2: Sulfuric soil occurring within the channel bank. • Site 40860_3: Subaqueous soil occurring under current standing water level in the wetland. • Site 40860_4: Hydrosol – sandy or loamy occurring within the channel bank. • Site 40861_1: Subaqueous soil occurring under current standing water level in the wetland. • Site 40861_2: Hydrosol – sandy or loamy occurring near water edge within channel. • Site 40861_3: Hydrosol – sandy or loamy occurring within the channel bank. • Site 40861_4: Hydrosol – sandy or loamy occurring near water edge within channel with large surface cracking. • Site 40862_1: Sulfuric soil occurring under current standing water level in the wetland. • Site 40862_2: Hydrosol – sandy or loamy occurring within the channel bank. • Site 40863_1: Subaqueous soil occurring under current standing water level in the wetland. • Site 40863_2: Hydrosol – sandy or loamy occurring within the channel bank.
Hazard assessment:	• Acidification hazard – high level of concern. • De-oxygenation hazard – medium level of concern. • Metal mobilisation hazard – high level of concern.

Table 3 – Laboratory analytical data for acid sulfate soil assessment of Bet Bet Creek.

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40860_1.1	40860_1	0	3	0.1186	0.0791	33	5.59	2.65	4.50	468
40860_1.2	40860_1	3	20	0.1334	0.0930	30	4.80	2.37	4.25	-
40860_1.3	40860_1	20	45	0.1203	0.0738	39	6.25	2.89	5.00	-
40860_1.4	40860_1	45	75	0.1143	0.0621	46	6.83	3.23	5.29	-
40860_1.5	40860_1	75	105	0.1030	0.0521	49	6.99	4.22	5.44	-
40860_2.1	40860_2	0	5	0.1256	0.0850	32	4.24	1.59	4.45	481.5
40860_2.2	40860_2	5	20	0.1093	0.0613	44	4.07	1.36	3.51	-
40860_2.3	40860_2	20	30	0.1015	0.0562	45	3.63	1.36	3.21	-
40860_2.4	40860_2	30	60	0.1129	0.0623	45	3.96	1.79	5.29	-
40860_2.5	40860_2	30	110	0.1445	0.1157	20	7.18	3.42	5.64	-
40860_3.1	40860_3	0	15	0.1307	0.0942	28	4.89	1.94	4.16	400.5
40860_3.2	40860_3	15	30	0.1306	0.0907	31	6.02	3.08	4.03	-
40860_3.3	40860_3	30	50	0.1231	0.0863	30	5.59	3.41	5.30	-
40860_3.4	40860_3	50	75	0.1254	0.0847	32	6.94	4.73	5.22	-
40860_3.5	40860_3	75	100	0.1385	0.1007	27	7.24	2.72	4.76	-
40860_4.1	40860_4	0	10	0.1452	0.1118	23	6.83	3.52	6.20	205.5
40860_4.2	40860_4	10	20	0.1352	0.1049	22	6.95	3.53	6.34	-
40860_4.3	40860_4	20	45	0.1428	0.1118	22	7.26	7.10	6.47	-
40860_4.4	40860_4	45	75	0.1402	0.1107	21	7.27	5.49	6.79	-
40860_4.5	40860_4	75	110	0.1559	0.1270	19	7.72	4.93	6.77	-
40861_1.1	40861_1	0	5	0.1299	0.0975	25	6.07	2.83	4.76	315
40861_1.2	40861_1	5	15	0.1142	0.0764	33	5.33	2.40	4.56	-
40861_1.3	40861_1	15	40	0.1165	0.0694	40	4.97	2.49	4.35	-
40861_1.4	40861_1	40	60	0.1136	0.0687	40	6.03	4.55	4.81	-
40861_1.5	40861_1	60	110	0.1209	0.0784	35	5.54	2.85	4.35	-
40861_2.1	40861_2	0	5	0.1301	0.0901	31	6.13	2.79	5.02	208.5
40861_2.2	40861_2	5	15	0.1305	0.0912	30	6.73	5.68	5.65	-
40861_2.3	40861_2	15	35	0.1312	0.0957	27	6.48	3.44	5.59	-
40861_2.4	40861_2	35	55	0.1407	0.1046	26	6.99	6.11	6.01	-
40861_2.5	40861_2	55	75	0.1368	0.1048	23	6.63	3.57	5.75	-
40861_3.1	40861_3	0	5	0.0998	0.0857	14	6.84	3.27	5.85	225

