Investigations into the factors affecting the rates of recovery of acid sulfate soils in the Lower Lakes

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Investigations into the factors affecting the rates of recovery of acid sulfate soils in the Lower Lakes

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Cover Photograph

Sediment sampling at Tolderol, Lower Lakes. Photographer: Nick Ward.

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LIST OF ABREVIATIONS

ANC – acid neutralising capacity
AVS – acid volatile sulfide
$CaCO_3$ – calcium carbonate
CBD – citrate buffered dithionite
CDOM – coloured dissolved organic matter
Cl – chloride
CRS – chromium reducible sulfur
DIC – dissolved inorganic carbon
DOC– differential pulse voltammetry
DPV– dissolved organic carbon
EC – electrical conductivity
EEMs – excitation-emission-matrices
Eh – redox potential
Fe – iron
Fe^{2+} – ferrous iron
FIA – flow-injection analysis
HCl – hydrochloric acid
HNO_3 – nitric acid
HPLC – high-performance liquid chromatography
H_2O_2 – hydrogen peroxide
H_2SO_4 – sulfuric acid
ICP-MS – inductively coupled plasma - mass spectrometry
KCl – potassium chloride
LMW – low molecular weight
MBO – monosulfidic black ooze
NATA – National Association of Testing Authorities
NaOH – sodium hydroxide
NOM – natural organic matter
RA – retained acidity
RIS – reduced inorganic sulfur
S^0 – elemental sulfur
SO_4^{2-} – sulfate
TAA – titratable actual acidity
TOC – total organic carbon
UV – ultraviolet
XRD – x-ray diffraction

Executive Summary

This project addresses a critical knowledge gap in the geochemical behaviour of acid sulfate soil processes of the Lower Lakes. Specifically, this project examines the role of organic carbon on the recovery of acidified sediments and mobilisation of metal(loid) contaminants. The outcomes will underpin the development of the strategies and practices necessary for appropriate wetland management.

Extensive areas of acid sulfate soils in the Lower Lakes were exposed during the last drought which resulted in soil acidification (pH<4) over large areas and localised acidification of surface waters (DENR 2010). The presence of littoral vegetation around the lake margins assisted in reducing soil erosion and provided a source of carbon for microbial reduction processes. Microbial reduction processes that use organic carbon as an energy source consume acidity within the sediment, and therefore the presence of oxidisable organic carbon can significantly affect the rate of recovery. Low concentrations of easily oxidisable organic matter have been identified as an important factor affecting the recovery rate of the sediments in the Lower Lakes foreshore (e.g. Sullivan *et al.* 2010). Metal immobilisation may also occur due to the sulfide formation and the pH increase associated with reduction processes reducing metal solubility. However, the reductive dissolution of iron and manganese minerals within the sediments can lead to high dissolved concentrations of these metals and other associated metal(loid)s sorbed to the mineral surfaces.

In this study we examine the role of natural organic matter (NOM) on the recovery of acidified sediments from the Lower Lakes foreshore and metal(loid) mobilisation utilising both a laboratory-based mesocosm and batch experiments. The mesocosm experiment examines the rate of recovery and the kinetics and magnitude of metal(loid) mobilisation from NOM-enriched and NOM-depleted sediments. Two vegetation types (*Phragmites australis* and *Schoenoplectus validus*) were used and are commonly found on the fringes of the Lower Lakes. The batch experiment examines the effect of various organic components (including acetate, glucose and humic acid) that potentially form during the microbial degradation of plant material on the rate of recovery and mobilisation of metal(loid)s. The effect of two common acid sulfate soil minerals (i.e. schwertmannite and jarosite) on organic carbon utilisation and metal(loid) mobilisation is also examined.

An additional component of this project was to examine the likely mobility and uptake by vegetation of metal(loid)s from the formerly acidified lake sediments. This was undertaken to assess ongoing environmental risks posed by the presence of very high bio-accessible concentrations of potentially toxic metal(loid)s as identified in previous studies of bioremediating formerly strongly acidified Lower Lakes sediments (Sullivan *et al.* 2012a, 2013).

This project focuses on two of the sites examined in studies by Sullivan *et al.* (2011, 2012b, 2013) including the control site at Tolderol, Lake Alexandrina and the *Cotula* trial revegetation site at Waltowa, Lake Albert.

The key findings of this study are:

1) The addition of organic carbon (i.e. *Phragmites australis* and *Schoenoplectus validus*) to the surface and sub-surface sediments (0-10 cm) from Tolderol and Waltowa slowed the rate of recovery due to the release of organic acids from the vegetation.

2) The addition of *Phragmites* and *Schoenoplectus* showed a similar recovery response, although the rate of recovery differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. The surface sediments recovered at a faster rate due to the rapid breakdown of organic acids, particularly formic acid.

3) The effect of various organics (including acetate, glucose and humic acid) on the rate of recovery varied. Whilst the addition of both acetate and humic acid had minimal effect on the rate of recovery, the addition of glucose slowed the rate of recovery (due the formation of organic acids).

4) The hydrolysis of schwertmannite and jarosite led to acidification of the surface water, however, the presence of sufficient organic matter led to a rapid rate of recovery as a consequence of the reductive dissolution of these minerals.

5) The addition of NOM to both the Waltowa and Tolderol sediments resulted in an increase in the mobilisation of many of the metal(loid)s. The addition of either *Phragmites* or *Schoenoplectus* to each of the sediments often resulted in a similar metal(loid) behaviour, although slightly higher metal concentrations were often found associated with the *Phragmites* treated sediments (e.g. Co, Cu, Mn, Ni, Zn).

6) The addition of NOM enhanced the reduction of iron and manganese oxides and oxyhydroxides in the sediment to more soluble forms (i.e. Fe^{2+}, Mn^{2+}). The magnitude of iron and manganese release varied depending on NOM type added, with the addition of vegetation resulting in the greatest release.

7) Trace metals including arsenic (As), cobalt (Co) and nickel (Ni) associated with these iron and manganese minerals were also released into the surface water. Elevated levels of copper (Cu) and zinc (Zn) were associated with both *Phragmites* and *Schoenoplectus*.

8) The surface water arsenic (As) concentration increased with all sediments as the conditions became more reducing and the pH increased. The addition of *Phragmites* and *Schoenoplectus* suppressed arsenic mobilisation in the sub-surface sediments (2.5-10 cm) compared to the untreated sediments due to the relatively low pH of these sediments.

9) The hydrolysis and reductive dissolution of jarosite and schwertmannite led to metal(loid) mobilisation, although in the presence of vegetation immobilisation was sometimes observed (possibly as the result of the precipitation of sulfides). The presence of schwertmannite was particularly effective in suppressing the release of arsenic due to arsenic sorption.

10) The concentration of many of the metal(loid)s in the surface waters exceeded the ANZECC water quality guidelines under the experimental conditions. The magnitude of metal(loid) mobilisation suggest the levels measured represent a low to moderate hazard. However, the potential impacts of the metal(loid) concentrations measured in this study on the surrounding aquatic environment is dependent on numerous factors (such as the rate of metal(loid) flux from the sediments and dilution in the receiving waters).

11) The addition of *Phragmites australis* to all sediments led to very high ammonia levels in the surface waters (up to 66 mg/L). Elevated ammonia levels were not observed when *Schoenoplectus validus* was added to the sediments. Whether the high ammonia levels measured under the conditions in the mesocosm experiment would potentially lead to the development of algal blooms is dependent on the rate of ammonia flux from the sediments, dilution within the lakes and other processes (e.g. nitrification/denitrification).

12) Although universally accepted critical metal(loid) contents for wetland vegetation are not available, this study has clearly shown elevated levels of some metals (i.e. Mn, Al) in the vegetation growing in the formerly acidified sediments. Such elevated metal concentrations are important as even moderate concentrations of metals have been shown to disrupt aquatic ecologies.

Recommendations

1) We recommended that the effect of the organic carbon concentration on these processes is examined in detail using this experimental approach.

2) The role of sulfate reduction on metal immobilisation was not directly assessed in this study. The formation of sulfide minerals is potentially capable of strong metal immobilisation. We recommended that the effect of sulfate concentration is examined in detail using this experimental approach.

3) We recommended that the impact of *Phragmites* on the lake margins on the nutrient dynamics within the lakes is quantified.

1.0 Introduction

In this project a critical knowledge gap is addressed: the geochemical behaviour of acid sulfate soil processes of the Lower Lakes. Specifically, the role of organic carbon on the recovery of acidified sediments and mobilisation of metal(loid) contaminants will be examined. The outcomes will underpin the development of the strategies and practices necessary for appropriate wetland management.

Recent studies of sediments in the Lower Lakes and the effects of bioremediation (Sullivan *et al*. 2010, 2011, 2012b, 2013) have highlighted the hazard of acid sulfate soils and their potential to impact on ecological processes. The studies showed that the role of sulfate reduction and associated processes during the re-inundation of the acidified Lower Lakes' sediments is critical for on-going management.

Sullivan *et al*. (2011, 2012b, 2013) examined the effects of various bioremediation options which aimed at facilitating sulfate reduction and, consequently, remediation of often strongly acidified acid sulfate soil materials around drought-exposed margins of the Lower Lakes. The results of these studies indicate that bioremediation of the exposed acidified lake sediments by certain types of vegetation produced substantial environmental benefits from a combination of vegetation-associated processes including the provision of alkalinity from plant roots, provision of organic carbon for sulfate reducing bacteria and the role of vegetation in minimising soil erosion and hence preventing further exposure of severely acidic subsoils that occurred under unvegetated sites.

The studies also highlight that several of the likely future hazards associated with a strategy of enhancing organic matter input into sediments to stimulate sulfate reduction and the beneficial co-production of alkalinity, had been substantially avoided in the initial refilling period of the Lower Lakes, particularly where annual vegetation was too short to survive inundation. This hazard avoidance was due to the characteristic nature of the sulfur cycling occurring in these sediments, the consequent lack of accumulation in the surficial lake sediments of sulfide minerals such as monosulfides and pyrite and their associated hazards of acidification, metal and metalloid mobilisation, and deoxygenation.

However, the study by Sullivan *et al.* (2012b) showed when *Phragmites* (a species that survived lake re-filling and continued to grow vigorously when water levels in the lake increased) bioremediated these sediments, there was considerable accumulation of both pyrite and monosulfide (as Monosulfidic Black Ooze (MBO)) in the uppermost sediment layers. These accumulated sulfides indicated that alkalinity had been produced via sulfate reducing processes enabled by the ongoing production of organic matter by *Phragmites.* In addition, these uppermost sediments under *Phragmites* appeared likely to act as sources of soluble phosphate that could lead to increased nutrient flux/accumulation to lake water. While the Sullivan *et al.* (2012b) study strongly indicated a number of potentially important hazards would arise in the presence of *Phragmites* (e.g. increased accumulation of sulfides), such hazards were avoided almost completely with inundation intolerant vegetation (such as Bevy rye, *Cotula*, *Juncus* and *Puccinellia*).

Natural organic matter (NOM) plays an essential role on biogeochemical reactions that dominate acid sulfate soil chemistry and water quality outcomes in aquatic environments. Inundation often removes acidity in partially-oxidised sediments through the reduction of iron oxides, sulfates and other oxidised species by anaerobic bacteria (e.g. Dent 1986). However, low concentrations of easily oxidisable organic matter have been identified as a significant factor affecting the recovery rate in these landscapes (e.g. Sullivan *et al.* 2010).

The potential for metal(loid) mobilisation from sediments in the Lower Lakes has been clearly shown (e.g. Simpson *et al.* 2008, 2009, 2010; Sullivan *et al.* 2008, 2010; Hicks *et al.* 2009; Shand *et al.* 2012). In addition to the release of metal(loid)s as a consequence of sulfide oxidation, metal(loid)s can also be mobilised when acid sulfate soils are subject to prolonged inundation. For example, under reducing conditions iron oxides and oxyhydroxides are prone to microbial reductive dissolution potentially leading to high dissolved concentrations of ferrous iron (Fe^{2+}) and other associated metal(loid)s sorbed to the iron mineral surfaces, such as arsenic (e.g. Burton *et al.* 2008). Sediment fractions vary in the mechanism and strength by which the metal(loid)s are bound (e.g. Claff *et al.* 2011a, 2011b) and subsequently released during inundation by these reductive processes. Natural organic matter may govern the medium- to long-term behaviour of metal(loid)s in these sediments following inundation through its redox-active capacities and by enabling sulfidisation.

This project builds on the results of the Sullivan *et al*. (2011, 2012b, 2013) studies to allow a more accurate assessment of the progression of remediation of these sediments. A combination of innovative approaches has been used to examine the role of organic carbon in the recovery of acidified sediments and mobilisation of metal(loid)s from the Lower Lakes foreshore utilising both laboratory-based mesocosm and batch experiments. The mesocosm experiment examines the rate of recovery and the kinetics and magnitude of metal(loid) mobilisation from NOM-enriched and NOM-depleted sediments. Two vegetation types (*Phragmites australis* and *Schoenoplectus validus*) were used and are commonly found on the fringes of the Lower Lakes. Batch experiments examine the effect of various organic components (including acetate, glucose and humic acid) that potentially form during the microbial degradation of plant material on the rate of recovery and mobilisation of metal(loid)s. The effect of two common acid sulfate soil minerals (i.e. schwertmannite and jarosite) on organic carbon utilisation and metal(loid) mobilisation is also examined.

This project focuses on two of the sites examined in studies by Sullivan *et al.* (2011, 2012b, 2013) including the control site at Tolderol, Lake Alexandrina and the *Cotula* trial revegetation site at Waltowa, Lake Albert.

An additional component of this project is to continue to examine the likely mobility and uptake of metal(loid)s (particularly manganese, nickel and aluminium) by vegetation from Tolderol and Waltowa, two formerly acidified lake sediment sites. This will be undertaken to assess ongoing environmental risks posed by the presence of very high bio-accessible concentrations of these potentially toxic metals, as identified in previous studies of bioremediating formerly strongly acidified Lower Lakes sediments (Sullivan *et al.* 2012a, 2013).

2.0 Aim

The primary aim of this project is to determine the role of organic carbon in the recovery of acidified sediments and mobilisation of metals from Lower Lakes acid sulfate soil foreshore materials using a combination of innovative approaches. The information will be of direct relevance to remediation management strategies involving in situ neutralisation (under reductive geochemical conditions) such as broad scale vegetation of the Lower Lakes foreshore.

3.0 Materials and Methods

3.1 Field Sampling of Soils and Vegetation

3.1.1 Field Sampling of Sediments

In this project sediments were collected from the two of the four study areas sampled by Sullivan *et al.* (2011, 2012b, 2013). Only two of the study areas were examined as this project is now more targeted at examining the role of organic carbon on recovery of acid sulfate soils and mobilisation of metal(loid)s. The two study areas around the Lower Lakes sampled in this study included Tolderol (north Lake Alexandrina) and Waltowa (east Lake Albert). The locations of the sediment sampling study areas are shown in Figure 3-1.

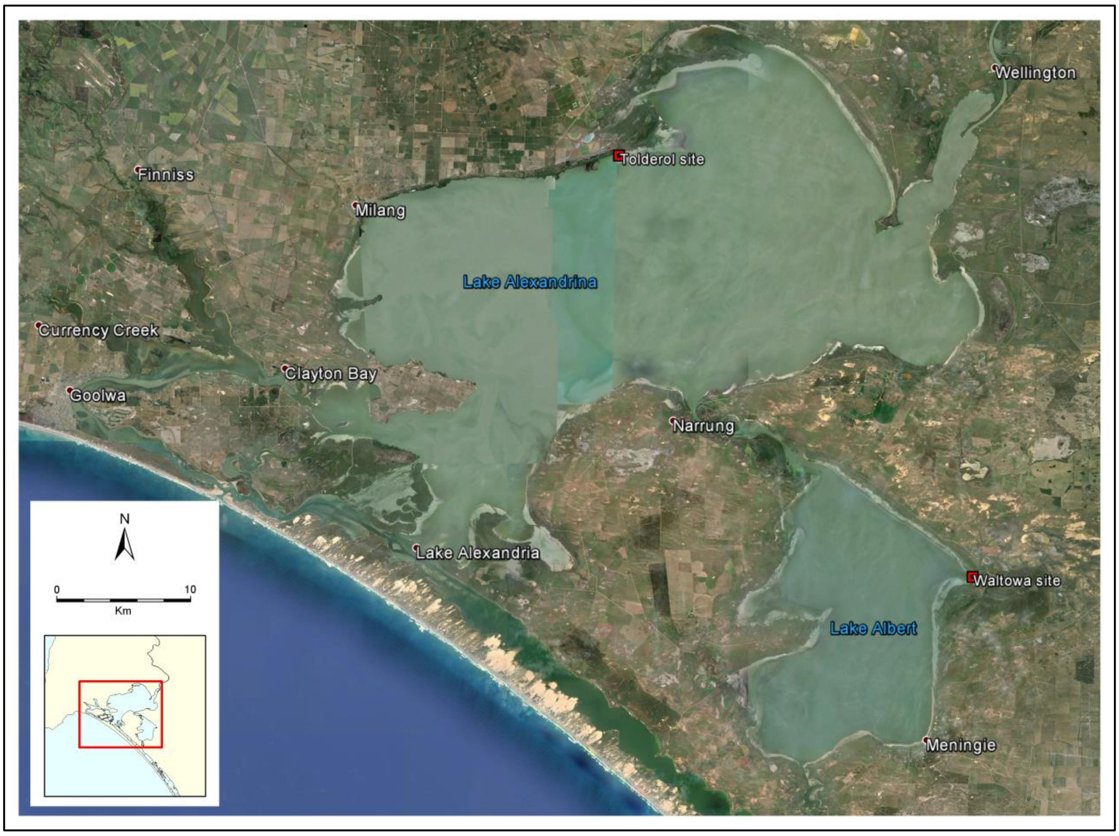

Figure 3-1. Map showing study areas in the Lower Lakes (Source: Google Maps).

Sediments were collected from the previously scalded site at Tolderol and from the site planted with *Cotula* at Waltowa. The *Cotula* site was chosen at Waltowa as both the *Phragmites* and *Juncus* sites at Waltowa had been limed prior to bioremediation.

Field sampling at the Tolderol and Waltowa study areas was undertaken on 31st October 2013. Intact sediment cores were collected using a 5 cm diameter push-tube coring device (see Figure 3-3) from three replicate sampling sites at each location to a depth of 10 cm. Each core was collected within approximately 4 m of the initial sites sampled by Sullivan *et al.* (2011).

The pH and redox potential (Eh) were determined on duplicate samples at each of the replicate sites using calibrated electrodes linked to a TPS WP-80 meter; Eh measurements are presented versus the standard hydrogen electrode. Each suboxic core was separated into two layers including the upper horizon layer (0-2.5 cm) and the lower horizon layer (2.5-10 cm). Approximately 10 kg of each sediment layer was collected for the laboratory incubation experiments.

All sediment samples were transported in sealed plastic bags in cold iceboxes, and were stored refrigerated on return to the Southern Cross GeoScience laboratory.

A soil description together with pH/Eh data for each 2.5 cm horizon is presented in Appendix 1 (Tables 8-1 and 8-2). The global positioning system (GPS) coordinates for each site are also presented in Appendix 1 (Tables 8-1 and 8-2).

Maps showing the sampling locations in each study area and selected photographs are presented in Sections 3.1.1.1 and 3.1.1.2. Bathymetry maps of each study area are presented in Appendix 8 (Figures 8-37 and 8-38).

3.1.1.1 Toldérol, North Lake Alexandrina Study Area Characteristics

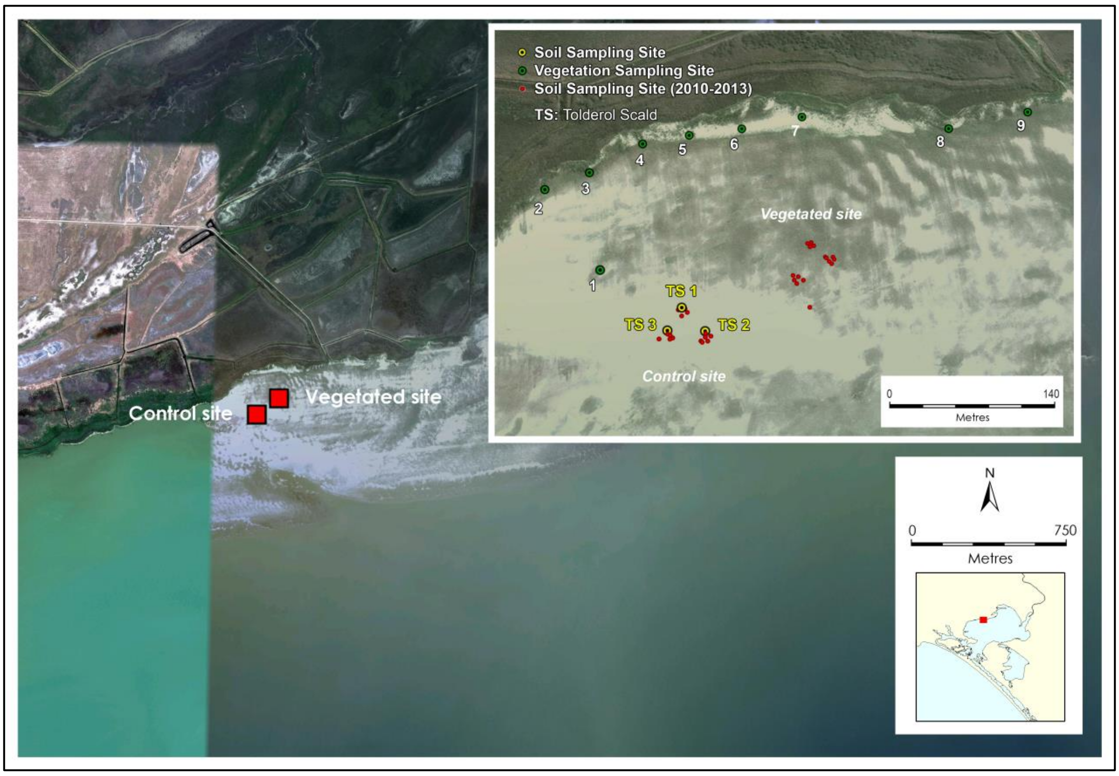

Figure 3-2. Tolderol sediment and vegetation sampling locations (Source: Google Maps).

Figure 3-3. Sediment sampling at Tolderol (October 2013).

Figure 3-4. Sediment cores (10 cm depth) collected at Tolderol.

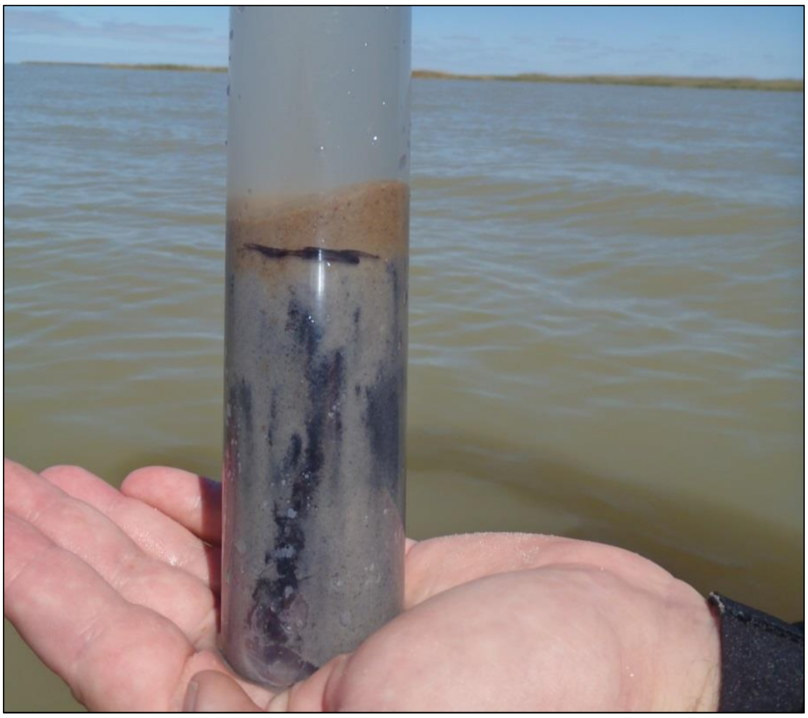

Figure 3-5. Sediment core (10 cm depth) collected at Tolderol.

Figure 3-6. *Phragmites australis* at site 1 at Tolderol.

Figure 3-7. Shoreline *Phragmites australis* at Tolderol.

3.1.1.2 Waltowa, East Lake Albert Study Area Characteristics

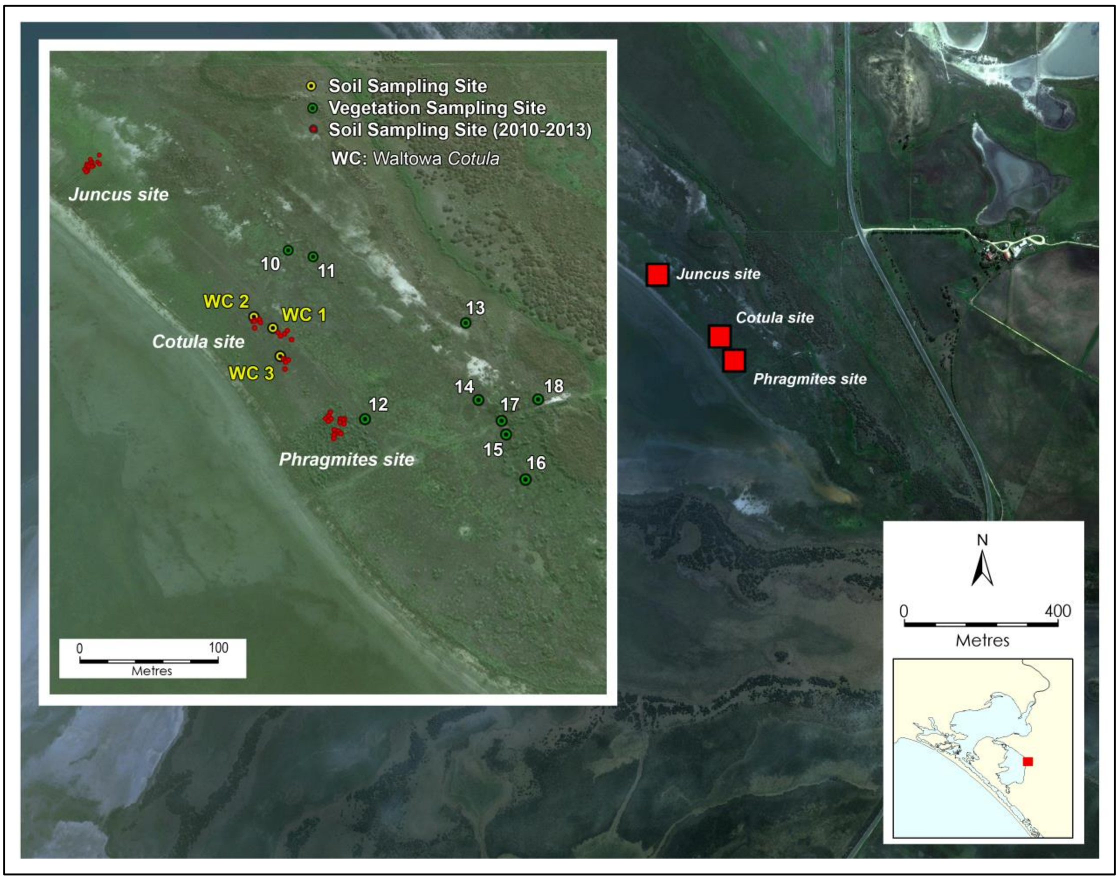

Figure 3-8. Waltowa sediment and vegetation sampling locations (Source: Google Maps).

Figure 3-9. Sediment sampling at Waltowa (October 2013).

Figure 3-10. Sediment core (10 cm depth) at Waltowa.

Figure 3-11. Collection of *Phragmites australis* samples at site 10 at Waltowa.

Figure 3-12. Collection of *Schoenoplectus validus* samples at site 14 at Waltowa.

Figure 3-13. Collection of *Phragmites australis* samples at site 17 at Waltowa.

3.1.2 Field Sampling of Vegetation

Plant materials (including *Phragmites australis* and *Schoenoplectus validus*) were collected from a total of 18 sites from Tolderol on the fringes of Lake Alexandria and Waltowa on the fringes of Lake Albert that had been exposed during the recent drought. The locations sampled at Tolderol and Waltowa in October 2013 are shown in Figures 3-2 and 3-8, respectively.

Phragmites australis was the dominant vegetation type at the time of sampling. Samples of *Schoenoplectus validus* were only collected from four sites at the Waltowa study area. The GPS locations of the vegetation sampling sites and the type of vegetation collected each site are presented in Table 3-1.

Vegetation samples were placed into sealed plastic bags and stored in a cold icebox during transportation. All samples were refrigerated on return to the Southern Cross GeoScience laboratory. A comprehensive analysis of metals in the plant tissues (including leaves and stems) was undertaken, and selected vegetation was used in the laboratory incubation experiments (see Sections 3.2.1 and 3.3.4).

Table 3-1. Tolderol and Waltowa vegetation sampling locations and vegetation types collected in October 2013.

Location	Site	GPS Co-ordinates Zone East, North.	Vegetation Types Collected
Tolderol	Site 1	54H 0330986, 6083468	*Phragmites australis*
Tolderol	Site 2	54H 0330930, 6083542	*Phragmites australis**
Tolderol	Site 3	54H 0330964, 6083560	*Phragmites australis*
Tolderol	Site 4	54H 0331005, 6083591	*Phragmites australis*
Tolderol	Site 5	54H 0331044, 6083601	*Phragmites australis*
Tolderol	Site 6	54H 0331089, 6083609	*Phragmites australis*
Tolderol	Site 7	54H 0331141, 6083623	*Phragmites australis*
Tolderol	Site 8	54H 0331268, 6083612	*Phragmites australis*
Tolderol	Site 9	54H 0331339, 6083632	*Phragmites australis*
Waltowa	Site 10	54H 0352239, 6059267	*Phragmites australis*
Waltowa	Site 11	54H 0352260, 6059261	*Schoenoplectus validus*
Waltowa	Site 12	54H 0352309, 6059116	*Phragmites australis*
Waltowa	Site 13	54H 0352385, 6059200	*Schoenoplectus validus**
Waltowa	Site 14	54H 0352394, 6059133	*Schoenoplectus validus*
Waltowa	Site 15	54H 0352414, 6059105	*Phragmites australis*
Waltowa	Site 16	54H 0352427, 6059070	*Schoenoplectus validus*
Waltowa	Site 17	54H 0352411, 6059116	*Phragmites australis*
Waltowa	Site 18	54H 0352439, 6059134	*Phragmites australis*

* Samples used in laboratory incubation experiments

3.2 Mesocosm and Batch Experiments

3.2.1 Sample Preparation

All sediment samples were oven dried at 40˚C for at least 72 hours. Any large fragments present (such as shells, wood and rock fragments) were removed. Large aggregates were gently separated using a mortar and pestle and then the sediment samples were thoroughly mixed.

The two vegetation types used in the laboratory incubation experiments were *Phragmites australis* from Tolderol (site 2) and *Schoenoplectus validus* from Waltowa (site 13) (see Table 3-1). The plant materials collected for the mesocosm and batch experiments were initially washed thoroughly in tap water and then in deionised water (Milli-Q) to remove any potential contamination (i.e. dust). The washed plant materials were dried at 70˚C for 48 hours prior to being ceramic mill ground.

3.2.2 Mesocosm Experiment

The mesocosm experiment was designed to examine the change in pH and mobilisation of metals under anoxic conditions from the four sediments collected as NOM-enriched and NOM-depleted sediments. In this experiment duplicate surface (i.e. 0–2.5 cm) and sub-surface (i.e. 2.5–10 cm) sediments from both Tolderol and Waltowa were incubated with and without the addition of the two vegetation types (*Phragmites australis* and *Schoenoplectus validus*). A summary of the treatments in the mesocosm experiment is presented below in Table 3-2.

Table 3-2. Summary of the mesocosm experiment sample treatments.

Sample No.	Tolderol		Waltowa		Treatment	
	0-2.5 cm	2.5-10 cm	0-2.5 cm	2.5-10 cm	*Phragmites australis*	*Schoenoplectus validus*
1	●					
2	●				●	
3	●					●
4		●				
5		●			●	
6		●				●
7			●			
8			●		●	
9			●			●
10				●		
11				●	●	
12				●		●

In this experiment 8.00 g (± 0.01 g) of the oven dried sediments was added to 50 mL acid washed centrifuge tubes. Mill ground samples of *Phragmites australis* and *Schoenoplectus validus* were added to selected sediments at a concentration of 5% (i.e. 0.40 g ± 0.002 g) (see Table 3-2). A total of 40 mL of deoxygenated Milli-Q water was added to each centrifuge tube resulting in a 1:5 sediment:water mixture (see Figure 3-14). In the mesocosm experiment it was necessary to prepare two samples for each analytical duplicate due to the sample volume needed for the laboratory analyses.

Deoxygenated Milli-Q water was prepared by purging the Milli-Q water with high purity nitrogen gas for at least 1 hour. The dissolved oxygen concentration was checked using a calibrated dissolved oxygen probe linked to a TPS 90-FLMV multi-parameter meter, and consistently had a concentration of less than 1.0 ppm.

All centrifuge tubes were gently shaken and incubated in an anaerobic chamber at 24°C (± 2°C) (Figure 3-15) over four time intervals including 10 minutes, 4 weeks, 8 weeks and 16 weeks. All centrifuge tubes were also gently shaken on a weekly basis and 24 hours prior to sampling. During the incubation the caps on the centrifuge tubes were not tightened, so any gases produced during incubation were able to escape. The gas in the anaerobic chamber was partially replenished every 2 hours when a compressed nitrogen/hydrogen gas mix (95%: 5% nitrogen: hydrogen) was added for 3 seconds. The oxygen free conditions were maintained by passing the gas mixture in the chamber over a palladium (Pd) catalyst.

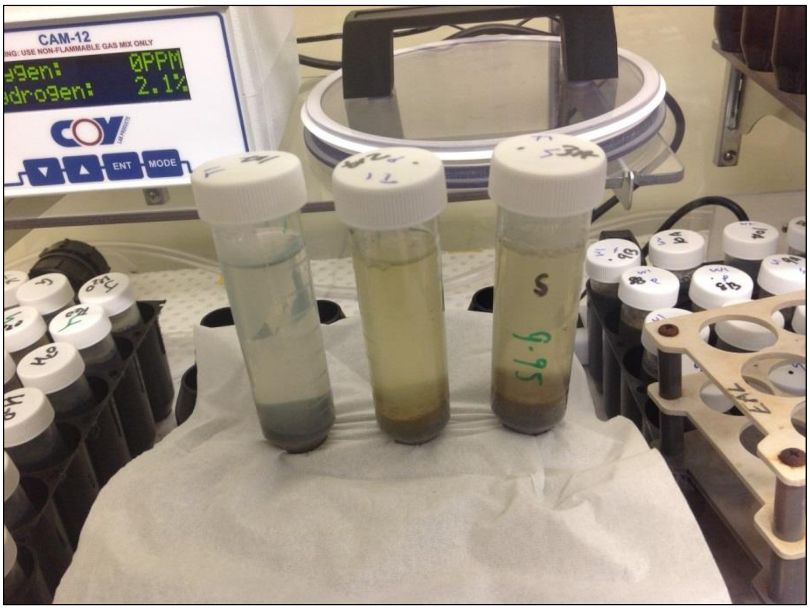

Figure 3-14. Tolderol surface sediments (0-2.5 cm) after 48 days of incubation (*left tube* - sediment only; *middle tube* – sediment + *Phragmites*; *right tube* – sediment + *Schoenoplectus*).

Figure 3-15. Incubating samples in the anoxic chamber.

At the end of each incubation period, the two surface water samples for each analytical duplicate were poured into a 120 mL polyethylene tube and gently mixed. Surface water samples for analysis (see Section 4.3.2) were extracted using a 50 mL syringe and filtered (0.45 µm). All sediments for analysis (see Section 4.3.3) were immediately frozen at the end of each incubation period.

3.2.3 Batch Experiment

The batch experiment was designed to examine the change in pH and mobilisation of metals under anoxic conditions in the presence of different labile organic carbon sources with and without the presence of common acid sulfate soil minerals. In this experiment triplicate sub-surface sediment samples (i.e. 2.5–10 cm) from the Waltowa study area were incubated with and without the addition of the various organic carbon treatments (i.e. acetate, glucose, humic acid, *Phragmites australis* and *Schoenoplectus validus*). Two common acid sulfate soil minerals (i.e. jarosite and schwertmannite) were also added to each treatment to examine their effect. A summary of the treatments examined in the batch experiment is presented in Table 3-3.

Table 3-3. Summary of the batch experiment sample treatments.

Sample No.*	Treatment							
	Control (No organic matter)	Glucose	Acetate	Humic Acid	*Phragmites australis*	*Schoenoplectus validus*	Jarosite	Schwertmannite
1	●							
2	●						●	
3	●							●
4		●						
5		●					●	
6		●						●
7			●					
8			●				●	
9			●					●
10				●				
11				●			●	
12				●				●
13					●			
14					●		●	
15					●			●
16						●		
17						●	●	
18						●		●

* *Sub-surface (2.5–10 cm) sediment from the Waltowa study area was used in this experiment.*

The sub-surface sediment (2.5–10 cm) was used in this study as it was expected that there would be less interference from the NOM present, helping to clarify the role of added organics. The hypothesis was that the sub-surface sediment would respond greater to the addition of organics than the surface sediment, providing greater clarity to the effect of the various treatments. The visual observation of jarosite in the sub-surface sediment at the Tolderol site prevented the use of this sediment in the batch experiment.

The three organic compounds added to the batch experiment (i.e. acetate, glucose, and humic acid) all potentially form during the microbial degradation of plant material. Acetate is the simplest organic compound added in this batch experiment, and is the most readily available to bacteria (e.g. Chacon *et al.* 2006). It is also expected that glucose would be more bioavailable than humic acid. The addition of these organic compounds will indicate the relative importance of these electron donors on the reduction processes within the sediments, particularly the geochemical kinetics. The addition of two commonly found acid sulfate soil minerals (i.e. jarosite and schwertmannite) will indicate the relative importance of these reactive minerals on the rate of recovery and metal(loid) mobilisation with and without the presence of various organic materials. These iron minerals have a large surface area and may represent a significant sink for metal(loid)s. However, it is also expected that the reductive dissolution of these iron minerals will increase the concentrations of both iron and sulfate, two important terminal electron acceptors (TEAs). Under suitable geochemical conditions this will lead to sulfidisation and the formation of sulfide minerals which are capable of strong metal(loid) immobilisation.

As in the mesocosm experiment, a total of 8.00 g (± 0.01 g) of the oven dried sediment was added to each acid washed centrifuge tube. A total of 40 mL of deoxygenated Milli-Q water or deoxygenated Milli-Q water containing known organic concentrations (i.e. glucose, acetate or humic acid) were added to each centrifuge tube resulting in a 1:5 sediment:water mixture (see Figure 3-16).

A stock humic acid solution was prepared by dissolving 400 mg/L of a humic acid reference material (Pahokee Peat – 1R103H-2) from the International Humic Substances Society (IHSS) in a deoxygenated 0.002 M NaOH solution (Richie and Perdue 2003); NaOH was required as humic acid is insoluble under near neutral pH conditions. The stock solution had an initial pH of >9.5, so sufficient HCl (<0.3 mL) was added to each tube containing humic acid to lower the pH to 5.8. A pH of 5.8 was chosen so all the treatments in the batch experiment had a similar starting pH to the sediment sample with only Milli-Q water added.

Figure 3-16. Waltowa sediments (2.5-10 cm) with no organic matter added after 47 days of incubation (*left* - sediment only; *middle* – sediment + jarosite; *right* – sediment + schwertmannite).

The humic acid reference material used in this experiment had an organic carbon content of 56.76%, which equates to a carbon content of 227 mg C/L in the humic acid stock solution. The glucose and acetate stock solutions were prepared so that they contained the equivalent total organic carbon contents to the humic acid solution. The glucose stock solution was prepared by dissolving 568 mg/L of glucose ($C_6H_{12}O_6$) in deoxygenated Milli-Q water and adjusting the pH to 5.8 with NaOH. The acetate stock solution was prepared by dissolving 776 mg/L of sodium acetate ($C_2H_3NaO_2$) in deoxygenated Milli-Q water and adjusting the pH to 5.8 with HCl.

The two vegetation types (i.e. *Phragmites australis* and *Schoenoplectus validus*) were added at the same concentrations as used in the mesocosm experiment (i.e. 0.40 g ± 0.002 g). Whilst the organic carbon concentration added with the two vegetation types was substantially higher than that used with the three organic compounds, it is expected that only a fraction of the organic carbon added would be readily decomposable and bacterially available over the period of incubation.

Synthetic jarosite ($KFe_3(SO_4)_2(OH)_6$) and schwertmannite ($Fe_8O_8(OH)_xSO_y$) were added separately to each of the batch experiment treatments (Table 4-3). Synthetic jarosite was prepared following the method of Baron and Palmer (1996). Synthetic schwertmannite was prepared following the short-term synthesis method (method 2) outlined in Regenspurg *et al.* (2004). The formation of these two synthetic minerals was confirmed by x-ray diffraction (XRD) using a Bruker D4 Endeavour x-ray diffractometer with a Lynxeye position sensitive detector. Synthetic jarosite and schwertmannite were incorporated with the sediments at a concentration of 5% (i.e. 0.40 g ± 0.002 g); the same concentration as used in the mesocosm experiment. The tubes containing jarosite and schwertmannite were initially adjusted to approximately pH 5.8 by adding 0.04 mL of 0.2 M NaOH and 0.22 mL of 1.0 M NaOH, respectively.

As in the mesocosm experiment, all centrifuge tubes were gently shaken and incubated in an anaerobic chamber at 24°C (± 2°C). In the batch experiment the sediments were incubated over eight time intervals up to 12 weeks (i.e. 10 minutes, 2 days, 1 week, 2 weeks, 4 weeks, 6 weeks, 9 weeks and 12 weeks). All centrifuge tubes were also gently shaken on a weekly basis and 24 hours prior to sampling. The caps on the centrifuge tubes were not tightened, so any gases produced during incubation were able to escape. At the end of each incubation period, the surface water samples for analysis (see Section 3.3.2) were extracted in the anaerobic chamber using a 20 mL syringe and filtered (0.45 µm).

3.3 Laboratory Analysis Methods

3.3.1 General Comments

All laboratory glassware and plastic-ware were cleaned by soaking in 5% (v/v) HCl for at least 24 hours, followed by repeated rinsing with deionised water. Reagents were analytical grade and all reagent solutions were prepared with deionised water (Milli-Q). All solid-phase results are presented on a dry weight basis (except where otherwise noted).

3.3.2 Surface Water Analyses

A summary of the parameters analysed in the mesocosm and batch experiment surface waters are presented in Table 3-4.

Table 3-4. Summary of the parameters analysed in the surface water for the mesocosm and batch experiments.

Parameter	Mesocosm Experiment	Batch Experiment
pH, Eh and EC	●	●
Water soluble metals and ions (including Cl^-, SO_4^{2-}, Na^+, Ca^+, Mg^{2+}, K^+, Al^{3+})	●	●
Redox sensitive species (Fe^{2+}, S^{2-}, Mn^{2+})	●	●
Nutrients (NH_4-N, NO_3-N)	●	
Alkalinity	●	●
Titratable acidity	●	
Dissolved Inorganic Carbon (DIC)	●	
NOM - Dissolved Organic Carbon (DOC)*	●	●
NOM - Fluorescence Spectroscopy	●	●
NOM - UV Spectroscopy	●	●
NOM - Redox state determination	●	
NOM – Low Molecular Weight (LMW) organic acids	●	

* DOC only determined at the start and end of the batch experiment

Surface water pH, redox potential (Eh), and electrical conductivity (EC) were immediately measured on unfiltered samples, and all other properties were determined on filtered (0.45 µm) samples. Redox potential and pH were determined using calibrated electrodes linked to a TPS WP-80 meter; Eh measurements are presented versus the standard hydrogen electrode. Electrical conductivity was determined using a calibrated electrode linked to a TPS smart*CHEM*-LAB laboratory analyser.

Ferrous iron (Fe^{2+}), alkalinity and dissolved sulfide (S^{2-}) were immediately fixed. The Fe^{2+} trap was made up from a phenanthroline solution with an ammonium acetate buffer (APHA 2005). Bromophenol blue traps were used for alkalinity (Sarazin *et al.* 1999) and alkalinity standards were determined with 0.1 M HCl using the Gran procedure (Stumm and Morgan 1996). The dissolved sulfide fraction was determined by the spectrophotometric method of Cline (1969). Ferrous iron, alkalinity and dissolved sulfide were all quantified colorimetrically using a Hach DR/2800 spectrophotometer. It was not possible to quantify the ferrous iron, alkalinity and dissolved sulfide fractions in the majority of the batch experiment samples containing humic acid due to the colour interference. A colour interference was also sometimes observed with the determination of the dissolved sulfide fraction, and may possibly be due to the formation of organo-sulfur compounds that are known to interfere with the method used (Cline 1969).

Samples analysed for metal(loid)s (Ag, Al, As, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Se and Zn), cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) and anions (SO_4^{2-}, Cl^-) were acidified with 0.2 mL of concentrated nitric acid (HNO_3) and analysed using inductively coupled plasma-mass spectrometry (ICP-MS; Perkin Elmer NexION 300D ICP-MS) (APHA 3125 ICP-MS; APHA 2005); the dissolved sulfate (SO_4^{2-}) concentration was not quantified but was analysed as part of the total dissolved sulfur fraction. The dissolved nitrate and ammonia concentrations were analysed turbidimetrically using flow-injection analysis (FIA) colorimetry (Lachat QuikChem 8000) (APHA 4500 FIA; APHA 2005).

Changes in carbon functional groups of the NOM in the surface waters were followed by using a number of techniques (Table 4-4). Samples analysed for dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) content were acidified with concentrated sulfuric acid (H_2SO_4) and analysed using a Shimadzu TOC-L Analyser (e.g. APHA 5310 B; APHA 2005). Fluorescence analysis of the tryptophan-like peak using excitation-emission-matrices (EEMs) was measured using a Horiba Scientific Aqualog® Benchtop Flurometer. Excitation and emission were scanned simultaneously at wavelengths from 220-600 nm. Fluorescence analysis of the tryptophan-like peak (peak T_1 -

excitation/emission wavelength ($\lambda_{ex/em}$) region 275-296/330-378 nm) has been found to provide an accurate indication of the presence and relative proportions of bioavailable organic material present (Hudson *et al.* 2008). In addition to the T_1 peak data, data has also been collected for other peaks examined by Hudson *et al.* (2008) (i.e. T_2, C and A peaks) (see Figure 3-17). The optical properties of the NOM were also assessed as a function of time via UV-visible spectrophotometry (Varian Cary 50 UV-Visible spectrophotometer).

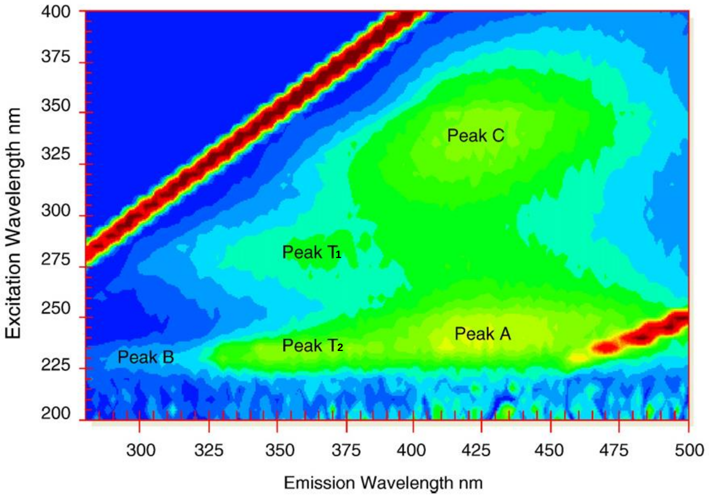

Figure 3-17. Example of excitation-emission-matrices (EMMs) illustrating positions of T_1, T_2, C and A peaks (source: Hudson *et al.* 2008).

Filtered sub-samples (0.45 µm) were frozen and subsequently defrosted in the anaerobic chamber prior to the determination of the redox properties, low molecular weight (LMW) organic acids and titratable acidity. The redox properties of the NOM were assessed using a direct electrochemical reduction technique (Bi *et al.* 2013). Electrochemical measurements were performed in the anaerobic chamber using an electrochemistry workstation CHI660D (CH Instruments, Inc., Austin, USA) with a conventional three-electrode cell at ambient temperature. Differential Pulse Voltammetry (DPV) was employed to investigate the redox-active components in the dissolved organic matter. A glassy carbon electrode was used as the working electrode, and a platinum (Pt) wire and silver/silver chloride (Ag/AgCl) electrodes as the counter and reference electrodes, respectively. A 0.5 mL filtrate was transferred to the electrochemical cell, and 2.5 mL of 5.0 mM ammonium acetate was added. The operating conditions used to obtain voltammograms included a scanning speed of 10 mV/s, pulse voltage of 50 mV, and operating voltage range of 0.5 to 1.0 V.

High-performance liquid chromatography (HPLC) was used to determine LMW organic acids including acetic acid (CH_3COOH), formic acid ($HCOOH$), malonic acid ($CH_2(COOH)_2$), oxalic acid ($H_2C_2O_4$) and succinic acid ($C_4H_6O_4$) (Goldstone *et al.* 2002). The presence of benzoic acid ($C_7H_6O_2$) was also examined by HPLC. The titratable acidity was determined by titration to pH 8.3 following the addition of hydrogen peroxide (H_2O_2) (APHA 2310 B; APHA 2005).

All surface water data for the mesocosm and batch experiments are presented in Appendix 2 (Tables 8-3 to 8-7) and Appendix 3 (Tables 8-8 to 8-31), respectively.

3.3.3 Sediment Analyses

Analyses of the sediment were only undertaken on the samples collected during the mesocosm experiment. The moisture content, reduced inorganic sulfur (RIS) content, iron mineralogy and iron fractionation were only measured at the start and end of the incubation experiment (i.e. Day 0 and Week 16). All other parameters were measured at all four time intervals (i.e. Day 0, Week 4, Week 8 and Week 16).

The parameters measured on the sediment included:

- Moisture content
- Reduced inorganic sulfur (RIS) content (including CRS, S(0) and AVS)
- Titratable actual acidity (only if pH_{KCl} is <6.5)

- Acid neutralising capacity (only if pH_{KCl} is >6.5)
- Retained acidity (only if pH_{KCl} is <4.5)
- Total C and N (by LECO)
- Organic carbon fractionation
- Iron mineralogy (by XRD)
- Iron fractionation

The sediment moisture content was determined by weight loss due to drying at 105°C; the moisture content was only required when wet samples were analysed (i.e. RIS and iron fractionation). Sediments for further analysis (with the exception of sediments analysed for RIS and iron fractionation) were oven-dried at 80°C and sieved (< 2 mm) prior to being ring mill ground.

Total carbon (%C) and total nitrogen (%N) were measured on powdered oven-dried samples by combustion using a LECO-CNS 2000 analyser. The acid volatile sulfide (AVS), elemental sulfur (S(0)) and pyritic sulfur fractions were determined using a sequential extraction procedure on frozen sub-samples. The AVS fraction was initially extracted via a cold diffusion procedure, with the use of ascorbic acid to prevent interferences from ferric iron (Fe (III)) (Burton *et al.* 2007). The solid phase S(0) fraction was extracted using methanol as a solvent and quantified by high-performance liquid chromatography (HPLC) (McGuire and Hamers 2000). The remaining RIS fraction (i.e. pyritic sulfur) was determined using the chromium reduction analysis method of Sullivan *et al.* (2000).