Sample ID	Site ID	Upper depth	Lower depth	Wet weight	Dry weight	Moisture	pH w	pH fox	pH incubation	Sulfate
-	-	cm	cm	kg	kg	%	unit	unit	unit	mg/L
40861_3.2	40861_3	5	20	0.1174	0.0986	16	6.65	3.25	5.61	-
40861_3.3	40861_3	20	50	0.1224	0.1042	15	6.34	3.43	5.62	-
40861_3.4	40861_3	50	80	0.1293	0.1109	14	6.46	4.04	5.79	-
40861_3.5	40861_3	80	100	0.1334	0.1135	15	7.16	6.37	6.22	-
40861_4.1	40861_4	0	5	0.1236	0.0789	36	6.63	3.10	5.69	238.5
40861_4.2	40861_4	5	20	0.1230	0.0798	35	5.38	2.71	4.73	-
40861_4.3	40861_4	20	40	0.1203	0.0778	35	4.85	2.55	4.45	-
40861_4.4	40861_4	40	75	0.1268	0.0841	34	6.14	4.84	5.60	-
40861_4.5	40861_4	75	110	0.1276	0.0855	33	6.33	3.34	5.86	-
40862_1.1	40862_1	0	15	0.0968	0.0559	42	4.69	1.82	4.20	579
40862_1.2	40862_1	15	35	0.1163	0.0757	35	3.85	1.16	2.55	-
40862_2.1	40862_2	0	5	0.1240	0.0865	30	6.43	2.25	4.85	477
40862_2.2	40862_2	5	20	0.1456	0.1156	21	6.55	2.43	4.60	-
40862_2.3	40862_2	20	50	0.1436	0.1169	19	6.65	3.03	5.02	-
40862_2.4	40862_2	50	85	0.1277	0.0905	29	6.77	2.03	5.47	-
40862_2.5	40862_2	85	110	0.1272	0.0891	30	7.16	1.92	6.62	-
40863_1.1	40863_1	0	5	0.1155	0.0748	35	6.03	2.44	4.55	1329
40863_1.2	40863_1	5	20	0.1135	0.0686	40	6.64	2.77	4.92	-
40863_1.3	40863_1	20	35	0.0985	0.0534	46	6.83	2.68	6.19	-
40863_1.4	40863_1	35	55	0.0992	0.0493	50	7.20	4.63	4.09	-
40863_1.5	40863_1	55	110	0.1048	0.0562	46	7.15	3.21	5.34	-
40863_2.1	40863_2	0	5	0.1199	0.0791	34	4.70	2.17	4.06	2205
40863_2.2	40863_2	5	15	0.0921	0.0432	53	5.11	1.67	4.44	-
40863_2.3	40863_2	15	30	0.1151	0.0759	34	6.16	2.40	4.36	-
40863_2.4	40863_2	30	60	0.1196	0.0824	31	7.16	1.98	5.81	-
40863_2.5	40863_2	60	100	0.1313	0.0991	25	6.62	2.62	4.56	-

Table 3 – (Continued) Laboratory analytical data for acid sulfate soil assessment of Bet Bet Creek.

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	$\%CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40860_1.1	40860_1	0	3	5.70	18	0.01	0	-	23	-	Hyposulfidic
40860_1.2	40860_1	3	20	4.90	31	0.01	0	-	35	-	Hyposulfidic
40860_1.3	40860_1	20	45	6.19	9	0.17	0	-	116	-	Hyposulfidic
40860_1.4	40860_1	45	75	6.54	0	0.42	0	1	128	-	Hyposulfidic
40860_1.5	40860_1	75	105	7.21	0	0.44	0	2	55	-	Hyposulfidic
40860_2.1	40860_2	0	5	4.53	72	0.02	0	-	83	-	Hyposulfidic
40860_2.2	40860_2	5	20	4.01	136	0.02	122	-	274	-	Hypersulfidic
40860_2.3	40860_2	20	30	3.74	166	0.09	28	-	248	-	Sulfuric
40860_2.4	40860_2	30	60	4.14	123	0.65	17	-	544	-	Sulfuric
40860_2.5	40860_2	30	110	6.34	2	0.12	0	-	77	-	Hyposulfidic
40860_3.1	40860_3	0	15	4.69	40	0.03	0	-	57	-	Hyposulfidic
40860_3.2	40860_3	15	30	5.80	20	0.12	0	-	93	-	Hyposulfidic
40860_3.3	40860_3	30	50	5.62	25	0.08	0	-	75	-	Hyposulfidic
40860_3.4	40860_3	50	75	6.46	1	0.16	0	-	100	-	Hyposulfidic
40860_3.5	40860_3	75	100	6.53	0	0.20	0	0	62	-	Hyposulfidic
40860_4.1	40860_4	0	10	6.11	8	0.01	0	-	13	-	Hyposulfidic
40860_4.2	40860_4	10	20	6.29	5	0.01	0	-	10	-	Hyposulfidic
40860_4.3	40860_4	20	45	6.61	0	0.01	0	-	8	-	Hyposulfidic
40860_4.4	40860_4	45	75	6.45	1	0.03	0	-	22	-	Hyposulfidic
40860_4.5	40860_4	75	110	6.53	0	0.01	0	-	9	-	Hyposulfidic
40861_1.1	40861_1	0	5	5.54	17	0.01	0	-	21	-	Hyposulfidic
40861_1.2	40861_1	5	15	4.82	37	0.01	0	-	42	-	Hyposulfidic
40861_1.3	40861_1	15	40	4.67	48	0.01	0	-	57	-	Hyposulfidic
40861_1.4	40861_1	40	60	5.81	19	0.12	0	-	91	-	Hyposulfidic
40861_1.5	40861_1	60	110	5.19	26	0.15	0	-	118	-	Hyposulfidic
40861_2.1	40861_2	0	5	5.37	15	0.01	0	-	22	-	Hyposulfidic
40861_2.2	40861_2	5	15	5.95	11	0.01	0	-	15	-	Hyposulfidic
40861_2.3	40861_2	15	35	5.81	13	0.01	0	-	21	-	Hyposulfidic
40861_2.4	40861_2	35	55	6.23	6	<0.01	0	-	9	-	Other soil
40861_2.5	40861_2	55	75	6.20	7	0.01	0	-	15	-	Hyposulfidic
40861_3.1	40861_3	0	5	6.18	7	<0.01	0	-	8	-	Other soil