The potassium chloride (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) (i.e. sum of soluble and exchangeable acidity) was determined by titration of the KCl extract to pH 6.5 (Method Code 23F) (Ahern *et al.* 2004). Titratable actual acidity is a measure of the actual acidity in soil materials. The acid neutralising capacity (ANC_{BT}) was quantified on the <0.5 mm sieved soil fraction (only if pH_{KCl} is >6.5) using a standard back-titration determination (Method Code 19A2) (Ahern *et al.* 2004). The retained acidity (RA) was not required to be determined as all samples had pH_{KCl} > 4.5. The net acidity was estimated by the acid-base account method of Ahern *et al.* (2004).

The organic matter fractionation (i.e. total organic C, hydrolysable C and non-hydrolysable C) were measured after the 1.0 M HCl method described by Silveira *et al.* (2008). The total organic carbon (TOC) content was determined by a LECO-CNS 2000 analyser following the removal of inorganic carbon by treatment with 1.0 M HCl. The non-hydrolysable organic carbon content was determined by a LECO-CNS 2000 analyser following treatment with 6.0 M HCl at 105°C for 2 hours. The hydrolysable organic carbon content was determined from the difference between the TOC and the non-hydrolysable carbon fractions.

The iron mineralogy was examined by XRD using a Bruker D4 Endeavour x-ray diffractometer with a Lynxeye position sensitive detector. All sediment samples were milled to a powder (<10 µm) by agate micronizer. Cobalt radiation was used at 40kV and 40mA over a range of 5° and 80° 2θ, a step size of 0.03572° 2θ and 1.65 sec./step. Crystalline materials were identified using Bruker "Diffrac*plus*EVA" Search/Match software and the ICDD PDF-2 database. The XRD has a mineral detection limit of approximately 2% by weight.

Iron fractionation was determined following a modified sequential extraction procedure of Claff *et al.* (2010). In this study, the sequential extraction procedure followed four steps to quantify (1) soluble and exchangeable (magnesium chloride extractable), (2) acid (hydrochloric acid) soluble, (3) crystalline oxide (citrate buffered dithionite (CBD)) extractable, and (4) residual (acid/peroxide digestible) forms of iron; the pyrite-bound (nitric acid extractable) fraction was determined using the chromium reduction analysis method of Sullivan *et al.* (2000). In the first step the total iron (Fe^{2+} + Fe^{3+}) fractions were immediately fixed following extraction, and in the third step ferrous iron (Fe^{2+}) was immediately fixed. The Fe^{2+} trap was made up from a phenanthroline solution with an ammonium acetate buffer (APHA 2005), and the total iron trap also included a hydroxylamine solution (APHA 2005). The iron fractions were quantified colorimetrically using a Hach DR/2800 spectrophotometer. The total iron content of the sediment with and without the presence of vegetation was analysed by ICP-MS (APHA 3125 ICP-MS; APHA 2005) for the acid soluble and residual steps (steps 2 and 4). Selected metal(loid)s (i.e. As, Co, Cu, Ni, Zn) extracted using this procedure were examined in one of the treatments, and were analysed by ICP-MS (APHA 3125 ICP-MS; APHA 2005).

The particle size distribution of the 4 sediments collected was also determined using a Malvern Mastersizer 2000 particle size analyser.

All sediment data are presented in Appendix 4 (Tables 8-32 and 8-33). Additional data including particle size distribution and XRD data is presented in Appendix 6 (Figures 8-1 to 8-6).

3.3.4 Vegetation Analyses

A comprehensive analysis of metals in the leaves and the stems was undertaken for the vegetation collected from the 18 sites at Tolderol and Waltowa. The metal contents of the vegetation used in laboratory incubation experiments were also determined. The plant materials were initially separated into leaves, stems and flowers (except for those used in the laboratory incubation experiments). All plant materials were then washed thoroughly in tap water followed by deionised water (Milli-Q) to remove any potential contamination. The plant materials were dried at 70˚C for 48 hours prior to being ceramic mill ground. The metal concentrations were determined using ICP-MS following microwave digestion with nitric acid (HNO_3). The total organic carbon (TOC) content was determined on the vegetation used in the laboratory mesocosm experiments by a LECO-CNS 2000 analyser following the removal of inorganic carbon by treatment with 1.0 M HCl.

Plant material analysis data are presented in Appendix 5 (Tables 8-35 and 8-36).

3.3.5 Expression of Results

The mean (Av.) values are often presented in tables in this document with graphs given to illustrate certain points. The standard errors (SE) are presented on many of the graphs.

3.3.6 Quality Assurance and Quality Control

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.

Blanks were collected for laboratory samples to examine whether contaminants had been introduced to the sample. Reagent blanks and method blanks were prepared and analysed for each method. All blanks examined here were either at, or very close to, the limits of detection.

Duplicates/triplicates were prepared for all the laboratory experiments and analysed separately. Selected analytical duplicate samples were prepared by dividing a test sample into two, then analysing these sub-samples separately. On average, the frequencies of quality control samples processed were: 10% blanks, ≥ 10% laboratory duplicates, and 5% laboratory controls. The analytical precision was usually ±10% for all analyses.

4.0 Results

4.1 Field Sediment Condition

This section presents the field pH and redox potential (Eh) data collected in October 2013. Further details of the sediment condition at the start of the mesocosm experiment are presented in Section 4.2.2.

4.1.1 Tolderol

4.1.1.1 pH (field)

The mean field pH of the surface layer (i.e. 0-2.5 cm) at the replicate sites ranged between 7.2 and 7.3 (Figure 4-1). The pH of the sediment decreased with depth to a minimum pH ranging between 4.2 and 6.6. The field pH of the top 10 cm at two of the sites (TS1 and TS3) is similar to that measured at this site in March 2013 (see Figure 8-7, Appendix 7). However, site TS2 had a substantially lower pH below 5 cm; traces of jarosite were also visible in the field below this depth.

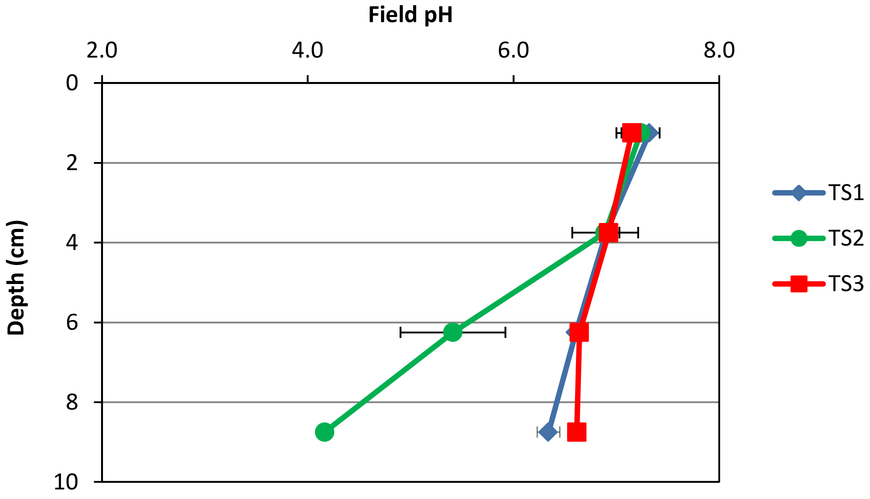

Figure 4-1. Field pH at the Tolderol scald sites (October 2013).

4.1.1.2 Redox Potential (Eh)

The mean field Eh of the suboxic surface layer (i.e. 0-2.5 cm) at the replicate sites ranged between 165 and 259 mV (Figure 4-2). The Eh of the sediment at two of the replicate sites (TS1 and TS3) decreased with depth to a minimum ranging between 127 and 136 mV. However, site TS2 showed a different trend with a maximum Eh of 333 mV at the lowest depth measured. The field Eh of the top 10 cm is slightly lower than that measured at this site in March 2013 (see Figure 8-8, Appendix 7).

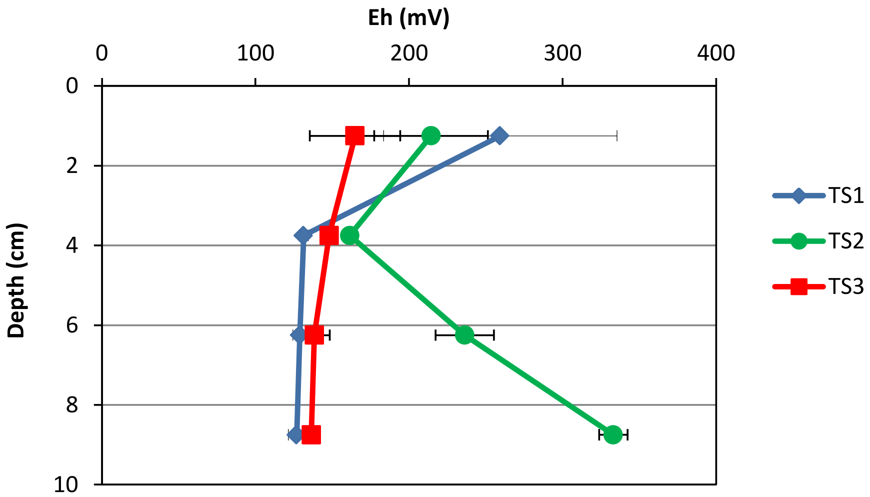

Figure 4-2. Field Eh at the Tolderol scald sites (October 2013).

4.1.2 Waltowa

4.1.2.1 pH (field)

The mean field pH of the surface layer (i.e. 0-2.5 cm) at the replicate sites was consistently pH 7.0 (Figure 4-3). The pH at the three sites decreased with depth to a minimum pH ranging between 6.4 and 6.7. The field pH of the top 10 cm is similar to that measured at this site in March 2012 and March 2013 (see Figure 8-9, Appendix 7).

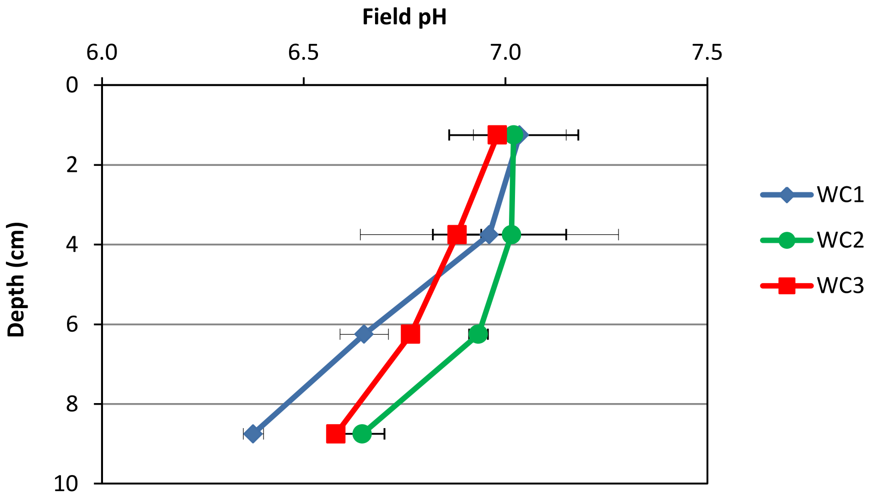

Figure 4-3. Field pH at the Waltowa Cotula sites (October 2013).

4.1.2.2 Redox Potential (Eh)

The mean field Eh of the suboxic surface layer (i.e. 0-2.5 cm) at the replicate sites ranged between 87 and 152 mV (Figure 4-4). The Eh of the sediment decreased with depth to a minimum Eh ranging between 54 and 73 mV. The field Eh of the top 10 cm is lower than that measured at this site in March 2013, but similar to that measured in March 2012 (see Figure 8-10, Appendix 7).

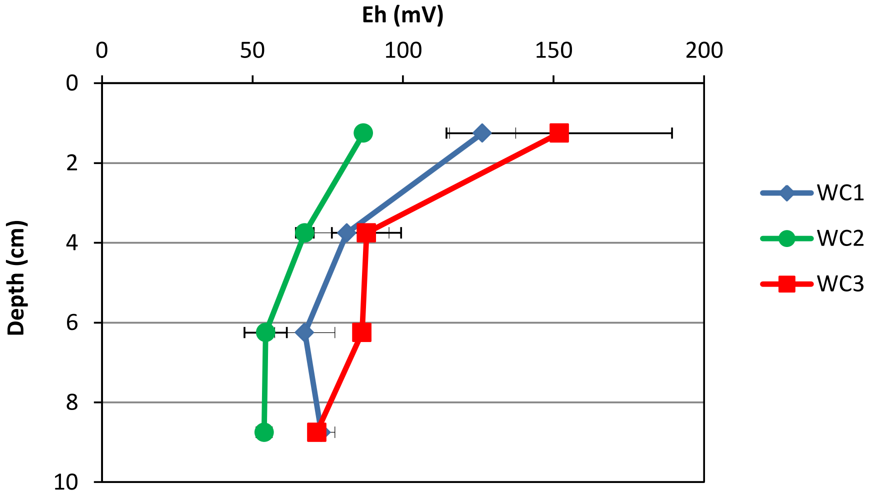

Figure 4-4. Field Eh at the Waltowa Cotula sites (October 2013).

4.2 Laboratory Mesocosm Experiment

4.2.1 Surface Water

In this section the behaviour of various parameters to 16 weeks of inundation is examined with and without the addition of vegetation (*Phragmites* and *Schoenoplectus)* for the Tolderol and Waltowa surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. The levels of nutrients (nitrate and ammonia) and metal(loid)s also are compared to the ANZECC Ecosystem Protection Freshwater Guidelines for protection of 95% of biota in 'slightly-moderately disturbed' systems (ANZECC/ARMCANZ 2000).

4.2.1.1 pH

The change in surface water pH during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-5. The initial surface water pH of the sediments without the addition of vegetation ranged between pH 4.3 and 8.3. The surface water of the Tolderol sub-surface sediment (2.5-10 cm) where field observations indicated the presence of jarosite had the lowest pH. The surface water pH of the untreated sediments largely increased during incubation, and was near-neutral to slightly alkaline after 16 weeks of incubation; the pH ranged between 7.4 and 8.4 after 16 weeks. The only exception was the surface water associated with the untreated Waltowa surface sediment (0-2.5 cm) which showed minimal change over the 16 week incubation period.

The addition of vegetation generally lowered the pH of the surface water, and was less than or equal to pH 5.0 with all sediments after 4 weeks of incubation. The surface sediment (0-2.5 cm) surface water pH at both sites showed a similar behaviour, with an initial decrease in pH over the first 4 weeks, followed by a pH increase to near-neutral conditions. The surface water pH of the treated sub-surface sediments (2.5-10 cm) continued to decease for at least 8 weeks. The addition of either *Phragmites* or *Schoenoplectus* to all sediments resulted in similar pH behaviour. The pH decrease observed with the sediments treated with vegetation is a consequence of the release of organic acids produced during the breakdown of organic matter (see Section 4.2.1.9.5 for further details).

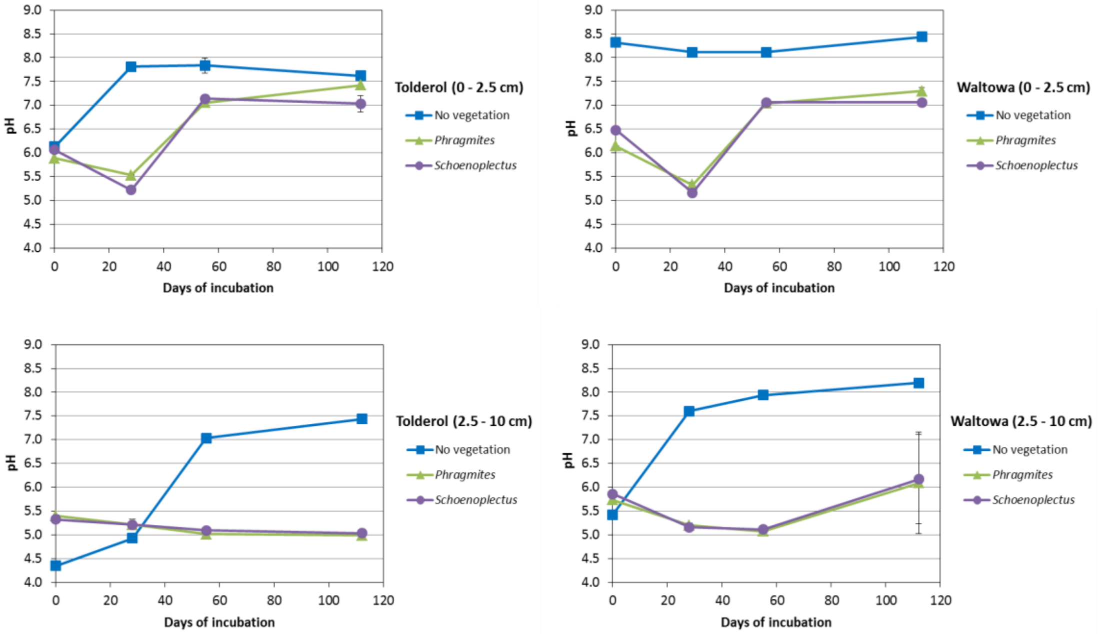

Figure 4-5. Toldero1 and Waltowa surface water pH dynamics.

4.2.1.2 Redox Potential (Eh)

The change in surface water Eh during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-6. As expected and as a consequence of reducing processes the surface water for all treated and non-treated sediments showed an overall decrease in Eh during the incubation experiment.

A rapid decrease in surface water Eh was observed during the initial 4/8 weeks of incubation, after which the rate of decrease reduced, and an increase in Eh was usually observed. The surface water Eh of the non-treated sediments was often less than that of the sediments treated with vegetation. Strongly reducing conditions (i.e. < -100 mV) in the surface water were observed with all non-treated sediments during the incubation experiment. Greater reducing conditions in the surface water were observed with the surface sediments (0-2.5 cm) treated with vegetation when compared to the sub-surface sediments (0-2.5 cm) treated with vegetation. The addition of *Phragmites* and *Schoenoplectus* to each sediment resulted in similar Eh behaviour.

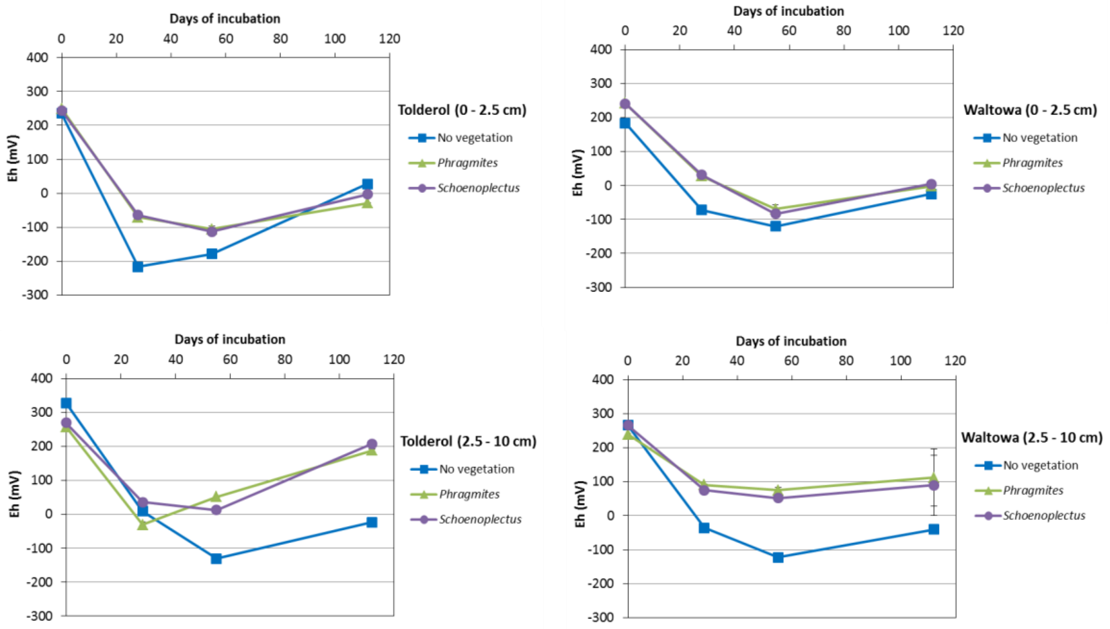

Figure 4-6. Tolderol and Waltowa surface water Eh dynamics.

4.2.1.3 Electrical Conductivity (EC)

The change in surface water EC during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-7. At the start of the incubation experiment the addition of the two vegetation types resulted in a substantial increase in the surface water EC when compared to the control. The initial surface water EC of the controls were less than 270 µS/cm compared to approximately 1,000 µS/cm and 1,300 µS/cm following the addition of *Phragmites* and *Schoenoplectus*, respectively. Substantially higher surface water cation and anion concentrations were also found with the vegetated treated samples (e.g. Figures 8-11– 8-15, Appendix 7).

The surface water EC of untreated sediments often showed minimal change over the 16 weeks incubation period, although the EC showed a gradual increase with the Waltowa surface sediment (0-2.5 cm). An overall increase in surface water EC was observed during the incubation experiment when treated with either *Phragmites* or *Schoenoplectus.* The addition of *Phragmites* and *Schoenoplectus* to each sediment largely resulted in similar EC behaviour.

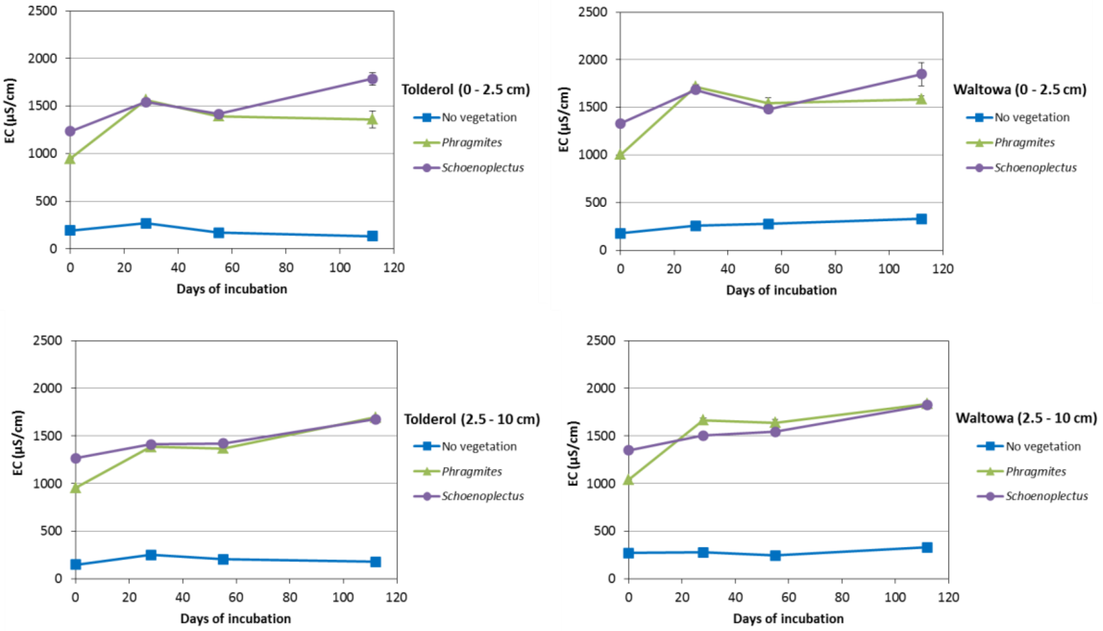

Figure 4-7. Tolderol and Waltowa surface water EC dynamics.

4.2.1.4 Titratable Acidity

The change in surface water titratable acidity during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-8. While the measurement of pH provides the concentration of hydrogen ions (H^+) in solution, the measurement of titratable acidity also includes any acidity that may be produced from the hydrolysis of metal ions (usually mainly iron (Fe) and aluminium (Al) in acid sulfate soil landscapes). Relatively low surface water titratable acidities were observed with all sediments without the addition of vegetation, and tended to decrease during incubation (Figure 4-8). The decrease in titratable acidity during incubation is a consequence of acidity being consumed as a result of reduction processes. As expected, the Tolderol sub-surface soil (2.5-10 cm) which had the lowest initial pH (Figure 4-5) had the highest titratable acidity (~50 mg/L $CaCO_3$).

The addition of vegetation resulted in substantial increases in the surface water titratable acidities (Figure 4-8). The surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments showed different behaviours in titratable acidity, but the behaviour was similar at each site. The addition of vegetation to the surface (0-2.5 cm) sediments showed a rapid increase over the initial 4 weeks, followed by a rapid decrease. It is expected that the rapid increase in titratable acidity is a combination of the acidity produced from the breakdown on organic matter (as indicated by the initial drop in pH (Figure 4-5)), and the release of metal ions during reduction (particularly ferrous iron (Figure 4-13)). After 4 weeks the acidity present (and any acidity produced) is rapidly broken down and consumed by reduction processes.

While the sub-surface (2.5-10 cm) sediments also showed a rapid increase in titratable acidity over the initial 4 weeks, the acidity was not rapidly consumed as observed with the surface (0-2.5 cm) sediments. While the addition of vegetation to the surface (0-2.5 cm) sediments resulted in more reducing conditions than observed with the sub-surface (2.5-10 cm) sediments (see Figure 4-6), the reason for this difference is currently not clear.

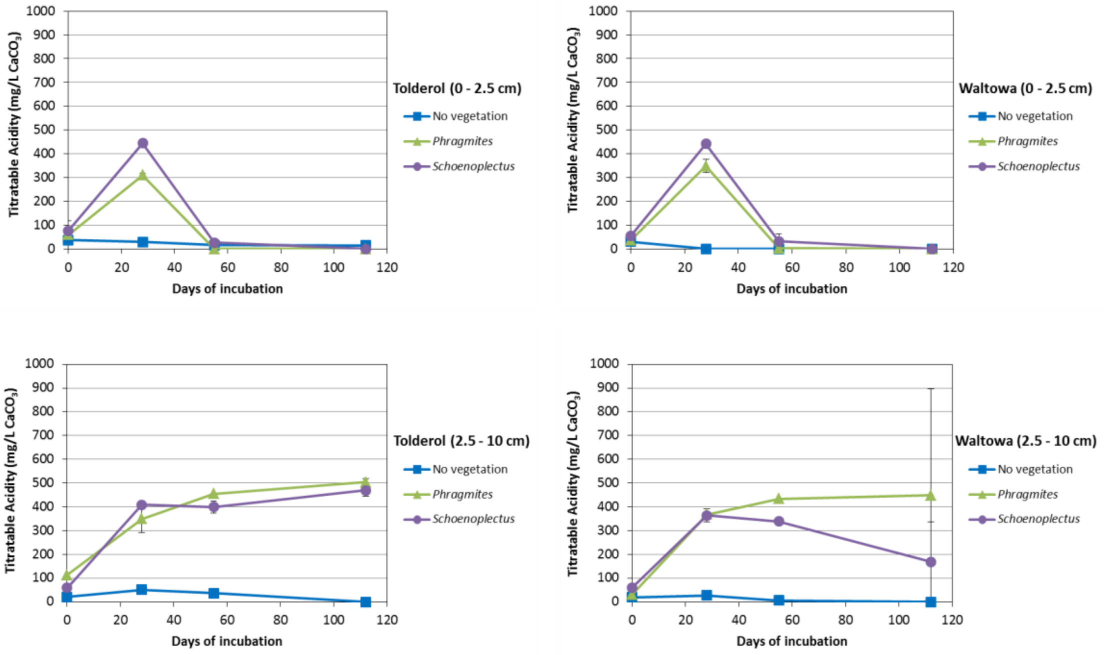

Figure 4-8. Tolderol and Waltowa surface water titratable acidity dynamics.

It is important to note that whilst significantly higher titratable acidities were observed when vegetation was added to the sediments, the titratable acidities were very low (i.e. ≤ 504 mg/L $CaCO_3$ or ≤ 0.01 mol H^+/L), particularly when compared to the sulfuric and sulfidic acidities previously observed within the sediments in the Lower Lakes (e.g. Fitzpatrick *et al.* 2008).

4.2.1.5 Nutrients

The change in surface water nitrate and ammonia concentrations during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figures 4-9 and 4-10, respectively. Very low surface water nitrate concentrations were observed with the Tolderol sediments (0-10 cm) and the Waltowa sub-surface sediment (2.5-10 cm) (i.e. ≤ 0.06 mg/L N) (Figure 4-9). The untreated and treated Waltowa surface sediments (0-2.5 cm) initially had higher surface water nitrate concentrations (i.e. >0.10 mg/L N), however, the nitrate concentrations rapidly decreased due to denitrification. The surface water nitrate concentrations were always substantially lower than the ANZECC freshwater water quality guideline of 0.7 mg/L.

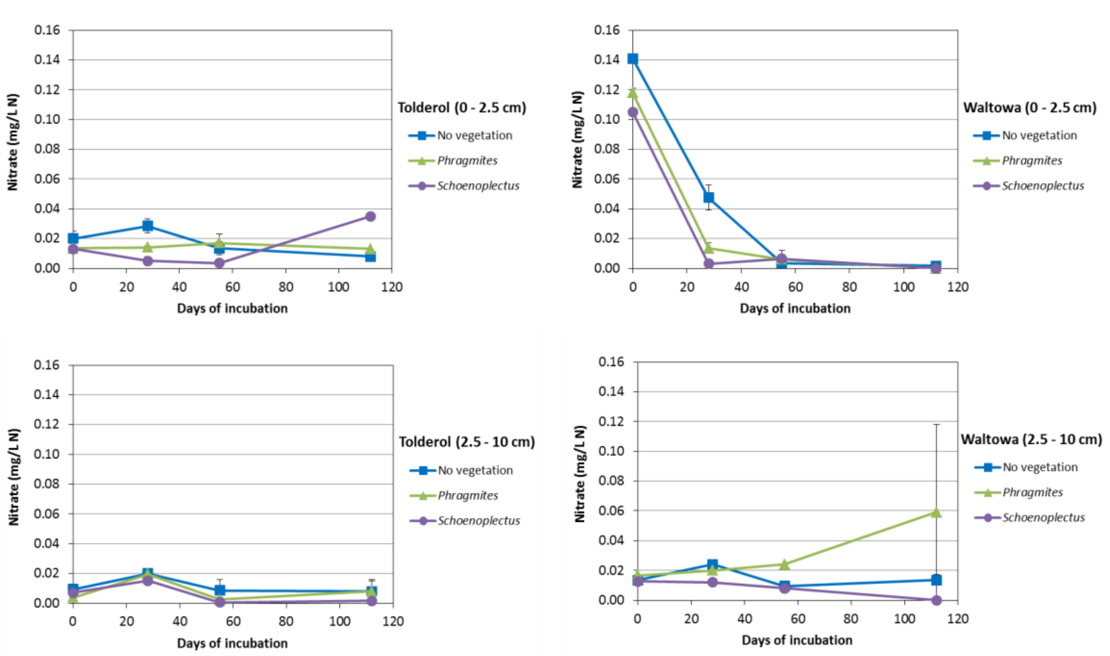

Figure 4-9. Tolderol and Waltowa surface water nitrate dynamics.

The surface water ammonia concentration of the sediments without the addition of vegetation increased over the initial 4/8 weeks of incubation, and the increase in the ammonia concentration was particularly evident for the Waltowa surface sediment (0-2.5 cm) (Figure 4-10). High surface water ammonia concentrations were observed with all the Tolderol and Waltowa sediments treated with *Phragmites* (i.e. 3.4 – 66 mg/L N) (Figure 4-10).

The surface water ammonia concentration in the *Phragmites* treated sediments showed a rapid increase over the initial 4 weeks, after which the concentration decreased with the surface sediments (0-2.5 cm) and largely remained constant with the sub-surface (2.5-10 cm). The surface water ammonia concentration in the sediments treated with *Schoenoplectus* showed a slight decrease over the 16 week incubation period. The increase in the surface water ammonia concentration often observed is a consequence of the breakdown of organic nitrogen by bacteria. The data suggests that the *Schoenoplectus* is much more resistant to breakdown by bacteria, particularly over the 16 week incubation period of this experiment.

The surface water ammonia concentrations were substantially higher than the ANZECC freshwater water quality guideline of 0.9 mg/L for all the sediments treated with *Phragmites*. The surface water ammonia concentration also often exceeded the ANZECC guideline with the control surface sediments (0-2.5 cm).

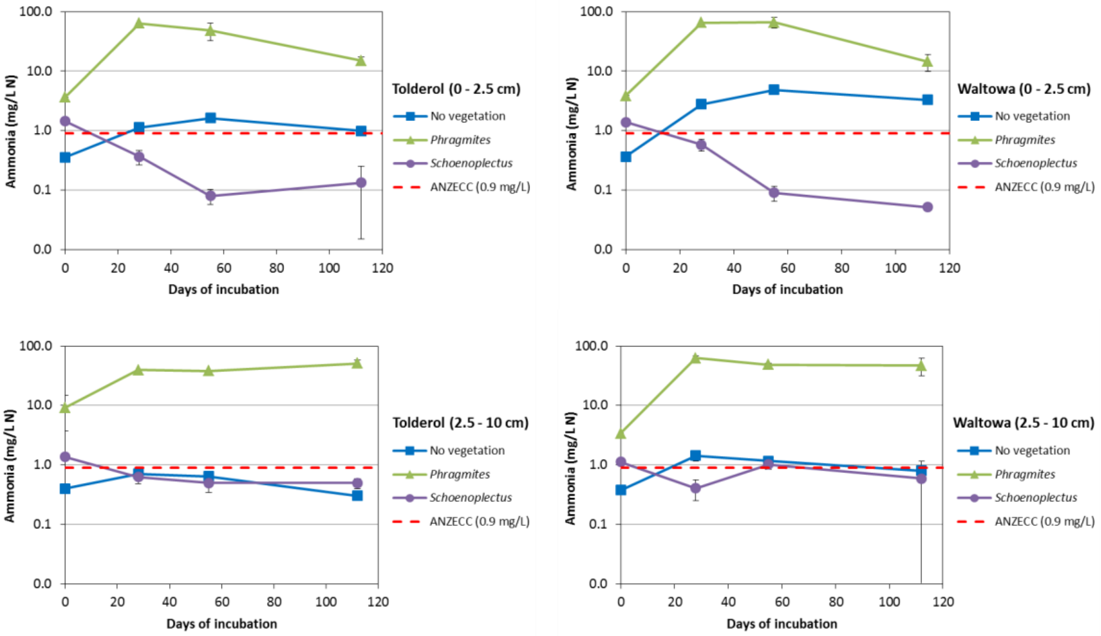

Figure 4-10. Tolderol and Waltowa surface water ammonia dynamics.

4.2.1.6 Sulfur and Sulfide

The change in surface water sulfur concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-11. The initial surface water sulfur concentration of the sediments without the addition of vegetation was low (<15 mg/L) and decreased during the incubation. The addition of *Phragmites and Schoenoplectus* to the sediments initially increased the total sulfur concentration by approximately 25 mg/L and 40 mg/L, respectively. The concentration of total sulfur in the *Phragmites and Schoenoplectus* treatments rapidly decreased within the initial 4 weeks of incubation.

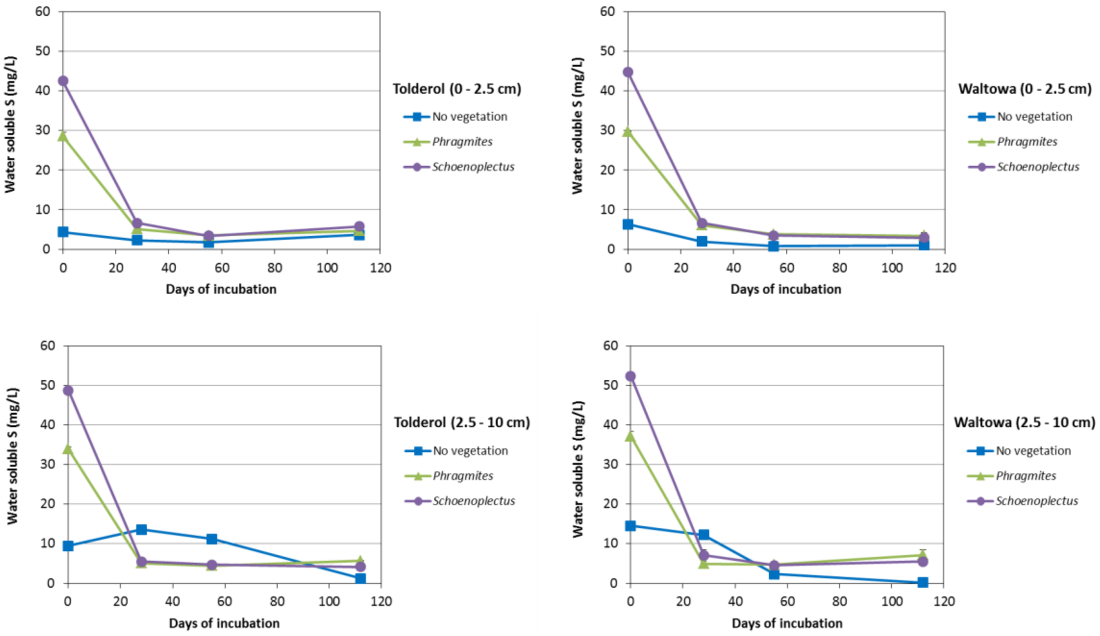

Figure 4-11. Tolderol and Waltowa surface water sulfur dynamics.

Sulfate reduction and the formation of dissolved sulfide were often observed (see Table 8-3, Appendix 2), although colour interference due to the presence of dissolved organic matter sometimes made it difficult to quantify the concentration. The great temporal resolution with the batch experiment showed that sulfide formed rapidly during the initial 2 weeks of incubation (particularly with the vegetated samples) and then rapidly decreased (see Figure 4-54, Section 4.3.4.2).

4.2.1.7 Dissolved Inorganic Carbon (DIC)

The change in surface water dissolved inorganic carbon (DIC) concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-12. The DIC concentration is a measurement of the sum of the inorganic carbon species including carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}). The DIC concentration often shows a substantial increase after 16 weeks of incubation, except with the vegetation treated sub-surface sediments (2.5-10 cm) at both sites. Minimal DIC concentration increase was observed in the vegetation treated sub-surface sediments due to the pH of the surface water (i.e. pH <6.2).

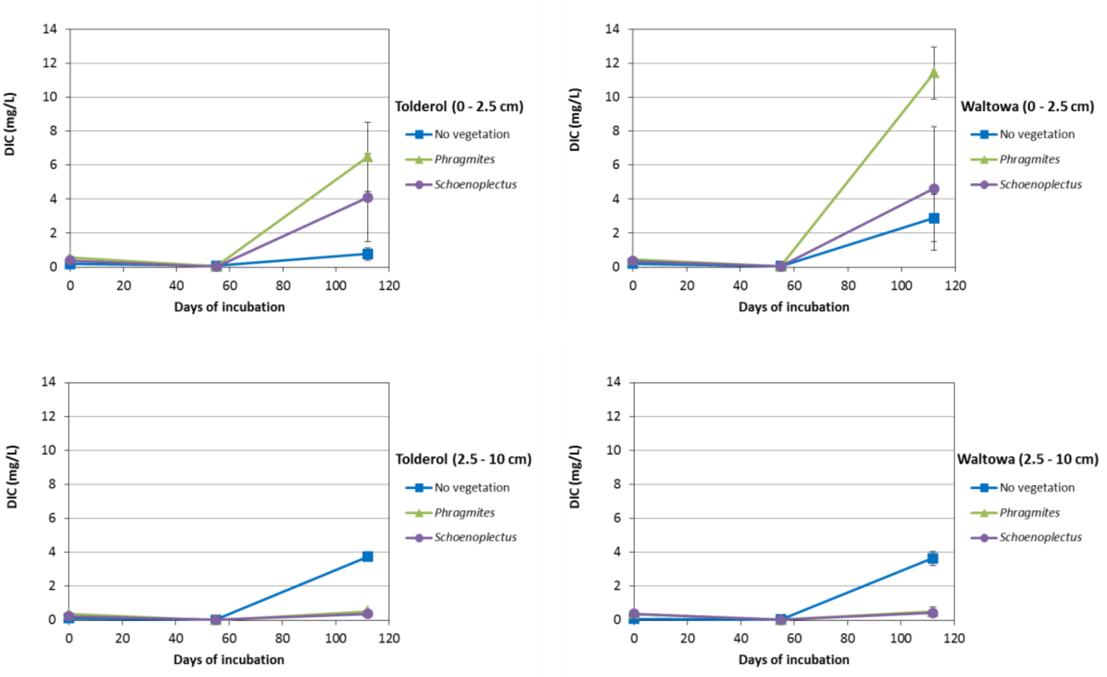

Figure 4-12. Tolderol and Waltowa surface water dissolved inorganic carbon (DIC) dynamics.

4.2.1.8 Summary of Surface Water Parameter Trends

A summary table was created to gain an understanding of the high level trends/relationships with the surface water parameters discussed in Sections 4.2.1.1.to 4.2.1.7 (see Table 4-1). Table 4-1 compares the rank of the maximum value/concentration (where 1 represents the highest value and 3 represents the lowest value) for each treatment (i.e. No vegetation, *Phragmites*, *Schoenoplectus*) within a sediment depth (i.e. 0-2.5 cm and 2.5-10 cm) for the two sites during the 16 week incubation period. For example, the *Schoenoplectus* treatment which had the highest sulfur concentration with the Tolderol surface (0-2.5 cm) sediment (see Figure 4-11) is ranked 1, and the no vegetation treatment at this site and depth had the lowest maximum concentration is ranked 3.

Table 4-1. Summary of the rank of the maximum parameter values/concentrations.

Depth (cm)	Treatment	Site	Parameter							
			pH	Eh*	EC	Titratable Acidity	Nitrate	Ammonia	Sulfur	DIC
0-2.5	No vegetation	Tolderol	1	3	3	3	1	**2**	3	3
		Waltowa	1	3	3	3	1	**2**	3	3
	Phragmites	Tolderol	2	1	1	2	3	**1**	2	1
		Waltowa	2	1	1	2	2	**1**	2	1
	Schoenoplectus	Tolderol	2	1	1	1	1	**2**	1	2
		Waltowa	2	1	1	1	2	**3**	1	2
2.5-10	No vegetation	Tolderol	1	3	3	3	1	3	3	1
		Waltowa	1	3	3	3	2	**2**	3	1
	Phragmites	Tolderol	2	1	1	1	1	**1**	2	2
		Waltowa	2	1	1	1	1	**1**	2	2
	Schoenoplectus	Tolderol	2	1	1	1	1	**2**	1	2
		Waltowa	2	1	1	2	2	**2**	1	2

Bold red values *indicate that the concentration exceeded ANZECC Guideline Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems (ANZECC/ARMCANZ 2000).*
** Eh decreased with time and therefore minimum value compared.*

Highest Value/ Concentration	1	2	3	Lowest Value/ Concentration

Table 4-1 shows that many of the parameters measured were at the lowest value/concentration in the surface waters associated with the sediments without the addition of vegetation; this was observed with both surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. However, some of the parameters were also found at their highest values/concentrations in these surface waters, including pH, nitrate, and DIC (with the sub-surface (2.5-10 cm) sediments only).

Table 4-1 highlights the fact that the addition of vegetation to the sediments from both sites and each depth often resulted in a similar behaviour. Table 4-1 shows the addition of either *Phragmites* or *Schoenoplectus* to the sediments resulted in a very similar maximum pH and EC, and minimum Eh. The behaviour of the vegetation treated sediments during incubation was similar with many of the other surface water parameters, with the only exception being the surface water ammonia concentrations.

Table 4-1 shows the ammonia ANZECC guideline concentration was often exceeded in the surface waters under the experimental conditions, and substantially higher concentrations were observed with the *Phragmites* treated sediments (Figure 4-10).

A summary of the surface water parameter trends is provided in the following 'Summary of Section'.

Summary of Section

The addition of *Phragmites* and *Schoenoplectus* to each of the sediments resulted in a similar behaviour with many of the parameters. The only clear exception was with the ammonia concentration where the addition of *Phragmites* resulted in substantially higher concentrations (Figure 4-10).

The surface water pH data showed without the addition of vegetation to the acidified sediments from both Tolderol and Waltowa recovery to a near-neutral pH occurred within 4 to 8 weeks (Figure 4-5). The addition of vegetation (*Phragmites* and *Schoenoplectus*) to the surface (0-2.5 cm) sediments initially resulted in some acidification, however, a near-neutral pH was still reached within 8 weeks. The addition of vegetation to the sub-surface (2.5-10 cm) sediments resulted in acidification for at least 8 weeks and a near-neutral pH was not reached within the timeframe of the mesocosm experiment (i.e. 16 weeks).

As expected, the surface water redox potential (Eh) decreased with all sediments and treatments during the incubation (Figure 4-6). A lower minimum Eh was reached with the sediments without vegetation.

The surface water electrical conductivity (EC) was much higher when vegetation was added to the sediments (Figure 4-7). The data showed the dissolution of salts associated with the vegetation was the cause of the EC increase.

The addition of vegetation caused surface water titratable acidities to increase, although the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments showed a different behaviour (Figure 4-8). The titratable acidity rapidly increased over the initial 4 weeks with the surface (0-2.5 cm) sediments and then rapidly decreased. The sub-surface (2.5-10 cm) sediment also showed a rapid increase over the initial 4 weeks, but then either increased slightly or steadily decreased. It is important to note that whilst significantly higher titratable acidities were observed when vegetation was added to the sediments, the titratable acidities were low (i.e. ≤ 504 mg/L $CaCO_3$ or ≤ 0.01 mol H^+/L), particularly when compared to the sulfuric and sulfidic acidities previously reported within the sediments in the Lower Lakes (e.g. Fitzpatrick *et al.* 2008). It is expected that the increase in titratable acidity observed is the result of a combination of the acidity produced from the breakdown on organic matter and the release of metal ions during reduction (particularly ferrous iron). The titratable acidity often decreases during incubation as the organic acids get broken down and acidity gets consumed by reduction processes.

High ammonia concentrations were especially observed with all sediments treated with *Phragmites* (up to 66 mg/L N). Low surface water nitrate concentrations were observed with all sediments and treatments (≤ 0.14 mg/L N). Under the experimental conditions, the surface water ammonia concentration often exceeded the ANZECC water quality guideline (see Table 4-1).

The initial surface water sulfur concentration of the sediments without the addition of vegetation was low (<15 mg/L). The addition of vegetation initially increased the total sulfur concentration (by up to 40 mg/L), but had decreased substantially after 4 weeks of incubation (Figure 4-11). Sulfate reduction and the formation of dissolved sulfide were also often observed.

Dissolved inorganic carbon (DIC) was largely only detected after 16 weeks of incubation, particularly with the surface (0-2.5 cm) sediments (Figure 4-12).

4.2.1.9 Metal(loid)s

4.2.1.9.1 Ferrous Iron (Fe^{2+})

The change in surface water ferrous iron (Fe^{2+}) concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-13. The surface water Fe^{2+} concentration for the sediments without the addition of vegetation only showed a slight or no increase over the 16 week incubation period. The addition of vegetation resulted in a substantial increase in the surface water Fe^{2+} concentration. The surface sediments (0-2.5 cm) treated with vegetation showed a rapid increase in the surface water Fe^{2+} concentration over the initial 4 weeks followed by a decrease; a greater decrease was observed with the *Phragmites* treatment. The surface water Fe^{2+} concentration increased with time with the vegetation treated sub-surface sediments (2.5-10 cm), except after 16 weeks with the Waltowa sediment where the duplicate samples showed a mixed response. The addition of either *Phragmites* or *Schoenoplectus* to all sediments resulted in similar Fe^{2+} behaviour.

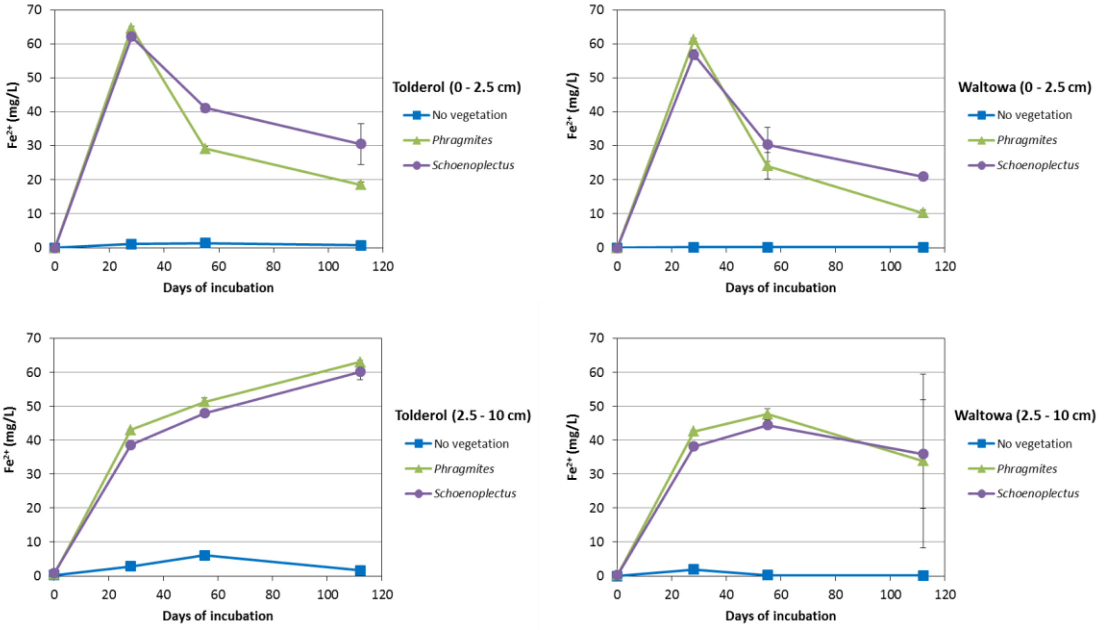

Figure 4-13. Tolderol and Waltowa surface water ferrous iron dynamics.

These results indicate that the addition of vegetation resulted in substantial iron reduction and dissolution of iron minerals (such as iron oxides and oxyhydroxides). The reduction and dissolution of iron minerals was more rapid with the surface (0-2.5 cm) sediments than the sub-surface (2.5-10 cm) sediments; iron may be in a more easily reducible form in the surface sediments. The Fe^{2+} concentration decrease with the surface (0-2.5 cm) sediments after 8 and 16 weeks of incubation initially indicates the formation of iron insoluble minerals and/or adsorption. However, analysis of the sediment after 16 weeks of incubation indicates the decrease in Fe^{2+} is not the result of iron sulfide formation (see Section 4.2.2.1). Sediment iron fractionation data indicate that the decrease in the iron concentration associated with the surface (0-2.5 cm) sediments is the result of iron moving to both 'soluble and exchangeable' and 'organically bound' pools (see Section 4.2.2.5.2).

The pH and redox potential for the mesocosm study have been plotted on an iron pE/pH diagram (Figure 4-14); note the stability fields have been estimated for the experimental conditions. The pH/Eh conditions measured in the surface water indicates that the precipitation of siderite ($FeCO_3$) is an unlikely explanation for the reduction in Fe^{2+} (Figure 4-14). As mentioned previously, the sorption of Fe^{2+} to mineral and organic matter surfaces is the explanation for the reduction in Fe^{2+} observed. A reduction in Fe^{2+} was not observed with the Tolderol sub-surface soil (2.5-10 cm) as the pH was less than 5.5 throughout the incubation; the sorption of Fe^{2+} is greater at pH values > 6.

A comparison of the total iron and ferrous iron concentrations showed that all the iron in solution is in the ferrous iron form (see Figures 8-16 and 8-17, Appendix 7). Further details on the iron fractionation for the four sediments during incubation are presented in Section 4.2.2.4.2.