Sample ID	Site ID	Upper depth	Lower depth	pH_{kcl}	TAA	RIS (S_{CR})	RA	ANC	Net acidity	AVS (DW)	ASS material type
-	-	cm	cm	-	mol $H^+ t^{-1}$	%	mol $H^+ t^{-1}$	$\%CaCO_3$	mol $H^+ t^{-1}$	%Sav DW	class
40861_3.2	40861_3	5	20	6.09	8	0.01	0	-	14	-	Hyposulfidic
40861_3.3	40861_3	20	50	5.91	10	0.01	0	-	16	-	Hyposulfidic
40861_3.4	40861_3	50	80	6.05	8	0.01	0	-	13	-	Hyposulfidic
40861_3.5	40861_3	80	100	7.22	0	<0.01	0	-	0	-	Other soil
40861_4.1	40861_4	0	5	6.27	6	0.01	0	-	12	-	Hyposulfidic
40861_4.2	40861_4	5	20	5.08	31	0.01	0	-	38	-	Hyposulfidic
40861_4.3	40861_4	20	40	4.63	53	<0.01	0	-	54	-	Other acidic
40861_4.4	40861_4	40	75	5.65	18	0.03	0	-	37	-	Hyposulfidic
40861_4.5	40861_4	75	110	5.80	11	0.01	0	-	15	-	Hyposulfidic
40862_1.1	40862_1	0	15	4.66	84	0.07	0	-	129	-	Hyposulfidic
40862_1.2	40862_1	15	35	4.07	86	0.07	14	-	145	-	Sulfuric
40862_2.1	40862_2	0	5	6.29	5	0.11	0	-	71	-	Hyposulfidic
40862_2.2	40862_2	5	20	6.28	5	0.11	0	-	71	-	Hyposulfidic
40862_2.3	40862_2	20	50	6.41	3	0.10	0	-	69	-	Hyposulfidic
40862_2.4	40862_2	50	85	6.41	2	0.15	0	-	95	-	Hyposulfidic
40862_2.5	40862_2	85	110	6.55	0	0.16	0	0	65	-	Hyposulfidic
40863_1.1	40863_1	0	5	5.93	15	0.13	0	-	98	-	Hyposulfidic
40863_1.2	40863_1	5	20	6.38	3	0.20	0	-	128	-	Hyposulfidic
40863_1.3	40863_1	20	35	7.47	0	0.28	0	1	17	-	Hyposulfidic
40863_1.4	40863_1	35	55	7.17	0	0.61	0	1	242	-	Hyposulfidic
40863_1.5	40863_1	55	110	7.09	0	0.65	0	1	243	-	Hyposulfidic
40863_2.1	40863_2	0	5	4.88	44	0.02	0	-	57	-	Hyposulfidic
40863_2.2	40863_2	5	15	5.35	41	0.06	0	-	78	-	Hyposulfidic
40863_2.3	40863_2	15	30	6.14	10	0.26	0	-	175	-	Hyposulfidic
40863_2.4	40863_2	30	60	6.57	0	0.43	0	1	176	-	Hyposulfidic
40863_2.5	40863_2	60	100	6.23	5	0.09	0	-	64	-	Hyposulfidic

Notes: red printed values indicate data results of potential concern.

Table 4 - Field hydrochemistry data for acid sulfate soil assessment of Bet Bet Creek.

Sample ID	(number)	*Lowland River**	*Freshwater Lakes**	40860_1.W1	40860_2.W1	-	40861_1.W1	40861_2.W1	-	40862_1.W1	40862_2.W1	40863_1.W1	40863_2.W1
Site ID	(number)	-	-	40860_1	40860_2	40860_3	40861_1	40861_2	40861_4	40862_1	40862_2	40863_1	40863_2
Wetland ID	(code)	-	-	40860	40860	40860	40861	40861	40861	40862	40862	40863	40863
Site Number	(number)	-	-	1	2	3	1	2	4	1	2	1	2
Upper depth	cm	-	-	-20	10	-45	-32	35	-21	-36	70	-35	10
Lower depth	cm	-	-	0	20	0	0	45	0	0	80	0	30
Temperature	(deg C)	-	-	6.6	8	10.2	9.6	10.8	15	8.1	12.1	10.1	12.1
Specific Electrical Conductivity	(uS/cm)	*125 - 2200*	*20 - 30*	3220	4500	2255	1853	2110	2205	2560	16920	5440	18570
Dissolved Oxygen	(%)	-	-	76.6	11.7	64	49.2	37.9	145	41.4	8.5	82.3	11.1
Dissolved Oxygen	(mg/l)	-	-	9.81	1.06	7.3	6.21	3.38	14.6	4.46	1.03	10.44	1.04
pH	(unit)	*6.5 - 8.0*	*6.5 - 8.0*	5.70	4.86	6.47	6.54	6.44	7.48	7.09	6.17	6.94	5.88
Redox potential	Eh	-	-	101	120	138	59	14	92	43	-24	10	-5
Turbidity	(NTU)	*6 - 50*	*1 - 20*	26.7	2606	32.4	407	>3000	18.9	60.5	910	24.4	-0.4
HCO_3	(mg/l)	-	-	0	0	0	80	100	120	120	>240	120	180
Comment	-	-	-	SW	PW	SW, no sample collected	SW	PW	SW, no sample collected	SW	PW	SW	PW

Notes:

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands' (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water, respectively.

Table 5 - Laboratory hydrochemistry data for acid sulfate soil assessment of Bet Bet Creek.

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	22-05-10	22-05-10	22-05-10	22-05-10	21-05-10	21-05-10	21-05-10	21-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201583	2201584	2201587	2201588	2201591	2201592	2201585	2201586
Sample ID	(number)	-	40860_1.W1	40860_2.W1	40861_1.W1	40861_2.W1	40862_1.W1	40862_2.W1	40863_1.W1	40863_2.W1
Site ID	(number)	-	40860_1 (SW)	40860_2 (PW)	40861_1 (SW)	40861_2 (PW)	40862_1 (SW)	40862_2 (PW)	40863_1 (SW)	40863_2 (PW)
Wetland ID	(code)	-	40860	40860	40861	40861	40862	40862	40863	40863
Site Number	(number)	-	1	2	1	2	1	2	1	2
Upper depth	cm	-	-20	10	-32	35	-36	70	-35	10
Lower depth	cm	-	0	20	0	45	0	80	0	30
Na	mg l^{-1}	-	420	530	260	470	350	2000	700	3100
K	mg l^{-1}	-	16	16	12	12	16	21	19	21
Ca	mg l^{-1}	-	57	110	34	63	57	310	95	260
Mg	mg l^{-1}	-	110	130	59	110	96	560	200	730
Si	mg l^{-1}	-	4.8	80	6.6	19	19	26	1.4	39
Br	mg l^{-1}	-	<5	<5	<5	<5	<5	<5	<5	<5
Cl	mg l^{-1}	-	860	1000	480	800	710	5200	1600	6000
NO_3	mg l^{-1}	0.7	0.1	<1.0 LINT	0.03	0.04	0.06	5.2	0.02	1.4
NH_4-N[K]	mg l^{-1}	0.01	0.1	5.2	0.1	1	1.1	2	5.2	<0.1
PO_4-P[E]	mg l^{-1}	0.005	<0.01	<0.01	0.03	<0.01	0.02	<0.01	<0.01	<0.01
SO_4	mg l^{-1}	-	260	1200	170	390	150	1500	270	1700
Ag	µg l^{-1}	0.05	<1	<1	<1	<1	<1	<1	<1	<1
Al[A]	µg l^{-1}	55	<10	2100	<10	<10	<10	50	<10	60
As[B]	µg l^{-1}	13	<1	15	<1	1	1	3	<1	2
Cd	µg l^{-1}	0.2	<0.2	0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Co	µg l^{-1}	2.8	4	170	1	43	8	22	3	55
Cr[C]	µg l^{-1}	1	<1	7	<1	<1	<1	<1	<1	<1
Cu[H]	µg l^{-1}	1.4	1	<1	<1	<1	<1	<1	<1	<1
Fe	µg l^{-1}	300	210	270000	440	90	2000	260000	130	170000