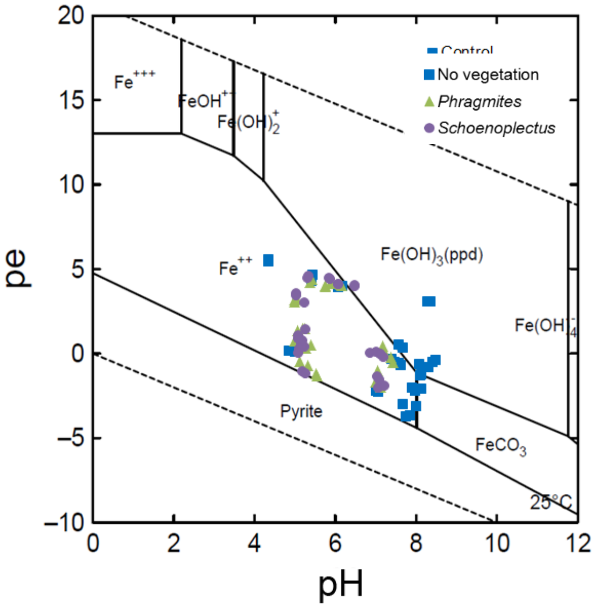

Figure 4-14. Iron pE/pH diagram for mesocosm surface waters.

4.2.1.9.2 Manganese (Mn)

The change in surface water manganese concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-15. The surface water manganese concentration showed a similar behaviour to the Fe^{2+} concentration, and tended to increase as the ferrous iron concentration increased (Figure 4-16). The reduction of manganese oxides (e.g. MnO_2) to Mn^{2+} would explain the initial increase in the surface water manganese concentration observed. The decrease in surface water manganese concentration often observed in the vegetation treated sediments after 4 weeks of incubation may be a result of the precipitation and/or adsorption.

The manganese concentration in the surface water only exceeded the ANZECC freshwater water quality guideline on Week 4 in the vegetation treated surface sediment (0-2.5 cm) at Waltowa.

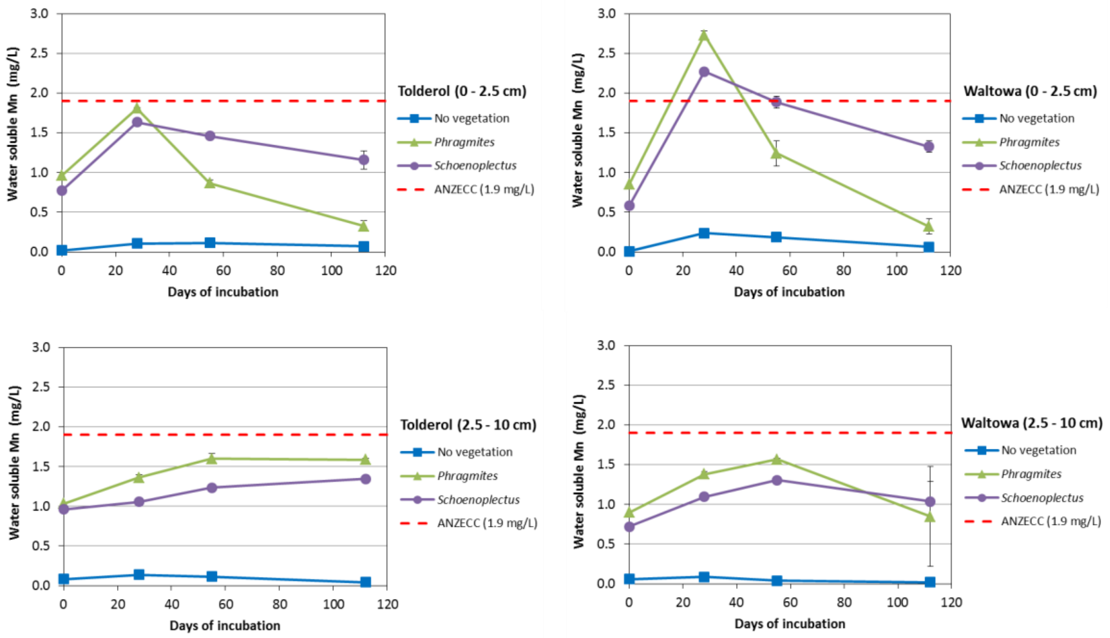

Figure 4-15. Tolderol and Waltowa surface water manganese dynamics.

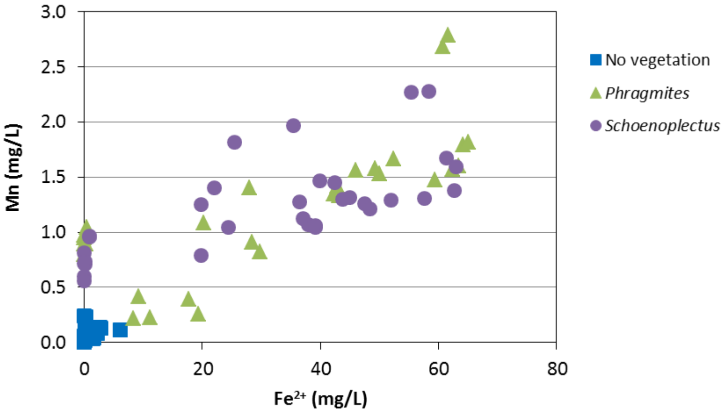

Figure 4-16. Comparison of the surface water Fe^{2+} and manganese concentrations for the mesocosm experiment.

4.2.1.9.3 Aluminium (Al)

The change in surface water aluminium concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-17. The surface water aluminium concentration tended to increase during the incubation with the non-treated sediments. The addition of vegetation to the Tolderol sub-surface sediment (2.5-10 cm) resulted in a substantial increase in the surface water aluminium concentration (Figure 4-18). This effect was not observed with the other three sediments examined in this study. The addition of *Phragmites* and *Schoenoplectus* to each sediment resulted in similar behaviour in the aluminium concentration.

The ANZECC water quality guideline of 0.055 mg/L for aluminium only applies when the pH > 6.5 and is often exceeded after 8 and 16 weeks of incubation (Figure 4-18). Aluminium has a low solubility at pH values of greater than 5.5, therefore the elevated aluminium concentrations at a near neutral pH values can be attributed to a fine particle fraction that passes through the 0.45 μm filter and/or the presence of soluble aluminium complexes (e.g. Ward *et al.* 2011).

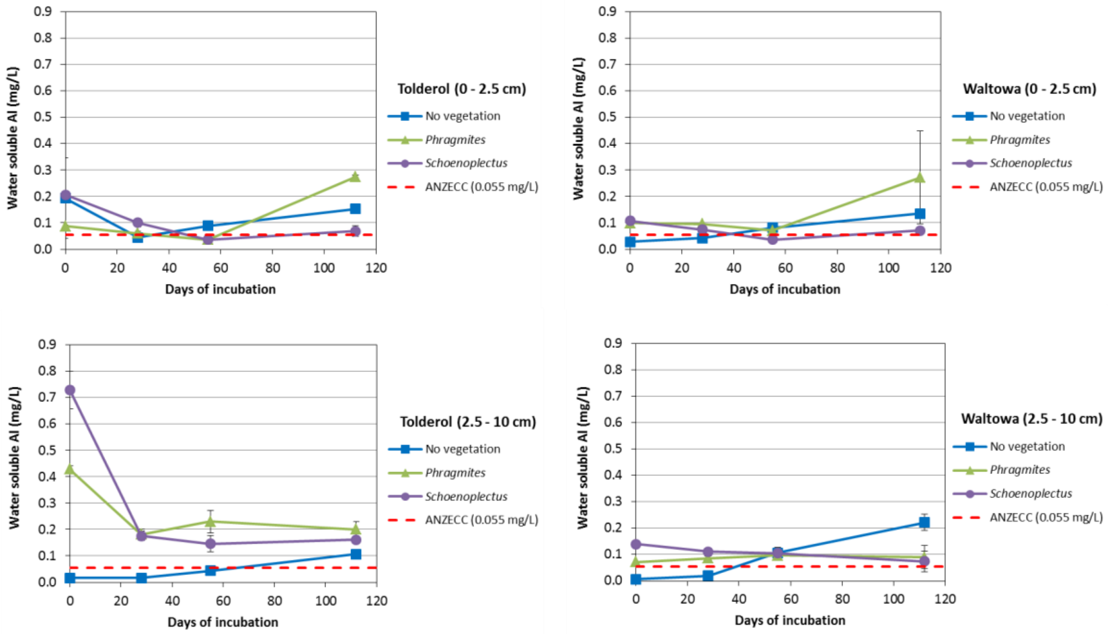

Figure 4-17. Toldérol and Waltowa surface water aluminium dynamics.

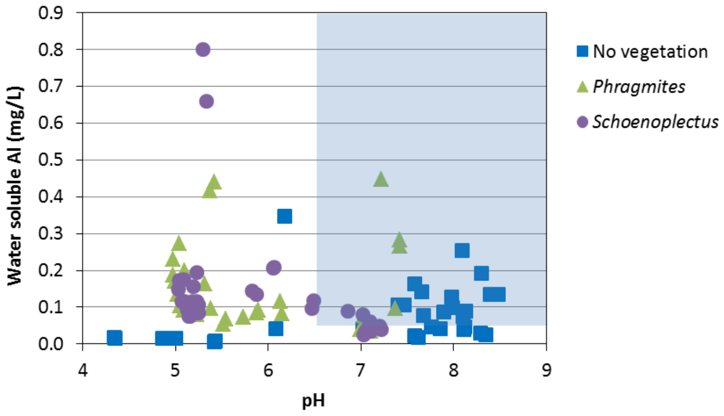

Figure 4-18. Comparison of the surface water pH and aluminium concentrations for the mesocosm experiment. Shaded area indicates surface water exceeding the ANZECC water quality guideline.

4.2.1.9.4 Arsenic (As)

The change in surface water arsenic concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-19. The surface water arsenic concentration for all sediments and treatments showed an increase after 16 weeks of incubation, however, the kinetics of arsenic release into the surface water varied between the sites, sediment depths and whether organic matter was added.

The surface water arsenic concentration with the untreated sediments was higher than the vegetated treated sediments after 16 weeks, except with the Waltowa surface layer (0-2.5 cm). A maximum arsenic concentration was largely observed after 4/8 weeks with the untreated sediments, except for the Tolderol surface layer (0-2.5 cm) which steadily increased over the 16 weeks. The addition of vegetation clearly supressed the release of arsenic in the sub-surface sediment layers (2.5-10 cm) at both sites; this is most likely due to the low pH associated with these sediments (see Figure 4-5). The addition of vegetation to the surface soils (0-2.5 cm) at the two sites a showed different response when compared to the control; the reason for this difference is not clear. However, the sediments treated with either *Phragmites* or *Schoenoplectus* showed a similar behaviour.

The surface water arsenic concentration was below the ANZECC water quality guideline at the start of the mesocosm experiment and was exceeded after 4/8 weeks with all sediments, except for the sub-surface layers (2.5-10 cm) at both sites treated with organic matter which released arsenic at a slower rate.

The adsorption of arsenic to the sediment is both redox sensitive and pH dependent. The increase in the surface water arsenic concentration as the Eh decreases and pH increases is clearly illustrated in Figures 4-20 and 4-21, respectively. The increase in the surface water arsenic concentration with the Tolderol control surface soil (0-2.5 cm) after week 4 despite minimal change in pH and no further decrease in Eh clearly indicates there are also other controls on arsenic release.

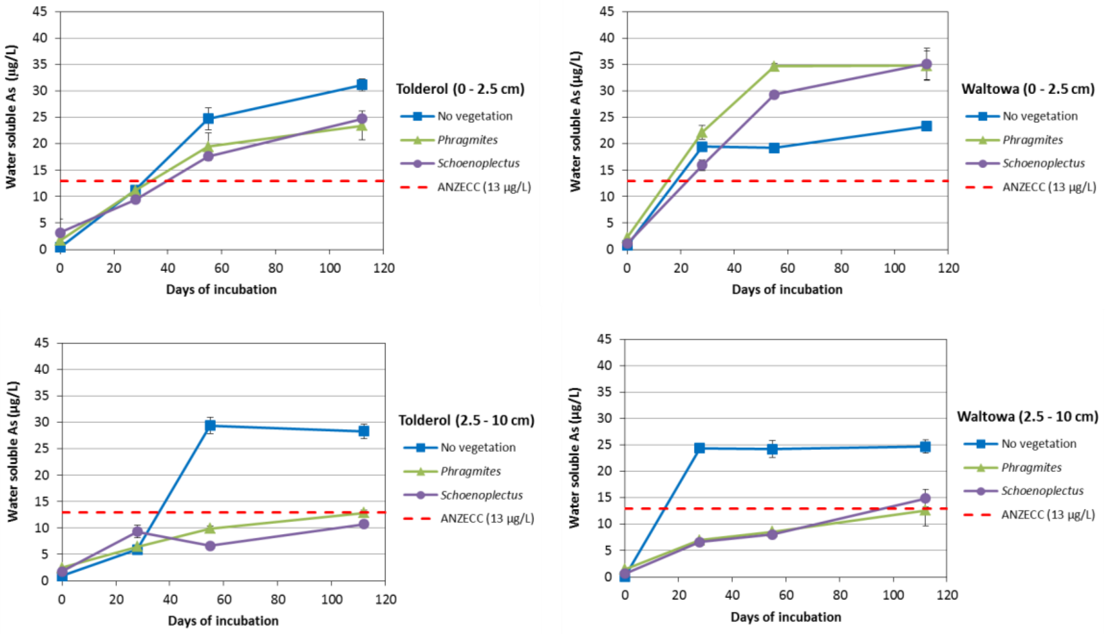

Figure 4-19. Tolderol and Waltowa surface water arsenic dynamics.

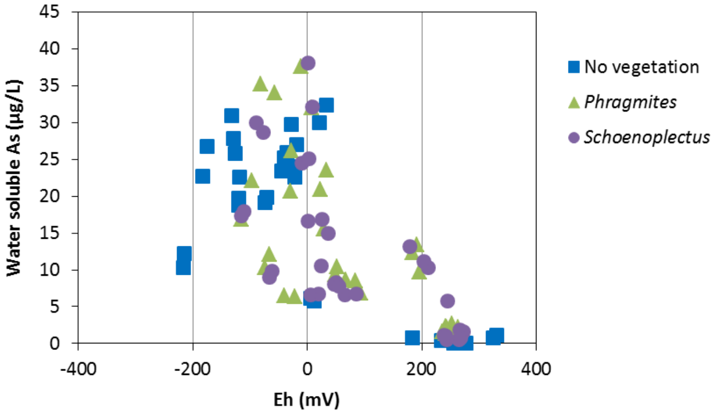

Figure 4-20. Comparison of the surface water Eh and arsenic concentrations for the mesocosm experiment.

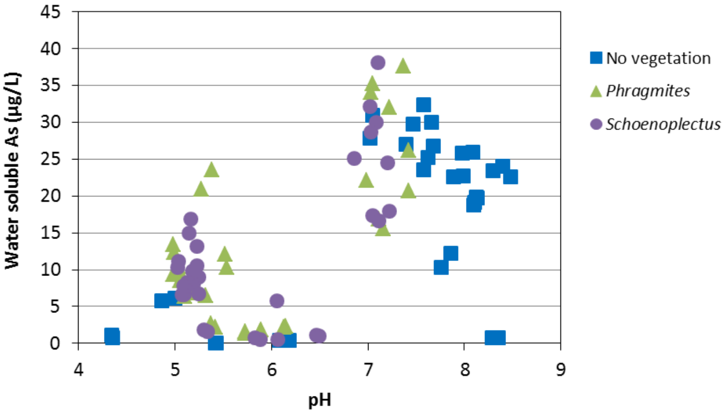

Figure 4-21. Comparison of the surface water pH and arsenic concentrations for the mesocosm experiment.

4.2.1.9.5 Cadmium (Cd)

The change in surface water cadmium concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-22. Low surface water cadmium concentrations were observed with all sediments and treatments (≤ 0.1 µg/L). The surface water cadmium concentration did not exceed the ANZECC water quality guideline, although the concentration had often increased by Week 16.

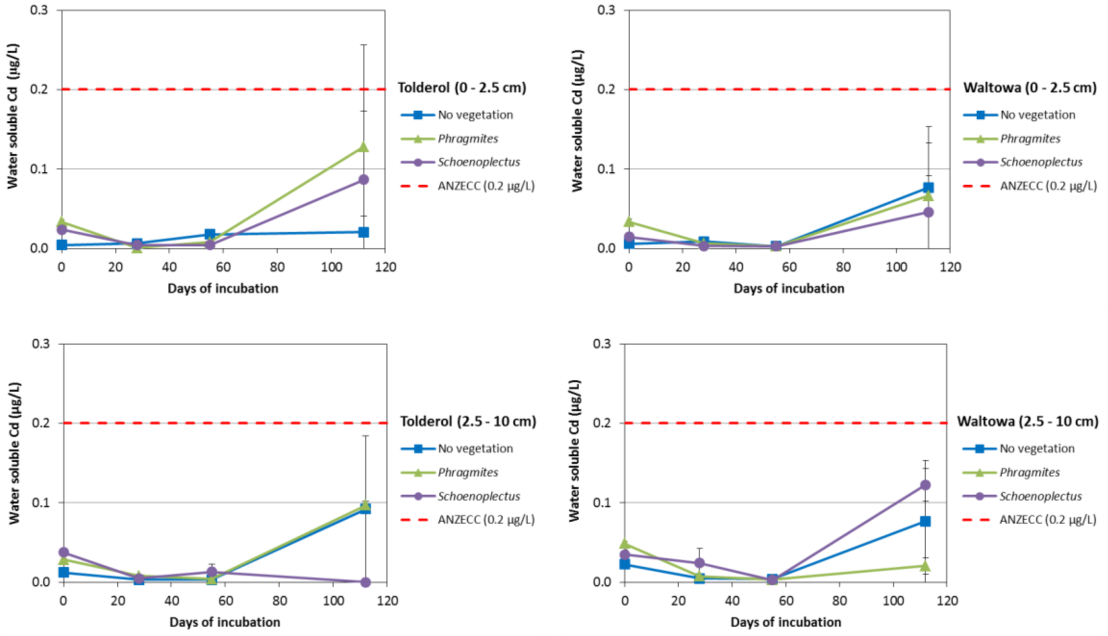

Figure 4-22. Tolderol and Waltowa surface water cadmium dynamics.

4.2.1.9.6 Cobalt (Co)

The change in surface water cobalt concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-23. Minimal changes in the surface water cobalt concentrations were observed with the surface sediments (0-2.5 cm) without the addition of vegetation, and concentrations were below the ANZECC water quality guideline. The surface water cobalt concentrations in sub-surface sediments (2.5-10 cm) without the addition of vegetation tended to decrease over the 16 weeks of incubation.

The addition of vegetation to all sediments resulted in a substantial increase in the cobalt concentration, particularly during the first 4 weeks of incubation. The increase in the surface water cobalt concentration was greater when *Phragmites* had been added when compared to *Schoenoplectus* treated samples. Higher cobalt concentrations were also observed when vegetation had been added to the Waltowa sediments when compared to the Tolderol sediments.

Whilst the ANZECC water quality guidelines for cobalt were only exceeded for up to 4 weeks with the sub-surface sediments (2.5-10 cm) without the addition of vegetation, the addition of vegetation resulted in the guideline being exceeded with all sediments. The addition of vegetation to the Waltowa sediments resulted in a greater exceedance than the Tolderol sediments, and also resulted in the ANZECC guideline being exceeded by more than 10 times.

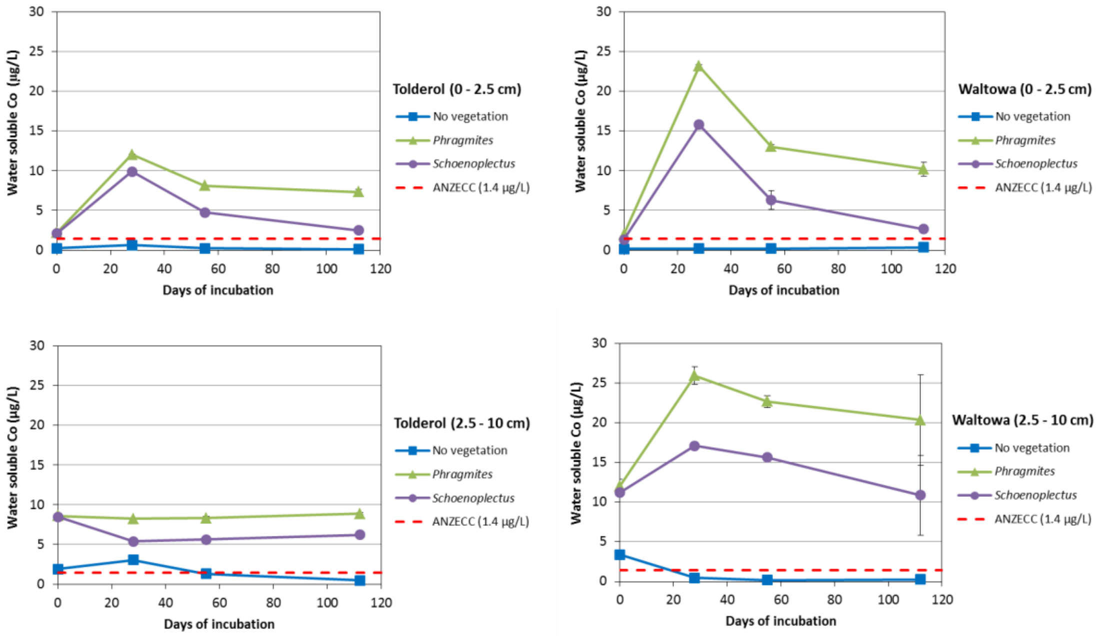

Figure 4-23. Tolderol and Waltowa surface water cobalt dynamics.

Cobalt is often strongly associated with iron and manganese oxides/oxyhydroxides. The behaviour of cobalt with the vegetated treated sediments often shows a similar trend to that observed with iron and manganese (see Figures 4-13 and 4-15). Figure 4-24 also shows the relationship between the cobalt surface water concentration and the iron and manganese concentrations. The lack of a strong correlation between the cobalt concentrations and the manganese/iron concentrations indicates that other factors (such as pH – see Section 4.5.2 for further details) also play an important role.

The lower surface water cobalt concentration with the vegetated treated Tolderol sediments than the Waltowa sediments may reflect the greater sorption capacity of the Tolderol sediments. Particle size analysis data (see Figure 8-5, Appendix 6) and x-ray diffraction (see Section 4.2.2.4.1) have indicated there is more clay and silt (< 63 µm) in the Tolderol sediment which would may have a greater capacity to sorb metals. Alternatively, cobalt maybe associated with more crystalline minerals with the Tolderol sediments and is therefore less likely to be readily released into solution.

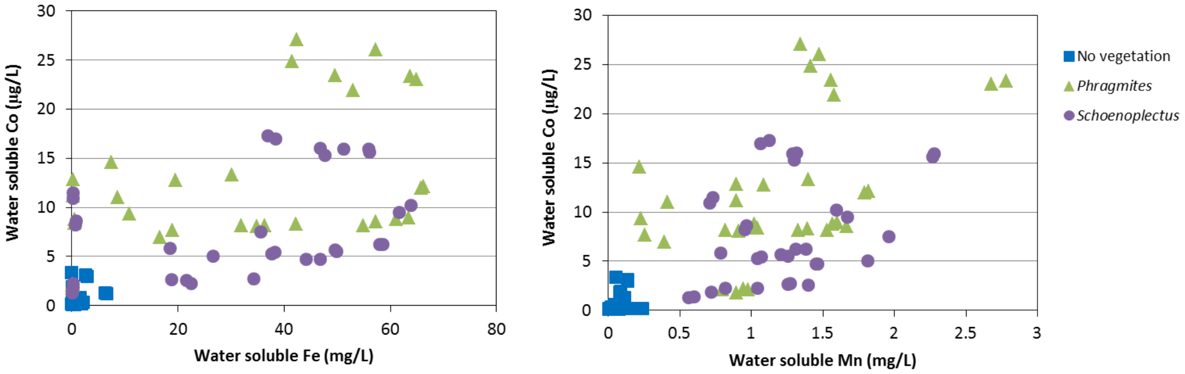

Figure 4-24. Comparison of the surface water cobalt concentrations with the iron and manganese concentrations for the mesocosm experiment.

4.2.1.9.7 Copper (Cu)

The change in surface water copper concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-25. Elevated surface water copper concentrations were observed with all sediments at the start of the mesocosm experiment (Day 0) where vegetation had been added. However, the surface water copper concentration rapidly decreased probably due to adsorption by organic matter.

Whilst the surface water copper concentration often exceeded the ANZECC water quality guideline at the start of the mesocosm experiment, the concentration was just above or below the guideline for the following 16 weeks.