Lab Analysis Date	(day-month-year)	*ANZECC Guidelines*	22-05-10	22-05-10	22-05-10	22-05-10	21-05-10	21-05-10	21-05-10	21-05-10
Laboratory	(code)	-	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS	Ecowise/ALS
Laboratory sample ID	number	-	2201583	2201584	2201587	2201588	2201591	2201592	2201585	2201586
Sample ID	(number)	-	40860_1.W1	40860_2.W1	40861_1.W1	40861_2.W1	40862_1.W1	40862_2.W1	40863_1.W1	40863_2.W1
Mn	µg l^{-1}	1700	500	6200	86	3700	2000	11000	530	11000
Ni[H]	µg l^{-1}	11	6	120	5	18	5	17	5	31
Pb[H]	µg l^{-1}	3.4	<1	<1	<1	<1	<1	<1	<1	<1
Se	µg l^{-1}	11	<1	8	<1	<1	<1	2	<1	1
Zn[H]	µg l^{-1}	8	5	360	2	9	4	34	3	38
DOC	mg l^{-1}	-	14	82	15	22	27	170	95	17

Notes:

The ANZECC guideline values for toxicants refer to the trigger values applicable to 'slightly-moderately disturbed' freshwater systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH_4 and PO_4, trigger values are provided for Freshwater Lakes and reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

[A]*Trigger value for Aluminium in freshwater where pH > 6.5.*

[B]*Trigger value assumes As in solution as Arsenic (AsV).*

[C]*Trigger value for Chromium is applicable to Chromium (CrVI) only.*

[E]*Guideline is for filterable reactive phosphorous (FRP).*

[H]*Hardness affected (refer to Guidelines).*

[K]*Guideline for South-east Australia-Freshwater Lakes and reservoirs.*

Table 6 - Site description data for acid sulfate soil assessment of Bet Bet Creek.

Site ID	Wetland ID	Site Number	Sampled Date	UTM Zone	easting	northing
40860_1	40860	1	22-05-10	54	217857	5913648
40860_2	40860	2	22-05-10	54	217860	5913649
40860_3	40860	3	22-05-10	54	217666	5913942
40860_4	40860	4	22-05-10	54	217662	5913939
40861_1	40861	1	22-05-10	54	217985	5914350
40861_2	40861	2	22-05-10	54	217980	5914355
40861_3	40861	3	22-05-10	54	217972	5914365
40861_4	40861	4	22-05-10	54	218394	5914553
40862_1	40862	1	21-05-10	54	218225	5911807
40862_2	40862	2	21-05-10	54	218217	5911819
40863_1	40863	1	21-05-10	54	217817	5912962
40863_2	40863	2	21-05-10	54	217815	5912955

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40860_1	-40	water	water	low point, subaqueous	Subaqueous sediment samples, river channel landform	30	Subaqueous soil	Middle of channel form
40860_2	10	soft	bare, minor low grasses	mid point	edge of water in channel	20	Sulfuric soil	-
40860_3	-45	water	water	low point, subaqueous	Subaqueous sediment samples, river channel landform	30	Subaqueous soil	Middle of channel form
40860_4	75	soft	bare, minor reeds, twig and leaf litter	mid point	edge of water in channel	20	Hydrosol - sandy or loamy	-
40861_1	-32	water	reeds	low point, subaqueous	Subaqueous sediment samples, river channel landform	50	Subaqueous soil	Middle of channel form
40861_2	35	soft	reed matting	mid point	edge of water in channel	10	Hydrosol - sandy or loamy	-

Site ID	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	Representativeness (%)	ASS Soil Classification	Comments
40861_3	-	soft	low grasses	high point	dry point in hydro toposequence, nearing channel bank	20	Hydrosol - sandy or loamy	No water evident
40861_4	-21	cracking	minor low grasses	mid point	cracking clays, edge of water in channel, large column surface peds	20	Hydrosol - sandy or loamy	-
40862_1	-36	water	long reeds	low point, subaqueous	Subaqueous sediment samples, river channel landform	40	Sulfuric soil	-
40862_2	70	firm	long reeds	mid point	dry point in hydro toposequence	60	Hydrosol - sandy or loamy	-
40863_1	-35	water	bare	low point, subaqueous	Subaqueous sediment samples, river channel landform	60	Subaqueous soil	-
40863_2	30	soft	minor low grasses	mid point	edge of water in channel	40	Hydrosol - sandy or loamy	-

Table 7 - Profile description data for acid sulfate soil assessment of Bet Bet Creek

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40860_1.1	SS	0	3	10YR42	Silty clay loam	Loamy	Wet	6.79	1:1
40860_1.2	SS	3	20	10YR44	Silty clay loam	Clayey	Wet	5.66	1:1
40860_1.3	PT	20	45	GLEY13N	Silty clay loam	Clayey	Wet	6.90	1:1
40860_1.4	PT	45	75	GLEY13N	Silty clay loam	Clayey	Wet	7.15	1:1
40860_1.5	PT	75	105	GLEY12.5N	Silty clay loam	Clayey	Wet	7.39	1:1
40860_2.1	SS	0	5	10YR43	Sandy clay loam	Loamy	Moist	7.76	1:1
40860_2.2	SS	5	20	10YR53	Sandy clay loam	Loamy	Moist	5.37	1:1
40860_2.3	PT	20	30	10YR52	Silty clay loam	Clayey	Wet	4.24	1:1
40860_2.4	PT	30	60	GLEY2410B	Silty clay loam	Clayey	Wet	5.13	1:1
40860_2.5	PT	30	110	10YR41	Clay	Clayey	Wet	6.80	1:1
40860_3.1	SS	0	15	10YR52	Silty loam	Loamy	Wet	5.72	1:1
40860_3.2	PT	15	30	10YR42	Clay	Clayey	Wet	5.60	1:1
40860_3.3	PT	30	50	10YR43	Silty clay loam	Clayey	Wet	5.08	1:1
40860_3.4	PT	50	75	10YR43	Silty clay loam	Clayey	Wet	6.92	1:1
40860_3.5	PT	75	100	GLEY235B	Silty clay loam	Clayey	Wet	7.01	1:1
40860_4.1	SS	0	10	10YR33	Silty clay loam	Loamy	Moist	7.08	1:1
40860_4.2	SS	10	20	10YR32	Silty clay loam	Clayey	Moist	7.06	1:1
40860_4.3	SS	20	45	10YR43	Clay	Clayey	Moist	7.07	1:1
40860_4.4	PT	45	75	10YR42	Clay	Clayey	Wet	6.92	1:1
40860_4.5	PT	75	110	10YR42	Clay	Clayey	Wet	7.62	1:1
40861_1.1	PT	0	5	10YR43	Clay loam	Loamy	Wet	6.43	1:1
40861_1.2	PT	5	15	10YR42	Silty clay loam	Loamy	Wet	5.40	1:1
40861_1.3	PT	15	40	10YR42	Silty clay loam	Clayey	Wet	4.81	1:1
40861_1.4	PT	40	60	GLEY22.55PB	Silty clay loam	Clayey	Wet	6.07	1:1
40861_1.5	PT	60	110	10YR41	Clay	Clayey	Wet	7.72	1:1
40861_2.1	SS	0	5	10YR43	Clay loam	Loamy	Moist	6.93	1:1
40861_2.2	SS	5	15	10YR53	Clay	Clayey	Moist	6.91	1:1
40861_2.3	SS	15	35	10YR54	Silty clay loam	Clayey	Moist	6.94	1:1
40861_2.4	PT	35	55	10YR56	Clay	Clayey	Moist	6.94	1:1
40861_2.5	PT	55	75	10YR32	Silty clay loam	Clayey	Wet	6.82	1:1
40861_3.1	SS	0	5	10YR33	Silty loam	Loamy	Moist	6.73	1:1

Sample ID	Observation Method Kind	Horizon Depth Upper (cm)	Horizon Depth Lower (cm)	Soil Color - moist	Texture Class	Texture Modifiers	Moisture State	pH (field measurement)	pH (method)
40861_3.2	SS	5	20	10YR32	Silty clay loam	Clayey	Moist	6.87	1:1
40861_3.3	SS	20	50	10YR32	Silty clay loam	Clayey	Moist	6.24	1:1
40861_3.4	SA	50	80	10YR34	Sandy clay loam	Clayey	Moist	6.54	1:1
40861_3.5	SA	80	100	7YR33	Sandy clay loam	Clayey	Moist	6.85	1:1
40861_4.1	PT	0	5	10YR44	Silty clay loam	Loamy	Moist	6.18	1:1
40861_4.2	PT	5	20	10YR43	Silty clay loam	Clayey	Moist	5.30	1:1
40861_4.3	PT	20	40	10YR43	Silty clay loam	Clayey	Moist	4.71	1:1
40861_4.4	PT	40	75	GLEY22.55PB	Clay	Clayey	Wet	6.22	1:1
40861_4.5	PT	75	110	10YR43	Clay	Clayey	Wet	6.40	1:1
40862_1.1	SS	0	15	10YR33	Loam	Loamy	Wet	6.25	1:1
40862_1.2	SS	15	35	10YR43	Clayey sand	Sandy	Wet	4.59	1:1
40862_2.1	SS	0	5	10YR33	Silty loam	Loamy	Moist	6.91	1:1
40862_2.2	SS	5	20	10YR33	Sandy loam	Loamy	Moist	6.85	1:1
40862_2.3	SS	20	50	10YR41	Silty clay loam	Clayey	Moist	6.92	1:1
40862_2.4	SA	50	85	GLEY255PB	Silty clay loam	Clayey	Wet	7.08	1:1
40862_2.5	SA	85	110	GLEY145GY	Silty clay loam	Clayey	Wet	7.16	1:1
40863_1.1	PT	0	5	10YR32	Silty clay loam	Loamy	Wet	6.26	1:1
40863_1.2	PT	5	20	GLEY12.5N	Silty clay loam	Clayey	Wet	6.30	1:1
40863_1.3	PT	20	35	GLEY22.55PB	Silty clay loam	Clayey	Wet	6.80	1:1
40863_1.4	PT	35	55	GLEY22.55PB	Silty clay loam	Clayey	Wet	7.06	1:1
40863_1.5	PT	55	110	GLEY22.55PB	Silty clay loam	Clayey	Wet	7.14	1:1
40863_2.1	SS	0	5	10YR34	Clay loam	Loamy	Moist	4.72	1:1
40863_2.2	SS	5	15	10YR33	Clay loam	Loamy	Moist	5.05	1:1
40863_2.3	SS	15	30	10YR41	Clay loam	Clayey	Wet	5.24	1:1
40863_2.4	SA	30	60	GLEY1410Y	Clay	Clayey	Wet	6.34	1:1
40863_2.5	SA	60	100	10YR32	Clay	Clayey	Wet	6.37	1:1