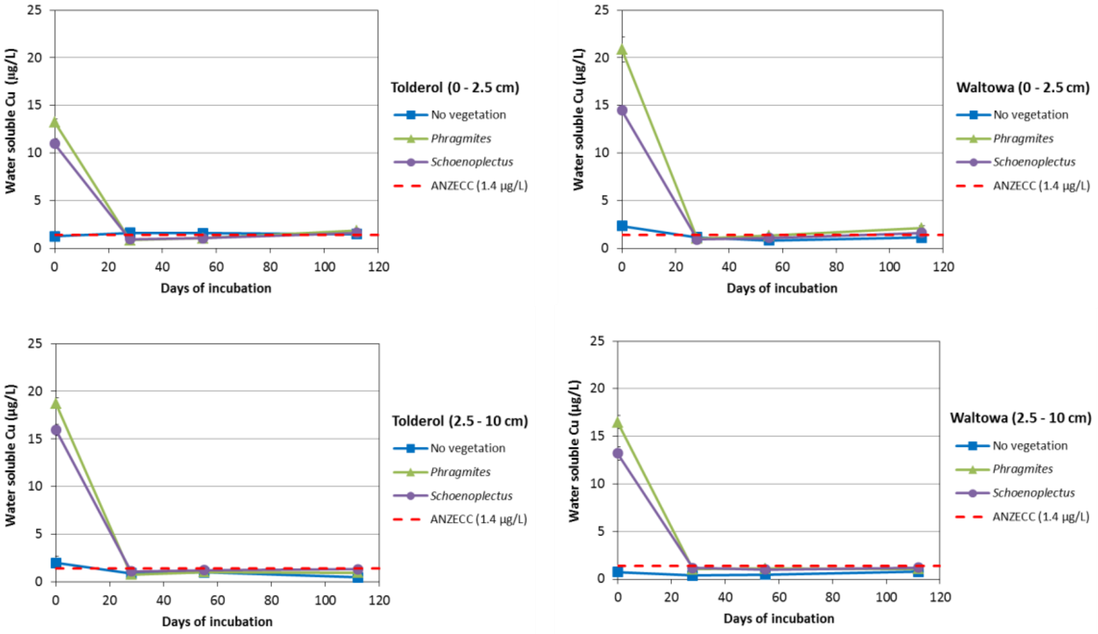

Figure 4-25. Tolderol and Waltowa surface water copper dynamics.

4.2.1.9.8 Chromium (Cr)

The change in surface water chromium concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-26. Low concentrations and minimal changes in the surface water chromium concentrations were observed with sediments without the addition of vegetation, except with the Waltowa sub-surface (2.5-10 cm) sediment for week 4. Higher surface water chromium concentrations were often observed with sub-surface (2.5-10 cm) sediments treated with vegetation.

The surface water chromium concentration occasionally exceeded the ANZECC water quality guideline, but was particularly evident with the sub-surface (2.5-10 cm) sediments treated with vegetation.

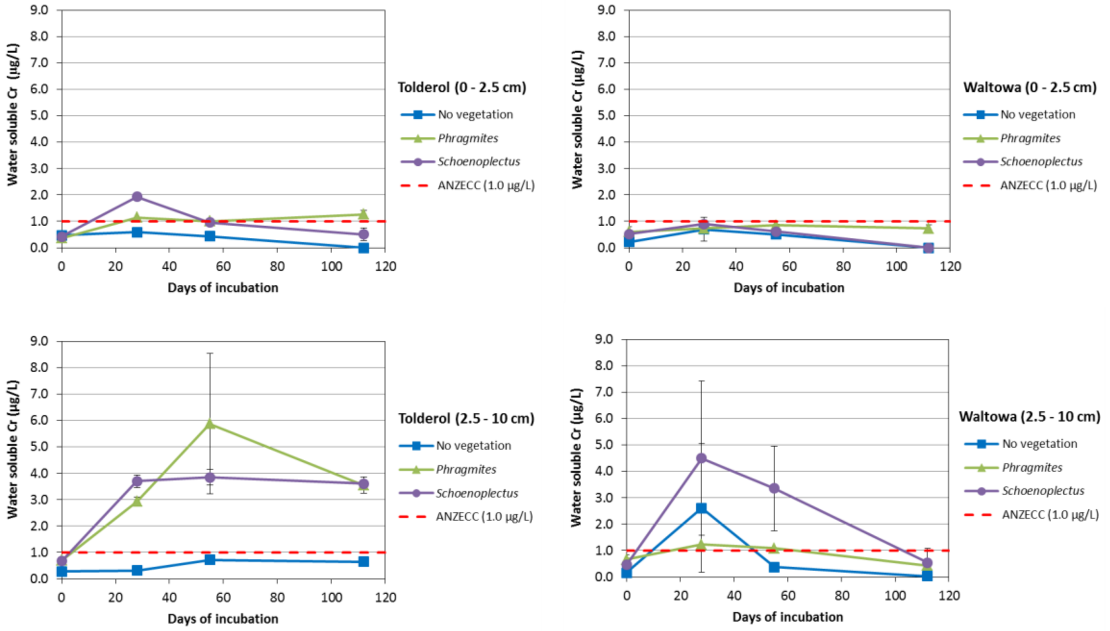

Figure 4-26. Tolderol and Waltowa surface water copper dynamics.

4.2.1.9.9 Lead (Pb)

The change in surface water lead concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-27. The surface water lead concentration for the sediments without the addition of vegetation were all low, except for the Tolderol surface sediment (0-2.5 cm). The addition of vegetation resulted in a slight increase in the lead concentration at the start of the incubation experiment with the Tolderol sediments, however, the concentration rapidly decreased within the initial 4 weeks.

The surface water lead concentration was only observed to exceed the ANZECC water quality guideline with the Tolderol surface sediment (0-2.5 cm).

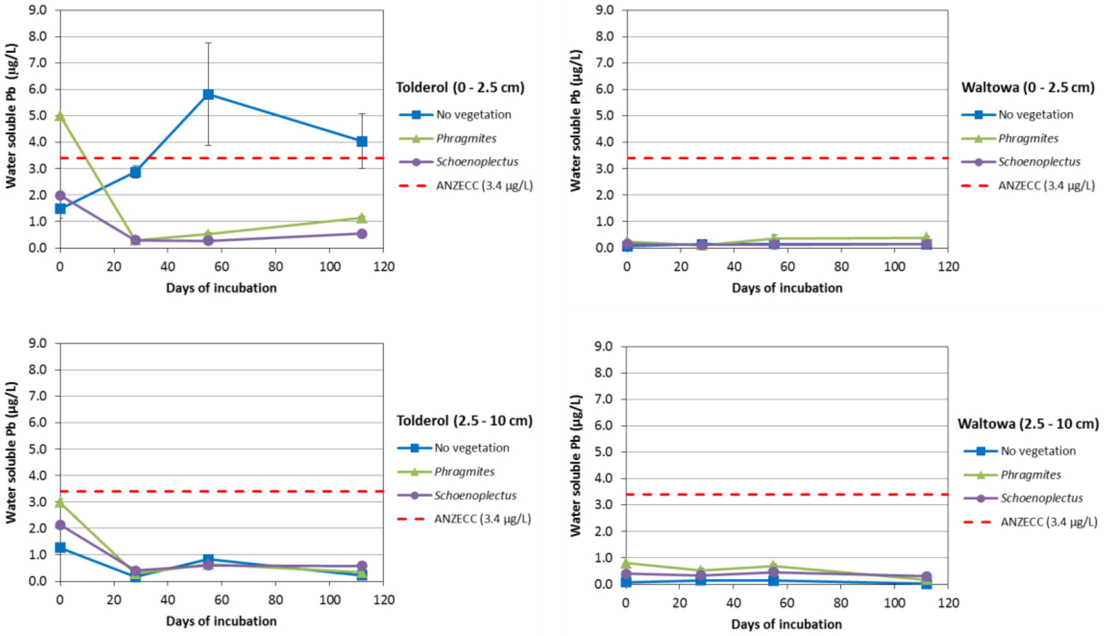

Figure 4-27. Tolderol and Waltowa surface water lead dynamics.

4.2.1.9.10 Nickel (Ni)

The change in surface water nickel concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-28. Minimal changes in the surface water nickel concentrations were observed with all sediments without the addition of vegetation, and concentrations were below the ANZECC water quality guideline. However, the addition of vegetation to all sediments resulted in an increase in the nickel concentration, particularly during the first 4 weeks of incubation. The increase in the surface water nickel concentration was greater when *Phragmites* had been added when compared to *Schoenoplectus* treated samples. Higher nickel concentrations were also observed when vegetation had been added to the Waltowa sediments when compared to the Tolderol sediments.

Whilst the ANZECC water quality guidelines for nickel were not exceeded with the sediments without the addition of vegetation, the addition of vegetation resulted in the guideline being exceeded with all sediments. This would suggest that some of the nickel originates from the vegetation. The addition of vegetation to the Waltowa sediments resulted in a greater exceedance than the Tolderol sediments. The addition of *Phragmites* to the Waltowa sediments often resulted in the ANZECC guideline being exceeded by more than 10 times.

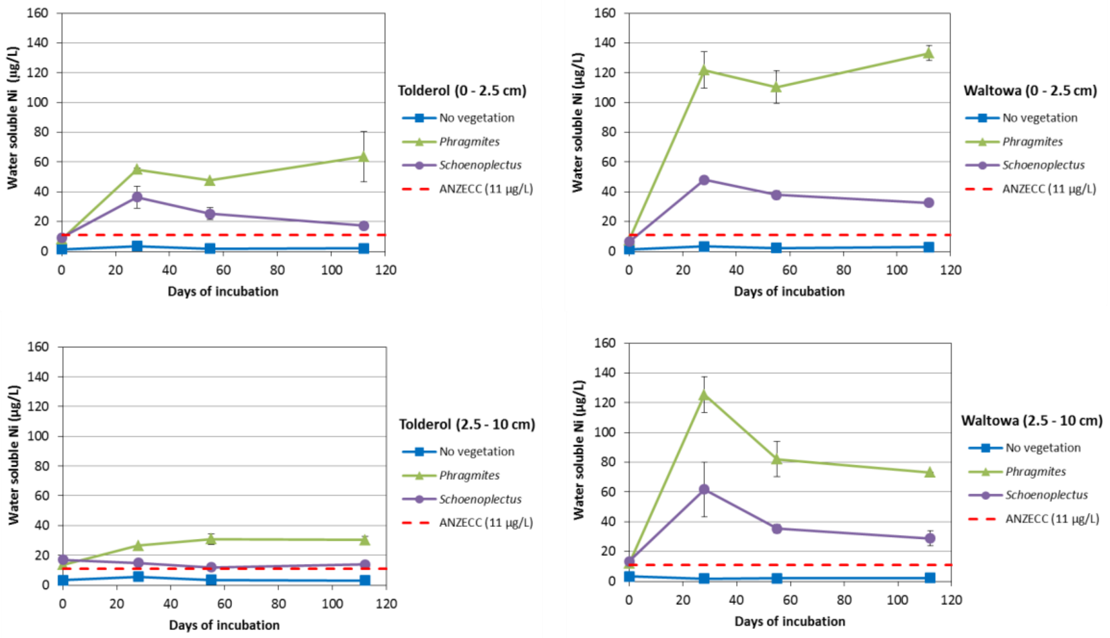

Figure 4-28. Tolderol and Waltowa surface water nickel dynamics.

The behaviour of nickel during incubation with the sediments where vegetation had been added was similar to that observed with cobalt (see Figures 4-23 and 4-29). As with cobalt, nickel is also often strongly associated with iron and manganese oxides/oxyhydroxides. However, whilst the lower surface water nickel concentration with the vegetated treated Tolderol sediments may largely reflect the greater sorption capacity of the Tolderol sediments, the previous study by Sullivan *et al.* (2013) also observed slightly higher HCl extractable nickel contents in the Waltowa sub-surface sediments (see Table 8-37, Appendix 6).

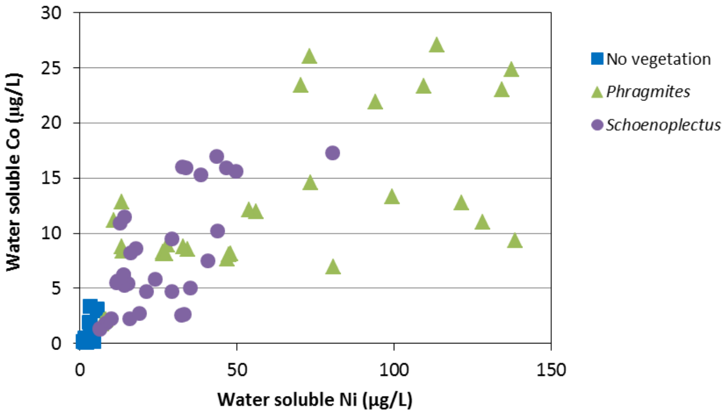

Figure 4-29. Comparison of the surface water nickel and cobalt concentrations for the mesocosm experiment.

4.2.1.9.11 Selenium (Se)

The change in surface water selenium concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-30. Low surface water selenium concentrations (≤ 1.0 µg/L) were observed with all sediments, although slightly higher concentrations were associated with the sediments treated with vegetation. All surface water selenium concentrations were substantially below the ANZECC water quality guideline value of 11 µg/L.

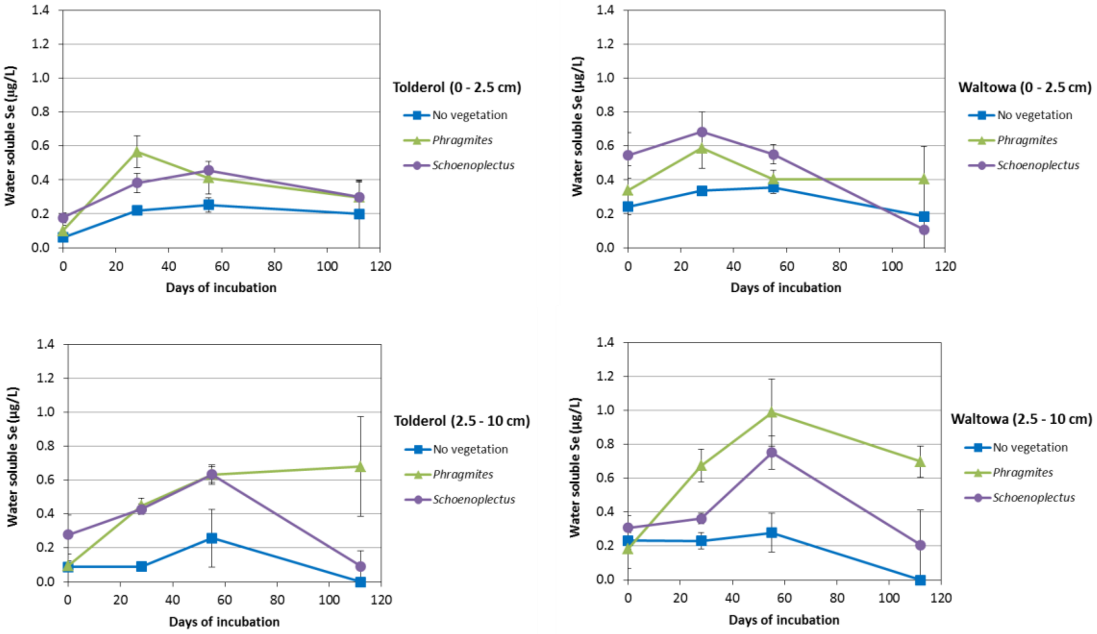

Figure 4-30. Tolderol and Waltowa surface water selenium dynamics.

4.2.1.9.12 Silver (Ag)

The change in surface water silver concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-31. Low surface water silver concentrations (< 0.2 µg/L) were observed with all sediments. The low ANZECC water quality guideline value of 0.05 µg/L was occasionally exceeded in the surface water associated with the sediments from both sites.

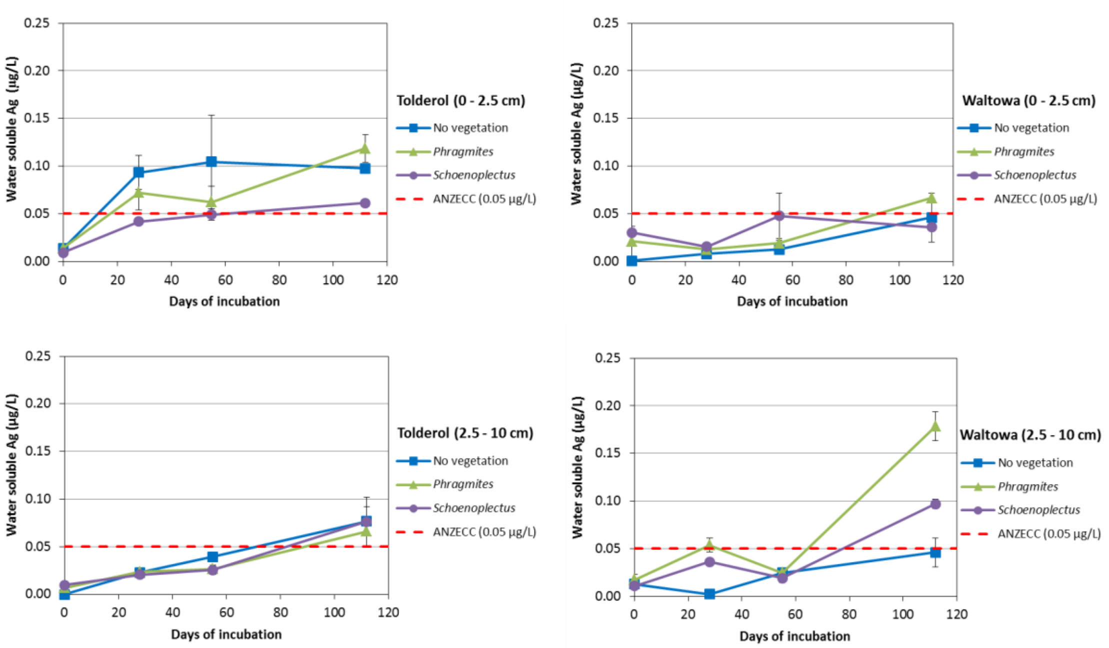

Figure 4-31. Tolderol and Waltowa surface water silver dynamics.

4.2.1.9.13 Zinc (Zn)

The change in surface water zinc concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-32. An initial increase in the surface water zinc concentration follow by a decrease was observed with all sediments without the addition of vegetation. The addition of vegetation resulted in a substantial increase in the surface water zinc concentration from Day 0 indicating the vegetation is the source of the high zinc concentration rather than the sediments.

The *Phragmites* treatment initially had a much higher surface water zinc concentration than the *Schoenoplectus* treatment. The determination of the zinc content of the two plant materials showed they had the same total zinc content (18 mg/kg) (Tables 8-35 and 8-36 , Appendix 5), indicating the zinc associated with the *Phragmites* is in a more soluble form. It is interesting to note that the surface water zinc concentrations were similar from and after 4 weeks of incubation, suggesting the same processes were controlling the water soluble zinc concentrations with both vegetation treatments.

The ANZECC water quality guideline value of 8.0 µg/L was exceeded (often by more than 10 times) in the surface water associated with all sediments and often by more than 10 times with the vegetation treatments. The only exception to this exceedance was on Day 0 with the non-vegetation treated Waltowa surface sediment (0-2.5 cm).

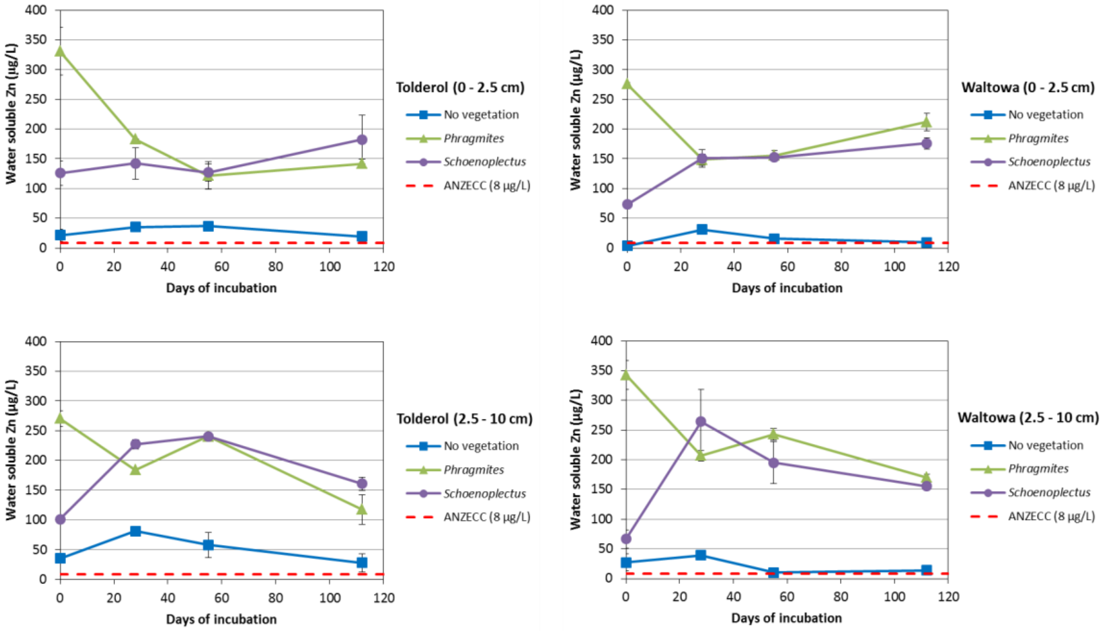

Figure 4-32. Tolderol and Waltowa surface water zinc dynamics.

4.2.1.9.14 Summary of Metal(loid) Trends

A summary table was created to gain an understanding of the high level trends/relationships with the surface water metal(loid) concentrations observed in the mesocosm experiment (see Table 4-2). Table 4-2 compares the rank of the maximum concentration (where 1 represents the highest concentration and 3 represents the lowest concentration) for each treatment (i.e. No vegetation, *Phragmites*, *Schoenoplectus*) within a sediment depth (i.e. 0-2.5 cm and 2.5-10 cm) for the two sites during the 16 week incubation period. For example, the *Phragmites* treatment which had the highest zinc concentration with the Tolderol surface (0-2.5 cm) sediment (see Figure 4-32) is ranked 1, and the no vegetation treatment at this site and depth had the lowest maximum concentration is ranked 3.

Table 4-2. Summary of the rank of the maximum metal(loid) concentrations.

Depth (cm)	Treatment	Site	Metal(loid)												
			Fe	Mn	Al	As	Cd	Co	Cu	Cr	Pb	Ni	Se	Ag	Zn
0-2.5	No vegetation	Tolderol	3	3	**2**	**1**	3	3	**3**	3	**1**	3	3	**1**	**3**
		Waltowa	3	3	**2**	**3**	1	3	**3**	1	1	3	3	**1**	**3**
	Phragmites	Tolderol	1	1	**1**	**2**	1	**1**	**1**	**2**	**2**	**1**	1	**3**	**1**
		Waltowa	1	**1**	**1**	**1**	1	**1**	**1**	1	1	**1**	2	**1**	**1**
	Schoenoplectus	Tolderol	1	2	**2**	**2**	2	**2**	**2**	**1**	3	**2**	2	**1**	**2**
		Waltowa	1	**2**	**2**	**1**	3	**2**	**2**	1	1	**2**	1	**1**	**2**
2.5-10	No vegetation	Tolderol	3	3	**3**	**1**	1	**3**	**3**	3	3	3	3	**1**	**3**
		Waltowa	3	3	**1**	**1**	2	**3**	3	**2**	1	3	3	**3**	**3**
	Phragmites	Tolderol	1	1	**2**	2	1	**1**	**1**	1	1	**1**	1	**1**	**1**
		Waltowa	1	1	**3**	2	3	**1**	**1**	**3**	1	**1**	1	**1**	**1**
	Schoenoplectus	Tolderol	1	2	**1**	2	3	**1**	**2**	2	2	**2**	1	**1**	**2**
		Waltowa	1	2	**2**	**2**	1	**2**	**2**	**1**	1	**2**	2	**2**	**2**

Bold red values *indicate that the concentration exceeded ANZECC Guideline Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems (ANZECC/ARMCANZ 2000).*

Highest Concentration	1	2	3	Lowest Concentration

The addition of vegetation (*Phragmites* and *Schoenoplectus*) to both the Waltowa and Tolderol sediments often resulted in an increase in the mobilisation of metal(loid)s (Table 4-2). Many of the metal(loid)s examined were at the lowest concentration in the surface waters associated with the sediments without the addition of vegetation; this was observed with both surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. However, some of the metal(loid)s were also found at their highest concentrations in these surface waters, particularly arsenic (As), lead (Pb) and silver (Ag). The surface water concentration of many of the metal(loid)s tended to be greater with the *Phragmites* treated sediments when compared to *Schoenoplectus* treated sediments (Table 4-2); this trend was often observed with sediments from both sites and sediment depths.

Under the experimental conditions, the ANZECC water quality guidelines for the metal(loid)s were often exceeded (Table 4-2). The number of metal(loid)s that exceeded the guidelines tended to be greater with the vegetation treated sediments, and a few more metal(loid)s exceeded the guidelines with the surface (0-2.5 cm) sediments treated with vegetation when compared to the sub-surface (2.5-10 cm) sediments treated with vegetation. The surface water guidelines for manganese (Mn) and nickel (Ni) were only exceeded when vegetation was added to the sediments. The guidelines for cadmium (Cd) and selenium (Se) were not exceeded with any of the sediments or treatments during the 16 week mesocosm experiment.

A summary of the surface water metal(loid) trends is provided in the following 'Summary of Section'.

Summary of Section

The addition of vegetation (*Phragmites* and *Schoenoplectus*) to the Waltowa and Tolderol sediments often resulted in an increase in the mobilisation of metal(loid)s.

The addition of vegetation to all sediments resulted in a substantial increase in the surface water iron (Fe) and manganese (Mn) concentrations compared to the sediments without vegetation (Figures 4-13 and 4-15). This finding would indicate that the addition of vegetation rapidly enhanced the reduction of iron and manganese oxides/oxyhydroxides present in these sediments.

Whilst iron and manganese showed a similar behaviour with the addition of vegetation, the behaviour of the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments differed (Figures 4-13 and 4-15). The concentration of these metals rapidly increased over the initial 4 weeks with the surface (0-2.5 cm) sediments and then decreased (probably due to precipitation and/or adsorption). On the other hand, the surface water iron and manganese concentrations associated with the sub-surface (2.5-10 cm) sediments increased for at least 8 and 16 weeks for the Waltowa and Tolderol sediments, respectively.

The addition of vegetation to the sediments resulted in an increase in the surface water cobalt (Co) and nickel (Ni) concentrations (Figures 4-23 and 4-28). These two metals showed a similar behaviour, and a similar behaviour to that observed with iron and manganese; cobalt and nickel are often strongly associated with iron and manganese oxides/oxyhydroxides. The lack of a strong correlation between these two metals and iron/manganese indicate other factors (such as pH) also play an important role. Higher cobalt and nickel concentrations were also observed when vegetation was added to the Waltowa sediments when compared to the Tolderol sediments; this may be due the greater sorption capacity of the Tolderol sediments (see Sections 4.2.1.9.6 and 4.2.1.9.10 for further details).