Table 7 – (Continued) Profile description data for acid sulfate soil assessment of Bet Bet Creek

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40860_1.1	5	FM	2.5YR48	MAT	MA	1	S	Ferric iron surface coating, organic materials
40860_1.2	5	FM	2.5YR48	MAT	MA	1	S	organic materials
40860_1.3	5	FM	2.5YR48	MAT	-	0	VW	minor organics, moderately decomposed organics
40860_1.4	0	-	-	-	-	0	VW	highly decomposed organics, organic odour
40860_1.5	0	-	-	-	-	0	VW	highly decomposed organics, organic odour
40860_2.1	0	-	-	-	MA	1	L	organic materials, leaf and twig litter
40860_2.2	0	-	-	-	MA	1	L	organic materials, leaf and twig litter
40860_2.3	0		-	-	-	0	S	organic materials, leaf and twig litter
40860_2.4	0	-	-	-	-	0	S	organic materials, leaf and twig litter, moderately decomposed organics
40860_2.5	0	-	-	-	-	0	S	highly decomposed organics
40860_3.1	0	-	-	-	MA	1	L	organic materials, leaf and twig litter, quartz gravels
40860_3.2	5	FM	2.5YR48	MAT	-	0	W	rootlets, organic materials
40860_3.3	0	-	-	-	-	0	W	rootlets, moderately decomposed organics
40860_3.4	0	-	-	-	-	0	S	rootlets, highly decomposed organics
40860_3.5	0	-	-	-	-	0	S	highly decomposed organics in lenses
40860_4.1	2	FM	2.5YR48	MAT	MA	1	S	organic materials, leaf and twig litter
40860_4.2	2	FM	2.5YR48	MAT	MA	1	S	organic materials
40860_4.3	10	FM	2.5YR48	MAT	MA	1	S	minor organic materials, rootlets
40860_4.4	2	FM	2.5YR48	MAT	MA	1	VW	minor organic materials, rootlets
40860_4.5	2	FM	2.5YR48	MAT		0	VW	minor organic materials, rootlets

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40861_1.1	5	FM	2.5YR48	MAT	MA	1	W	organic matter, rootlets
40861_1.2	15	FM	2.5YR48	MAT	MA	1	W	organic matter, rootlets, some moderately decomposed organics
40861_1.3	5	FM	2.5YR48	MAT	-	0	S	minor rootlets, some moderately decomposed organics
40861_1.4	0	-	-	-	-	0	S	highly decomposed organics, organic odour
40861_1.5	0	-	-	-	-	0	S	-
40861_2.1	0	-	-	-	MA	1	VS	organic matting, rootlets
40861_2.2	5	FM	2.5YR48	MAT	MA	1	VS	minor rootlets
40861_2.3	5	FM	2.5YR48	MAT, RPO	-	0	VW	minor rootlets
40861_2.4	10	FM	2.5YR48	MAT, RPO	-	0	VW	minor rootlets
40861_2.5	2	FM	2.5YR48	MAT	-	0	VW	highly decomposed organics
40861_3.1	0	-	-	-	MA	1	L	rootlets, organic odour, rootlets
40861_3.2	10	FM	2.5YR46	MAT, RPO	MA	1	VW	rootlets, organic odour, rootlets
40861_3.3	5	FM	2.5YR46	MAT, RPO	MA	1	VW	rootlets, rootlets
40861_3.4	5	FM	2.5YR46	MAT	-	0	VW	rootlets, rootlets
40861_3.5	5	FM	2.5YR46	MAT	-	0	VW	minor organics, minor charcoal fragments within matrix
40861_4.1	2	FM	2.5YR46	MAT	-	0	S	organic matter, rootlets
40861_4.2	5	FM	2.5YR46	MAT, RPO	-	0	VW	rootlets
40861_4.3	15	FM	2.5YR46	MAT	-	0	W	minor organics
40861_4.4	15	FM	2.5YR46	MAT	-	0	W	minor highly decomposed organics
40861_4.5	5	FM	2.5YR46	MAT	-	0	W	-
40862_1.1	0	-	-	-	MA	1	L	organic materials, leaf and twig litter
40862_1.2	0	-	-	-	MA	1	L	organic materials, leaf and twig litter, sub angular quartz gravels
40862_2.1	0	-	-		MA	1	S	organic matter, organic odour
40862_2.2	5	FM	2.5YR46	MAT	MA	1	S	organic materials, leaf and twig litter
40862_2.3	5	FM	2.5YR46	MAT	MA	1	S	minor organic materials, leaf and twig litter
40862_2.4	2	FM	2.5YR46	MAT	-	0	S	minor organics