Elevated surface water copper (Cu) and zinc (Zn) concentrations were initially observed with all sediments treated with vegetation (Figures 4-25 and 4-32). The increase in the concentrations at the start of the experiment indicates the vegetation is the source of these metals. The copper concentration rapidly decreased within the initial 4 weeks, probably due to adsorption by organic matter. The addition of vegetation sometimes resulted in an increase in the surface water chromium (Cr) concentration, particularly with the sub-surface (2.5-10 cm) sediments (Figure 4-19).

The behaviour of arsenic (As) varied between the sites, sediment depths and whether vegetation was added (Figure 4-19). All sediments and treatments showed an increase in the arsenic concentration during the incubation period. As the adsorption of arsenic is both redox sensitive and pH dependent, the arsenic concentration was observed to increase as the Eh decreased and pH increased (Figures 4-20 and 4-21). Whilst the addition of vegetation did not have a consistent effect with the surface (0-2.5 cm) sediments, the addition of vegetation to the sub-surface (2.5-10 cm) sediment clearly supressed the release of arsenic; this is most likely due to the relatively low pH associated with these sediments (Figure 4-5).

The addition of *Phragmites* and *Schoenoplectus* to each of the sediments resulted in a similar behaviour with many of the metal(loid)s. Some metal concentrations (e.g. Co, Cu, Ni, Mn, Zn) were often found to be slightly higher in the surface water associated with the *Phragmites* treated sediments, despite the two vegetation types usually having similar total metal contents (Table 8-35 and 8-36, Appendix 5).

Under the experimental conditions, the ANZECC water quality guidelines for the metal(loid)s were often exceeded (see Table 4-2). With many of the metals (e.g. Co, Cu, Cr, Ni, Mn, Zn) the ANZECC water quality guidelines were exceeded to a greater extent when vegetation was added to the sediments. The surface water guidelines for manganese and nickel were only exceeded when vegetation was added to the sediments. The guidelines for cadmium (Cd) and selenium (Se) were not exceeded with any of the sediments or treatments during the 16 week mesocosm experiment.

4.2.1.10 Natural Organic Matter (NOM)

4.2.1.10.1 Dissolved Organic Carbon (DOC)

The change in surface water DOC concentration during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-33. The surface water DOC concentration clearly increases during the incubation with all the sediments without the addition of vegetation. The addition of vegetation substantially increased the surface water DOC concentration, and the *Phragmites* treatment often had a greater DOC concentration than the *Schoenoplectus* treatment. The vegetation treated surface sediments (0-2.5 cm) showed a decrease in the DOC concentration over the 16 week incubation period, whist the vegetation treated sub-surface sediments (2.5-10 cm) showed minimal change or an increase in the DOC concentration.

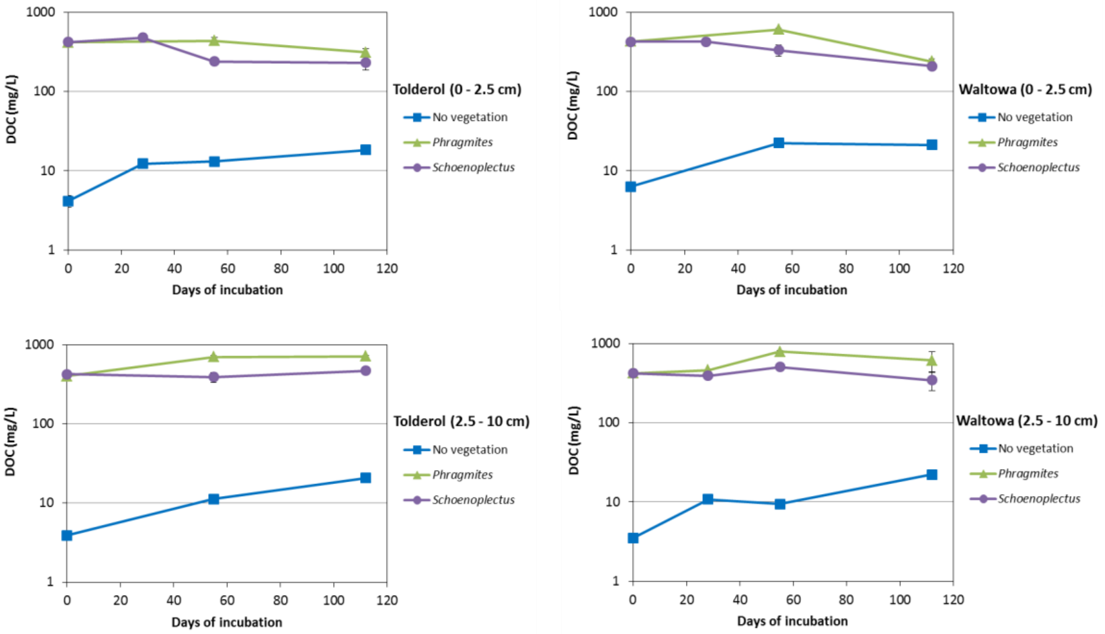

Figure 4-33. Tolderol and Waltowa surface water DOC dynamics.

4.2.1.10.2 Fluorescence Intensity

The change in surface water tryptophan-like peak (T_1) intensity during incubation with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-34. Fluorescence analysis of the tryptophan-like peak (T_1; excitation/emission wavelength region 275/340 nm) has previously been found to provide an accurate indication of the presence and relative proportions of bioavailable organic material present (Hudson *et al.* 2008). The surface water T_1 peak intensity clearly increases during the incubation with all the sediments without the addition of vegetation. The trend is similar to that observed with the DOC concentration (Figure 4-33). The addition of vegetation substantially increased the surface water T_1 peak intensity and indicates that more bioavailable organic material is associated with the *Phragmites* when compared to the *Schoenoplectus;* this was also often found with the DOC (Figure 4-33). No clear trend was observed in the T_1 peak intensity when vegetation was added.

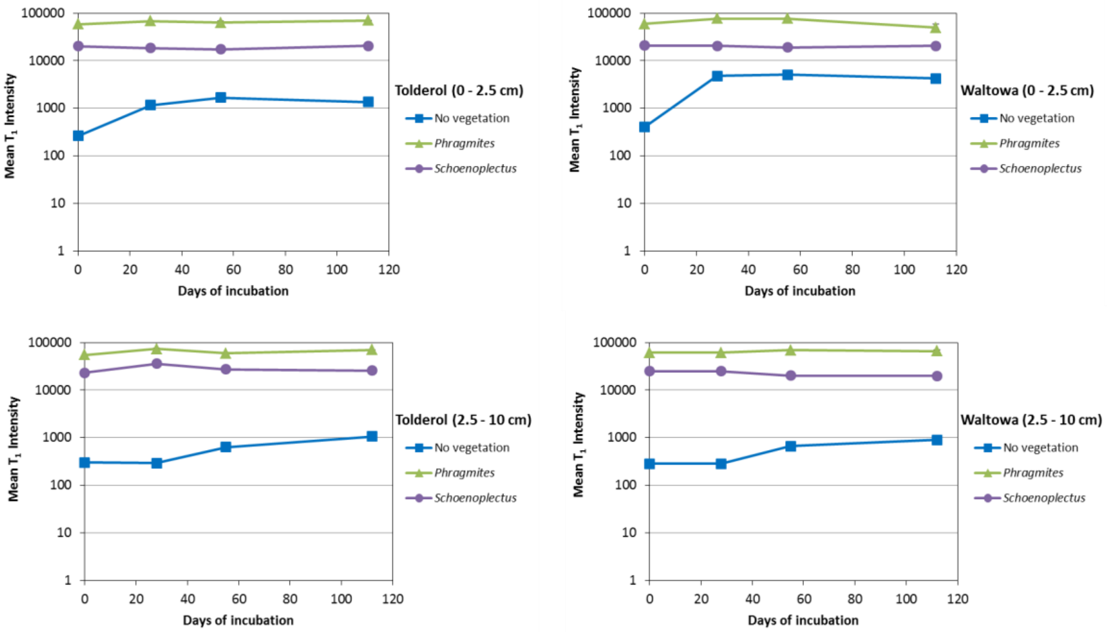

Figure 4-34. Tolderol and Waltowa surface water T_1 fluorescence intensity dynamics.

Figure 4-35 presents normalised plots of the T_1 peak intensity (normalised to the maximum peak value), and shows the change in the relative proportion bioavailable organic material over the 16 weeks of incubation. An increase in the relative proportion bioavailable organic material is often observed over initial 4 weeks, after which a decrease occurs. The only exceptions are the sub-surface sediments (2.5-10 cm) without the addition of vegetation which showed an increase over the initial 8 weeks. The rapid increase indicates that there is the breakdown of the easily decomposable organic materials over the initial 4 weeks after which the less decomposable organic materials remain.

A comparison of the T_1 peak intensity with the DOC concentrations is presented in Figure 4-36. The plot shows that the T_1 peak intensities for the two vegetation types each have a different relationship to the DOC concentration. The relationship indicates that a greater proportion of the DOC is bioavailable with the *Phragmites* when compared to the *Schoenoplectus.*

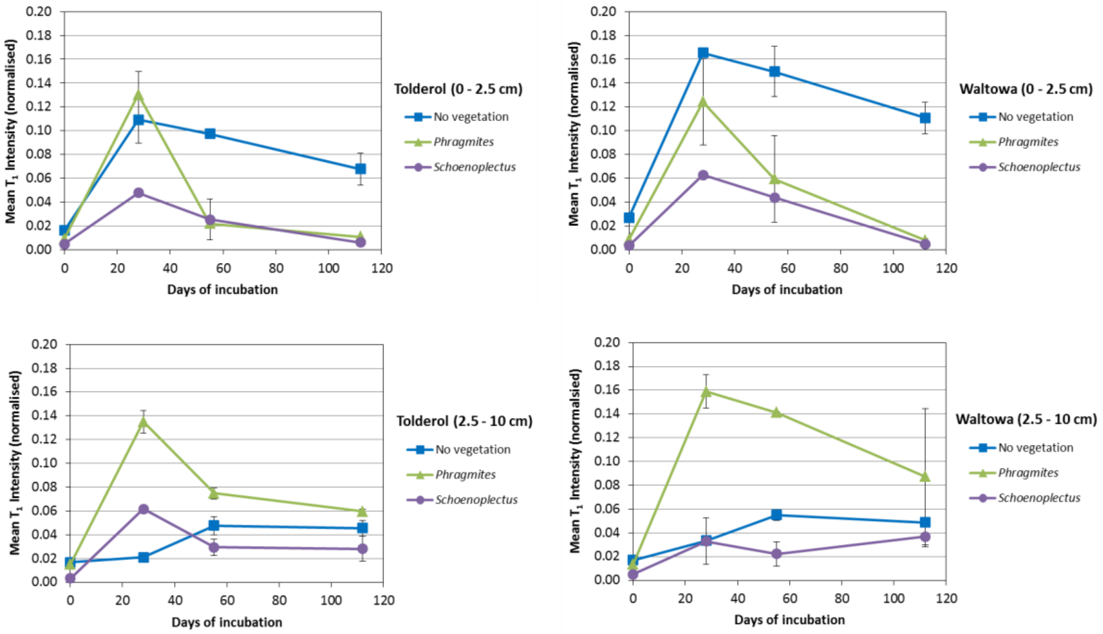

Figure 4-35. Tolderol and Waltowa surface water normalised T_1 fluorescence intensity dynamics.

A comparison of the T_1 peak intensity with the DOC concentrations is presented in Figure 4-36. The plot shows that the T_1 peak intensities for the two vegetation types each have a different relationship to the DOC concentration. The relationship indicates that a greater proportion of the DOC is bioavailable with the *Phragmites* when compared to the *Schoenoplectus*.

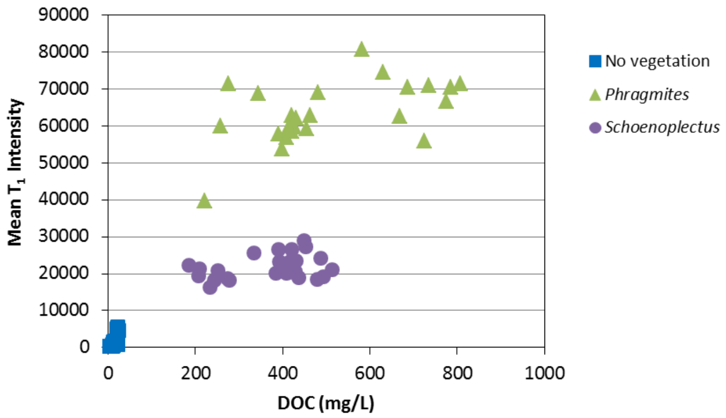

Figure 4-36. Comparison of the surface water DOC concentration and T_1 fluorescence intensity for the mesocosm experiment.

4.2.1.10.3 Optical Properties

The optical properties of the surface water NOM were assessed as a function of time using UV-visible spectrophotometry (Figure 4-37). UV-Visible spectroscopy is widely used as it is a simple and informative method for the description of the molecular properties of dissolved organic matter (e.g. Shirshova *et al.* 2006). Without the addition of vegetation, the UV-Vis spectra absorbance of the surface water increased with the incubation time. This increase implies that more water-soluble soil organic matter was liberated as the incubation progressed and is consistent with the DOC results (Figure 4-33).

With the initial addition of vegetation, the surface water UV-Vis spectra were broad, with a shoulder peak at around 350 nm, indicating parts of coloured dissolved organic matter (CDOM) in vegetation were present. The very intense absorption in the 200-250 nm regions indicates the presence of benzenoid. After 28 days of incubation, a new absorption band at 280 nm was observed, which represents the formation of total aromatic compounds (including phenolic arenes, aniline derivatives, benzoic acids, polyenes and polycyclic aromatic hydrocarbons with two or more rings). This specific absorbance λ_{280} can be used to characterise humification of the organic matter. The increase in λ_{280} with incubation time indicates that more labile structures (e.g. carbohydrates, amino acids, etc.) are destroyed, but thermodynamically more stable aromatic and polyaromatic structures emerge under the anaerobic experimental conditions.

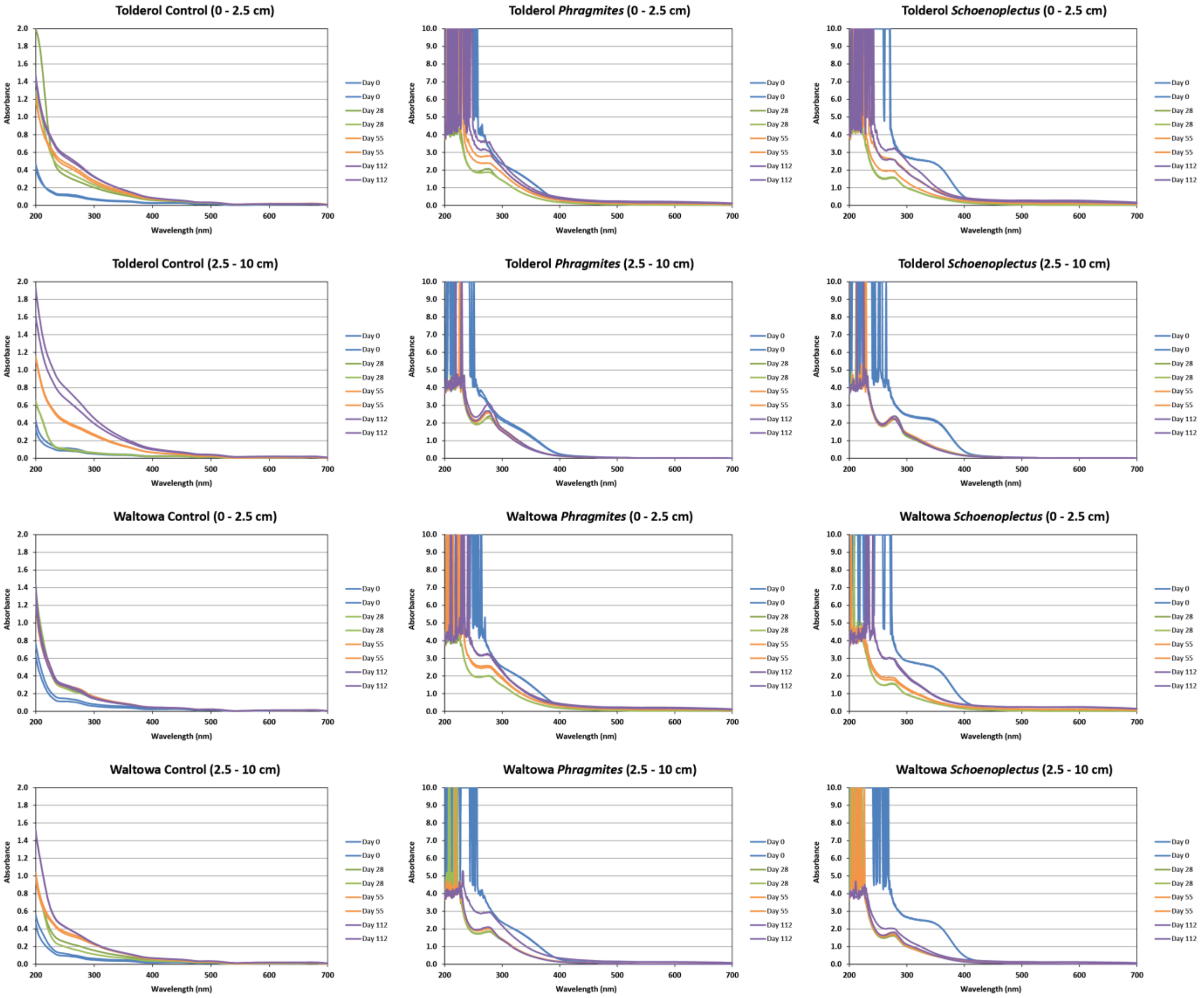

Figure 4-37. Tolderol and Waltowa surface water optical properties dynamics with and without the addition of vegetation.

4.2.1.10.4 Redox State Determination

The redox state properties of the surface water NOM were assessed as a function of time using Differential Pulse Voltammetry (DPV) (Figure 4-38). Differential Pulse Voltammetry was used to characterise the reducing dissolved organic matter in the complex system through peak intensity and potential. The lower redox potential represents a more reducing capacity. Without the addition of vegetation, no apparent current peak appeared. However, when the two vegetation types were initially added to the sediments (Day 0), a peak at 0.3 V was observed for the *Phragmites* treatment and two peaks were observed at 0.3 V and 0.6 V for the *Schoenoplectus* treatment. During the anaerobic decomposition of the vegetation and the water-soluble organic matter, the original peaks disappeared or were shifted and new peaks at 0.25 V and 0.75 V appeared. It is assumed that some refractory reducing dissolved organic matter and weakly reducing organic matter were produced during the humification processes. This finding aligns well with the results of UV-Vis spectroscopy (see Section 4.2.1.10.3).

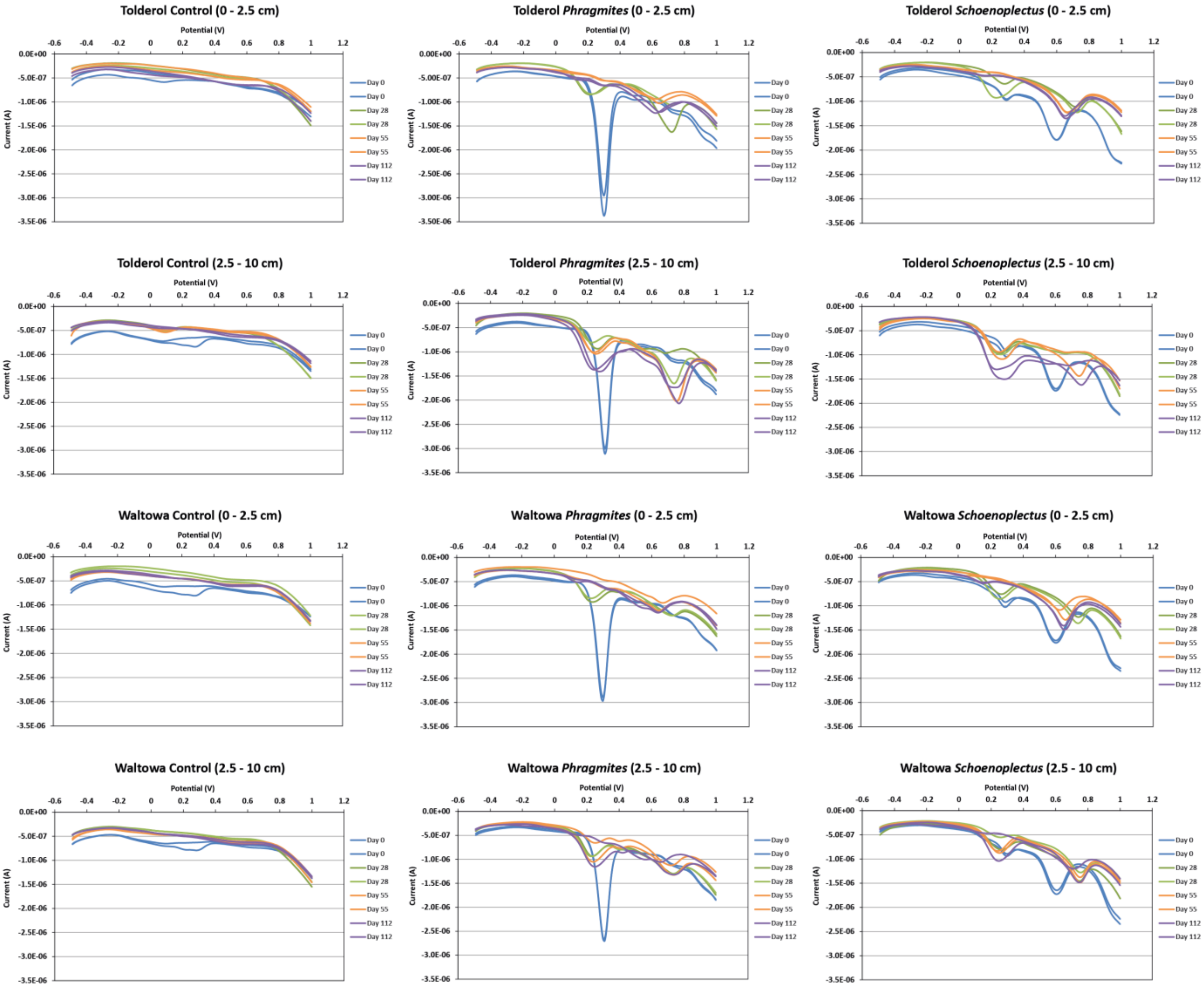

Figure 4-38. Tolderol and Waltowa surface water redox state dynamics with and without the addition of vegetation.

4.2.1.10.5 Low Molecular Weight (LMW) Organic Acids

The presence of five low molecular weight (LWM) organic acids was examined in the surface waters including acetic acid (CH_3COOH), formic acid ($HCOOH$), malonic acid ($CH_2(COOH)_2$), oxalic acid ($H_2C_2O_4$) and succinic acid ($C_4H_6O_4$). The presence of benzoic acid ($C_7H_6O_2$) was also assessed by HPLC. Chromatograms for the Tolderol surface (0-2.5 cm) sediment with the addition of *Phragmites* and *Schoenoplectus* are presented in Figures 4-39 and 4-40, respectively. The data clearly shows that there was a change in the nature of the dissolved organic compounds (including LMW organic acids) during the incubation experiment.

The chromatograms for Tolderol surface (0-2.5 cm) sediment with the addition of vegetation show that malonic acid was the only LWM organic acid identified at the start of the incubation experiment, particularly with the addition of *Phragmites* (Figures 4-39 and 4-40). After 4 weeks of incubation malonic acid was no longer present and formic acid was the only identified LMW acid. The numerous other peaks after 4 weeks of incubation indicate the formation of additional organic compounds (including an unknown phenolic and other aromatic compounds); this was also indicated by UV-Visible spectroscopy and DPV (see Sections 4.2.1.10.3 and 4.2.1.10.4). After 8 weeks of incubation formic acid was no longer identified with these treatments, and a greater concentration of the unidentified phenolic was present. Finally, after 16 weeks of incubation benzoic acid was identified in addition to the unidentified phenolic.

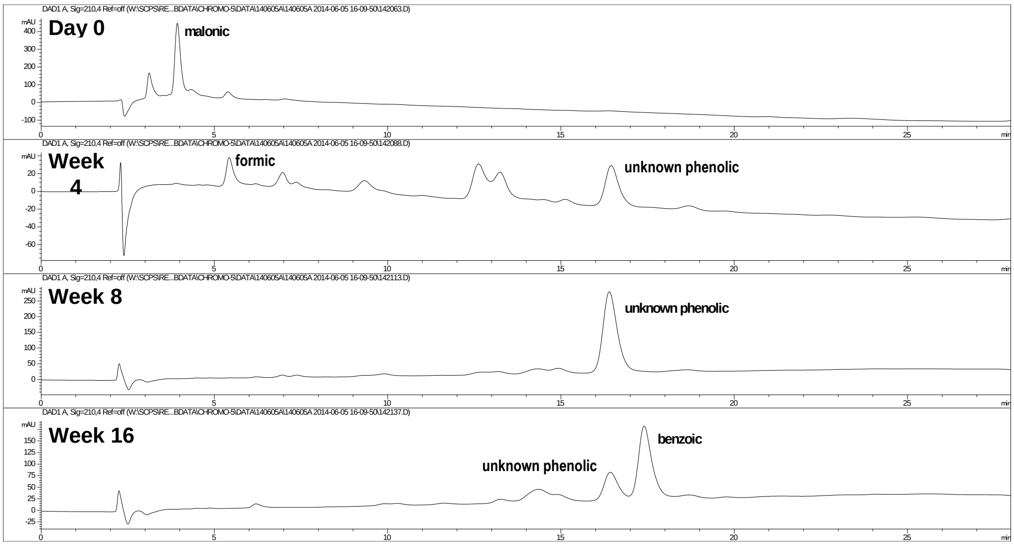

Figure 4-39. HPLC chromatograms for the Tolderol sediment (0-2.5 cm) with the addition of *Phragmites*.