Sample ID	Redoximorphic Features - Quantity (%)	Redoximorphic Features - Kind	Redoximorphic Features - Color	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	Comments
40862_2.5	0	-	-	-	-	0	S	minor organics
40863_1.1	5	FM	2.5YR48	MAT	-	0	VS	ferric iron coating on surface, organic materials, twigs
40863_1.2	0	-	-	-	-	0	VS	highly decomposed organics
40863_1.3	0	-	-	-	-	0	VS	highly decomposed organics
40863_1.4	0	-	-	-	-	0	S	highly decomposed organics
40863_1.5	0	-	-	-	-	0	S	highly decomposed organics
40863_2.1	0	-	-	-	MA	1	VS	organic materials, leaf and twig litter, difficult to bolus
40863_2.2	0	-	-	-	MA	1	VS	organic materials, leaf and twig litter, difficult to bolus
40863_2.3	0	-	-	-	MA	1	S	organic materials, leaf and twig litter, difficult to bolus
40863_2.4	0	-	-	-	-	0	S	moderately decomposed organics
40863_2.5	0	-	-	-	-	0	S	highly decomposed organics

Table 8 – Additional Data: Water watch Water Quality Data for Bet Bet Creek Collected by the NCCMA.

BET920 - Bet Bet Creek at Fremantles Bridge 2					
Date and (notes)	**Electrical Conductivity (µS/cm)**	**pH (pH Units)**	**Reactive Phosphorus (mg/L P)**	**Temperature (° C)**	**Turbidity (NTU)**
10/03/2007 (Stagnant (pool))	7650	8.00	0.2	21.9	80
13/04/2007 (Falling)	10960	8.50	0.05	24	55
09/05/2007 (Falling)	9160	8.00	0.07	13	10
18/06/2007 (Stagnant (pool))	-	7.50	0.03	7.2	<10
19/07/2007 (Stagnant (pool))	1230	7.50	0.1	9	30
14/08/2007 (Stagnant (pool))	1814	7.50	0.15	10	22
11/09/2007 (Stagnant (pool))	3360	8.00	0.03	15	60
15/10/2007 (Stagnant (pool))	4870	7.50	0.03	18	70
14/11/2007 (Stagnant (pool))	4300	7.50	0.1	22	35
19/12/2007 (Stagnant (pool))	6270	8.50	0.05	28	60
08/01/2008 (Stagnant (pool))	2210	7.50	0.05	24	170
08/02/2008 (Stagnant (pool))	3060	8.00	0.07	23.7	60
07/03/2008 (Stagnant (pool))	4970	8.50	-	23	60
29/06/2009 (Steady)	18100	5.70	-	-	<15
07/08/2009 (Stagnant (pool))	13980	3.70	0.02	14	20
18/09/2009 (Stagnant (pool))	14460	3.30	0.01	18	<10
19/10/2009 (Steady)	3690	6.70	-	19	60
25/11/2009 ()	7700	4.50	0.01	22	15

APPENDIX 14: ASSRAP SCREENING CRITERIA

Screening criteria for selecting detailed acid sulfate soil assessment study areas developed by the Scientific Reference Panel of the Acid Sulfate Soils Risk Assessment Project (source: MDBA 2010).

Parameter	Trigger value	Action required	Priority
pH soil*	<4 4 – 5.5 >5	Detailed assessment Detailed assessment No further assessment	Extreme Moderate N/A
pH water	<5.5 5.5 – 6.5 >6.5	Detailed assessment Detailed assessment No further assessment	High Moderate N/A
EC soil (1:5)	>1000 µS cm^{-1} 400 – 1000 µS cm^{-1} <400 µS cm^{-1}	Detailed assessment Detailed assessment No further assessment	High Moderate N/A
EC water	>5000 µS cm^{-1} 1750 – 5000 µS cm^{-1} <1750 µS cm^{-1}	Detailed assessment Detailed assessment No further assessment	High Moderate N/A
Sulfate soil	>500 mg/L 100 – 500 mg/L <100 mg/L	Detailed assessment Detailed assessment No further assessment	High Moderate N/A
Sulfate water	>50 mg/L 10 – 50 mg/L <10 mg/L	Detailed assessment Detailed assessment No further assessment	High Moderate N/A

* As determined by both in-field measurements and subsequent analysis of samples collected in chip-trays.

High Quality Consulting and Development Solutions

www.smec.com