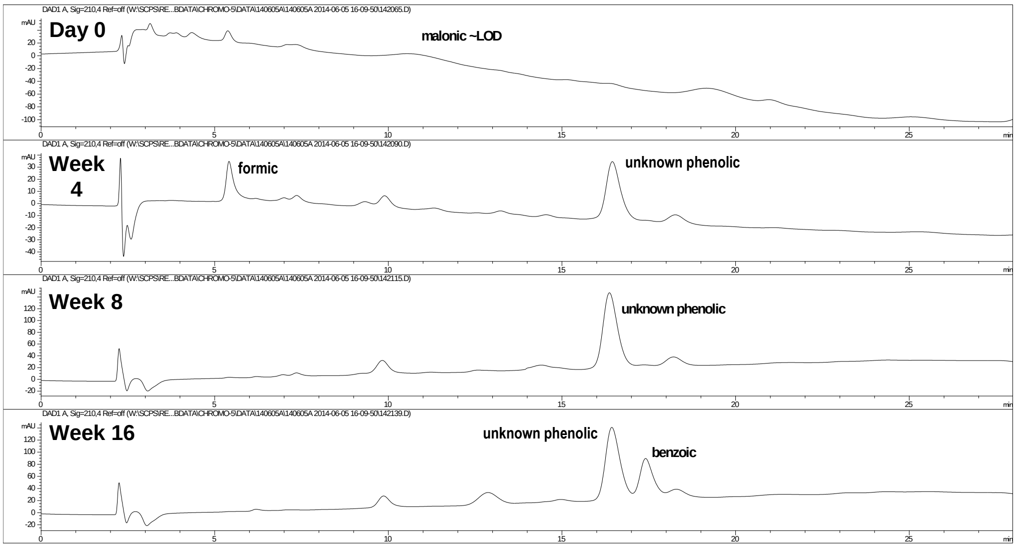

Figure 4-40. HPLC chromatograms for the Tolderol sediment (0-2.5 cm) with the addition of *Schoenoplectus*.

A closer examination of the data showed the LMW organic acids present at each time interval varied depending on the treatment and the sediment depth. Malonic acid was only clearly identified (up to 2.8 mg/mL) on at the start of the incubation experiment (Day 0) when *Phragmites* was added to all sediments (Figure 4-41). Malonic acid concentrations were close to the limit of detection (LOD) on Day 0 with the *Schoenoplectus* treated surface (0-2.5 cm) sediments (~0.02 mg/mL).

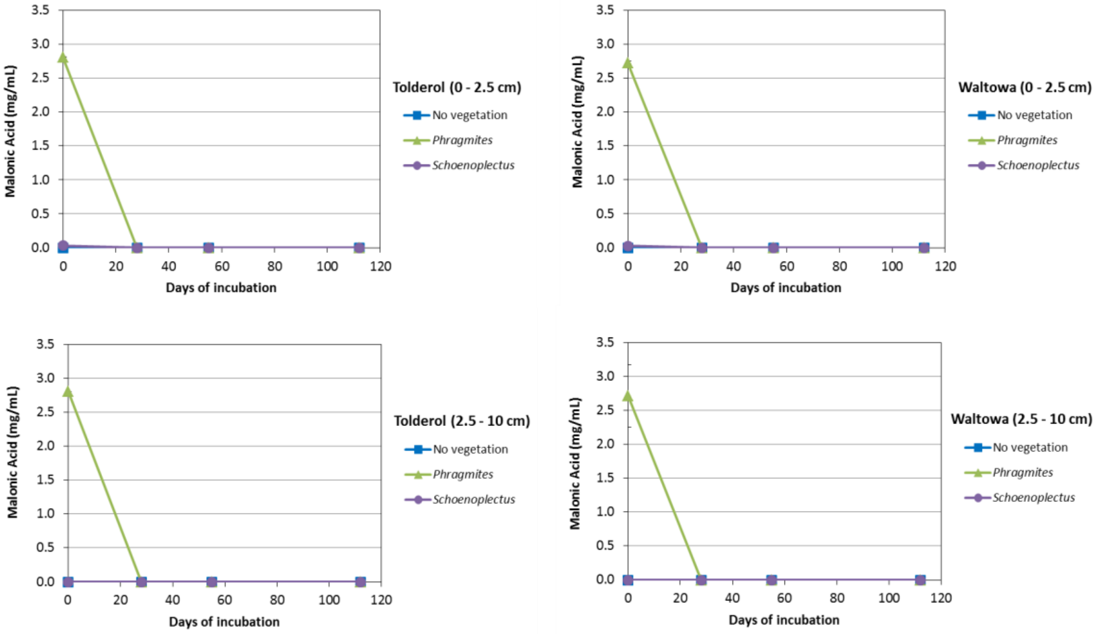

Figure 4-41. Tolderol and Waltowa surface water malonic acid ($CH_2(COOH)_2$) dynamics.

Formic acid was detected after 4 weeks of incubation with all sediments treated with vegetation, although the behaviour differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments (Figure 4-42). Formic acid also showed a similar trend to that observed with titratable acidity (see Figures 4-8 and 4-43). The addition of vegetation to the surface (0-2.5 cm) sediments showed a rapid increase in the formic acid concentration over the initial 4 weeks (up to 0.7 mg/mL), followed by a rapid decrease. While the sub-surface (2.5-10 cm) sediments also showed a rapid increase in the formic acid concentration over the initial 4 weeks, the organic acid was not rapidly broken down as observed with the surface (0-2.5 cm) sediments. Whilst the Waltowa sub-surface (2.5-10 cm) sediment showed an overall decline in the formic acid concentration over the following 12 weeks, the Tolderol sub-surface (2.5-10 cm) sediment showed a steady increase in the formic acid concentration over this period. The formic acid concentrations were slightly lower in the *Schoenoplectus* treated sub-surface (2.5-10 cm) sediments than those treated with *Phragmites*.

The cause of the difference in the formic acid behaviour between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments is not clear. The different behaviour may reflect differences in the bacterial populations between the two layers. The surface (0-2.5 cm) sediments may have sufficient bacteria present that can rapidly breakdown the formic acid. Further research is required to determine the exact cause of the differences between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments.

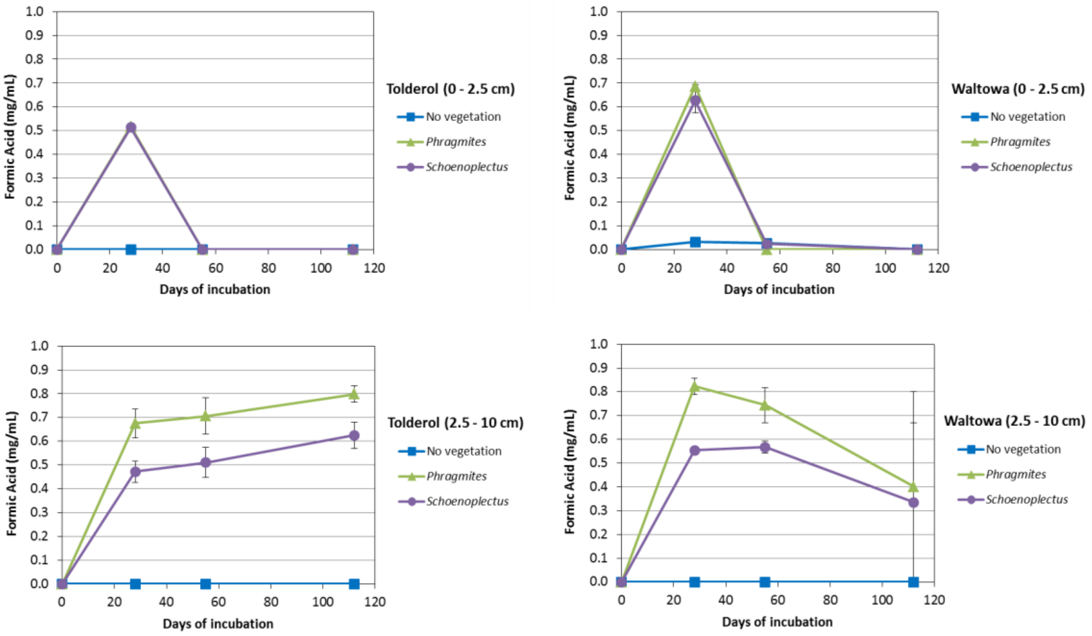

Figure 4-42. Tolderol and Waltowa surface water formic acid (HCOOH) dynamics.

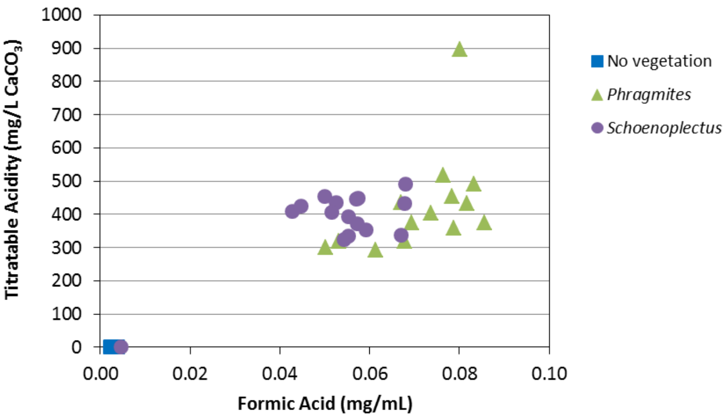

Figure 4-43. Comparison of the surface water formic acid (HCOOH) and titratable acidity concentrations.

Oxalic acid was only detected at very low concentrations (i.e. at the limit of detection) on Day 0 with the Tolderol sediments treated with *Schoenoplectus* (Table 8-7, Appendix 2). Acetic and succinic acids were not detected with any of the sediments or treatments. However, it is possible that some of these LMW organic acids (particularly acetic acid) may have formed under the experimental conditions, but were rapidly broken down over the initial 4 weeks. For example, the rapid breakdown of acetate under reducing conditions has previously been observed (e.g. Burton *et al.* 2012).

Benzoic acid was only detected in the surface waters after 16 weeks of incubation, particularly with the surface sediments (0-2.5 cm) treated with vegetation (Figure 4-44). An unidentified phenolic was also detected with the same retention time with many of the samples treated with vegetation at and after 4 weeks of incubation (Table 8-7, Appendix 2).

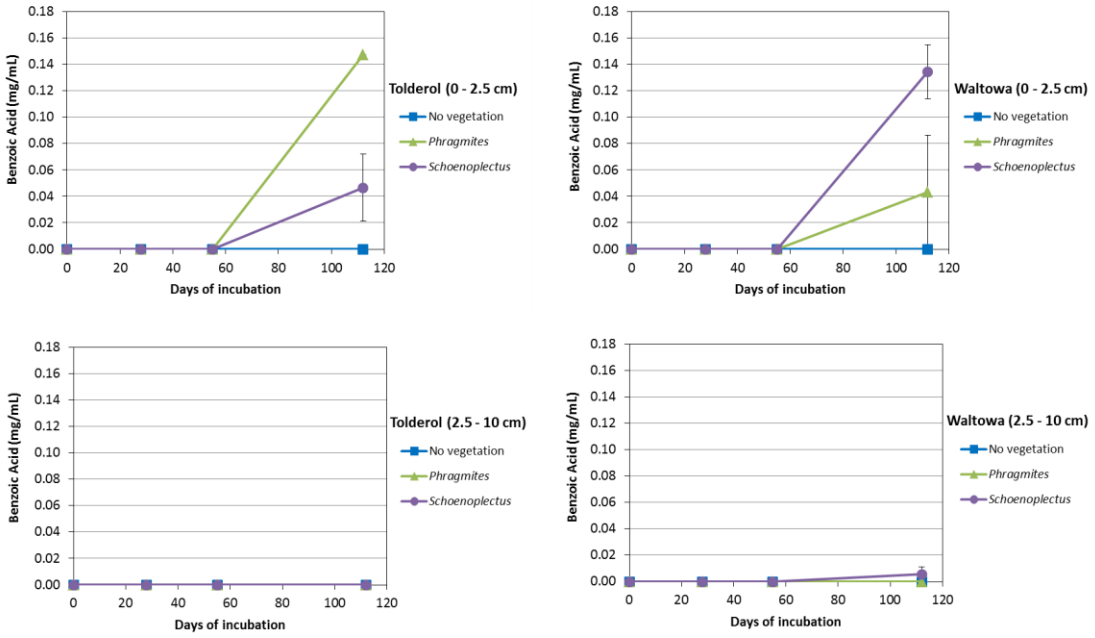

Figure 4-44. Tolderol and Waltowa surface water benzoic acid ($C_7H_6O_2$) dynamics.

Summary of Section

The surface water dissolved organic carbon (DOC) concentration increased during the incubation without the addition of vegetation (Figure 4-33). The addition of vegetation substantially increased the surface water DOC concentration, and the DOC concentration decreased during the incubation period with the vegetation treated surface (0-2.5 cm) sediments.

Fluorescence analysis of the surface water tryptophan-like peak (T_1) also showed the T_1 peak intensity increased during the incubation without the addition of vegetation indicating an increase in the amount of bioavailable organic material (Figure 4-34). The addition of vegetation substantially increased the surface water T_1 peak intensity.

UV-visible spectrophotometry indicated that without the addition of vegetation more water-soluble soil organic matter was liberated as the incubation progressed (Figure 4-37). With the addition of vegetation, the UV-Vis spectra indicated the formation of total aromatic compounds after 4 weeks of incubation. The data also indicated that more labile structures (e.g. carbohydrates, amino acids, etc.) were then destroyed and more thermodynamically stable aromatic and polyaromatic structures formed.

Differential Pulse Voltammetry (DPV) was used to characterise the reducing dissolved organic matter. DPV showed differences in the reducing dissolved organic matter content between the *Phragmites* and *Schoenoplectus* treatments (Figure 4-38). The data also indicated that some refractory reducing dissolved organic matter and weakly reducing organic matter were formed during incubation.

High-performance liquid chromatography (HPLC) was used to determine the nature of the low molecular weight (LMW) organic acids present. Malonic acid ($CH_2(COOH)_2$) was identified at the start of the incubation experiment, particularly with the addition of *Phragmites* (Figure 4-41). Oxalic acid ($H_2C_2O_4$) was also initially detected at very low concentrations. Formic acid (HCOOH) was first identified after 4 weeks of incubation and showed a similar trend to that observed with titratable acidity (Figures 4-8 and 4-42). The behaviour of formic acid differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments; this may reflect differences in the bacterial populations between the two layers. The presence of numerous other peaks after 4 weeks of incubation indicated the formation of additional organic compounds (including an unknown phenolic and other aromatic compounds). Benzoic acid ($C_7H_6O_2$) was detected with some of the vegetation treated sediments after 16 weeks of incubation (Figure 4-44).

4.2.2 Surface Sediment

Analyses of the surface sediment properties were only undertaken on mesocosm sediments. The following sub-sections present the changes that were observed in the surface sediment properties during the mesocosm experiment.

4.2.2.1 Reduced Inorganic Sulfur (RIS)

Reduced inorganic sulfur (RIS) compounds were not observed to form in any of the untreated and treated sediments during the 16 week incubation period. The pyritic sulfur and acid volatile sulfide (AVS) fractions were below the limit of detection (<0.01% S) in both untreated and treated sediments at the start and end of the mesocosm experiment (i.e. Day 0 and Week 16) (Table 8-32, Appendix 4). Very low concentrations of elemental sulfur were also observed at the start and end of the mesocosm experiment, ranging between <0.001 and 0.004% S (Table 8-32, Appendix 4).

The lack of RIS formation in the untreated sediments is consistent with field observations by Sullivan *et al.* (2013). Pyrite formation is also not expected with any of the sediments and treatments under the pH/Eh conditions observed (see Figure 4-14). It is expected that one of the factors limiting RIS formation is the low concentrations of dissolved sulfur (see Figure 4-11).

4.2.2.2 Titratable Actual Acidity, Acid Neutralising Capacity and Retained Acidity

All sediments and vegetation treatments had low titratable actual acidity (TAA) values (i.e. < 7 mol H^+/t) (Table 8-32, Appendix 4). No clear trend in TAA was observed during the 16 week incubation period (Figure 8-18, Appendix 7).

All sediments and vegetation treatments had no measurable acid neutralising capacity (ANC) (Table 8-32, Appendix 4).

The retained acidity was assumed to be zero as the pH_{KCl} values were all greater than 4.5 (Table 8-32, Appendix 4). Whilst visual observations in the field indicated the presence of jarosite at one of the sites at Tolderol (Table 8-1, Appendix 1), the jarosite content was quantified due to the lack of an accurate quantification procedure (see Vithana *et al.* 2013).

4.2.2.3 Total Carbon, Total Organic Carbon and Hydrolysable Organic Carbon

All surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments without vegetation had low total carbon contents (~0.2% C) (Figure 8-19, Appendix 7). The addition of vegetation increased the carbon content of the sediments to approximately 1.6% C. The *Phragmites* and *Schoenoplectus* vegetation used in the experiment had similar organic carbon contents of 43.8% C and 41.8% C, respectively (Tables 8-35 and 8-36, Appendix 5). Surface sediments with the addition of vegetation showed a slight decrease in the carbon content over the 16 week incubation period (up to ~0.4% C) (Figure 8-19, Appendix 7).

The determination of the total organic carbon content (TOC) showed that the total carbon virtually entirely consists of organic matter (Figure 8-20, Appendix 7). The lack of carbonate is in agreement with the ANC results. No measurable change in the hydrolysable organic carbon fraction was observed over the 16 weeks of incubation (Figure 8-21, Appendix 7).

4.2.2.4 Total Nitrogen

All surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments without and with vegetation had low total nitrogen contents (< 0.10% N) (Figure 8-22, Appendix 7). Minimal change in the total nitrogen contents was observed (Figure 8-22, Appendix 7). As expected the addition of vegetation increased the total nitrogen contents slightly (~0.02-0.03% N). The addition of *Phragmites* vegetation resulted in a slightly higher total nitrogen contents than the addition of *Schoenoplectus* vegetation (~0.01% N).

4.2.2.5 Mineralogy and Metal(loid) Fractionation

4.2.2.5.1 Mineralogy

The x-ray diffractograms of the sediments from both sites showed the sediments are predominantly composed of quartz, feldspar and some clay (see Figure 8-6, Appendix 6). The x-ray diffractograms also showed that the surface (0-2.5 cm) and sub-surface (2.5-10 cm) layers are mineralogically the same. X-ray diffractograms showed the Tolderol sediment had slightly more feldspar and clay than Waltowa sediment; the particle size distribution analysis also showed more fine material (i.e. < 63 µm) in the Tolderol sediment (Figure 8-5, Appendix 6).

A comparison of the X-ray diffractograms of all the sediments and treatments on Day 0 and Week 16 showed no significant differences in mineralogy for any of the treatments over the 16 week period (i.e. no new minerals were formed and none were lost). It is important to note that the x-ray diffractograms would only indicate differences where more than 1-2% of crystalline minerals formed.

4.2.2.5.2 Iron Fractionation

The change in the sediment iron fractions over the 16 week incubation period with and without the addition of vegetation for the Tolderol and Waltowa sediments is shown in Figure 4-45; note different scales have been used for the two sites. The iron fractionation data shows low levels of iron in the sediments at both sites (i.e. ≤ 2200 µg/g or equivalent to ≤ 0.22% Fe), with slightly lower iron concentrations observed in the Waltowa sediments (i.e. ≤ 1400 µg/g). The low iron levels in the sediments (≤ 0.22% Fe) indicate why changes in the iron mineralogy were not detected by XRD.

The iron fractionation results show an increase in the soluble and exchangeable ferrous iron fraction (*$MgCl_2$ Fe^{2+}*) over 16 weeks with all the sediments and treatments, although a low soluble and exchangeable iron fraction was observed after 16 weeks with the Waltowa surface (0-2.5 cm) sediments (i.e. < 20 µg/g).

A consistent change in the iron fractionations over the 16 week incubation period was observed with all the sediments where vegetation had been added. In addition to an increase in the soluble and exchangeable iron fraction, a decrease in both the hydrochloric acid (*HCl*) and citrate buffered dithionite (*CBD*) fractions was observed. The iron associated with the organic matter and residual fraction (*OM & Residual*) increased in the surface (0-2.5 cm) sediments and decreased slightly in the sub-surface (2.5-10 cm) sediments; a pyrite bound fraction was not observed in this study (see Section 4.2.2.1).

The iron fractionation changes with the samples without the addition of vegetation were less consistent. A slight decrease in the HCl fraction was observed over the 16 week incubation period, except for the Tolderol surface (0-2.5 cm) sediment which showed a slight increase. A decrease in the CBD fraction was observed with the sediments without the addition of vegetation, except for the Waltowa sub-surface (2.5-10 cm) sediment which showed an increase. The OM & Residual fraction also showed a mixed response (including no change, a decrease and an increase with two of the sediments).

The HCl fraction includes carbonates, poorly ordered sulfides and oxides, whilst the CBD fraction includes the more crystalline iron oxide minerals (Claff *et al.* 2010). The iron fractionation results would therefore clearly indicate that the addition of vegetation led to the reduction of poorly ordered and crystalline iron oxides to soluble and exchangeable iron (also indicated by an increase in the ferrous iron concentrations (Figure 4-13)), and organically bound iron with the surface (0-2.5 cm) sediments. However, in addition to organically bound iron, the OM & Residual fraction also includes iron residing in silicates and more crystalline iron oxide minerals; the CBD extraction step is not capable of completely dissolving crystalline iron oxide minerals (including goethite, hematite and magnetite) (Claff *et al.* 2010). It is therefore possible that more crystalline iron minerals may have also formed over the 16 week incubation period resulting in an increase in the OM & Residual fraction. This seems unlikely as an increase in the OM & Residual fraction was not consistently observed.

The surface water iron data showed the release of iron was more rapid with the surface sediments (0-2.5 cm) when compared to the sub-surface sediments (2.5-10 cm) (see Figure 4-13), and it was suggested that iron may be in a more easily reducible form in the surface sediments. A closer examination of the iron fractionation data on Day 0 shows that there is consistently a greater concentration of less crystalline iron minerals (i.e. HCl fraction) in the surface sediments (see Figure 8-23, Appendix 7).

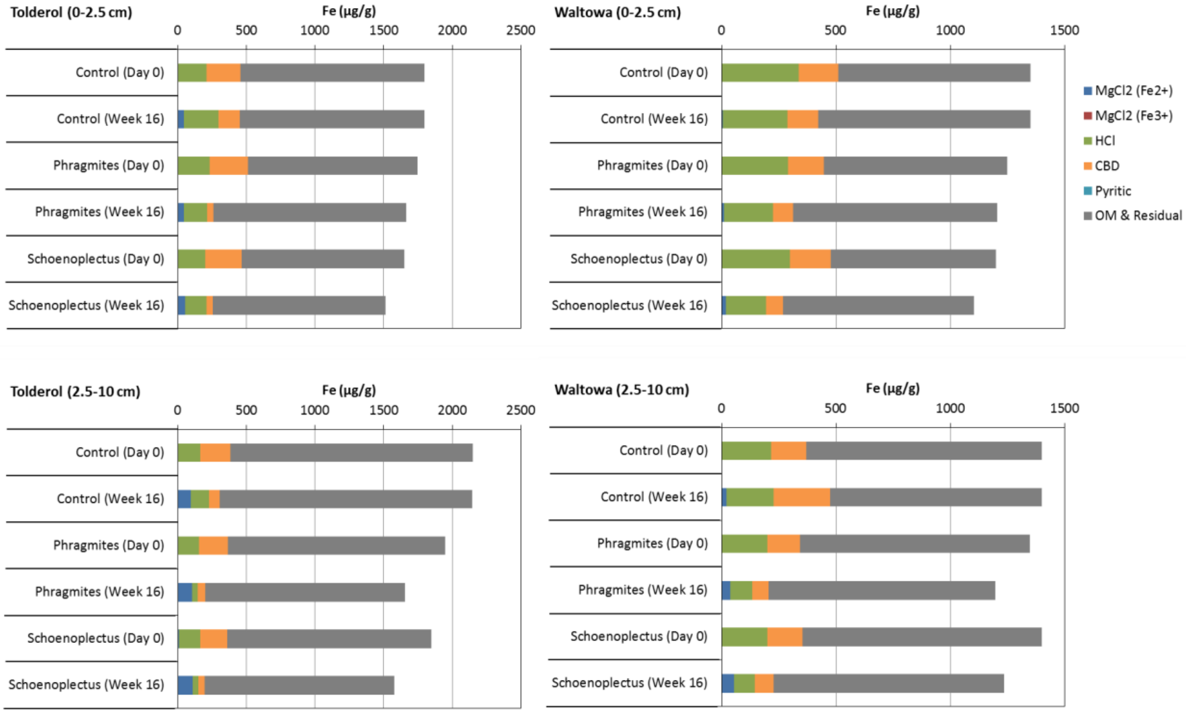

Figure 4-45. Tolderol and Waltowa sediment iron fractionation dynamics with and without the addition of vegetation. [The sequential extraction procedure ranges from the soluble and exchangeable fraction (*$MgCl_2$ Fe^{2+}, $MgCl_2$ Fe^{3+}*) with the greatest solubility through to the acid soluble fraction (*HCl*), crystalline oxide fraction (*CBD*), pyrite-bound fraction (*Pyritic*), and finally the least soluble acid/peroxide digestible fraction (*OM & Residual*)].

4.2.2.5.3 Metal(loid) Fractionation

In addition to examining the fractionation of iron, the sequential extraction procedure followed was also used to gain an understanding of the change in other metals and metalloids associated with the sediments. The change in metal(loid) fractions (i.e. As, Co, Cu, Fe, Ni, Zn) over the 16 week incubation period for the *Phragmites* treated Waltowa surface (0-2.5 cm) sediment is shown in Figure 4-46; note different scales have been used for each metal(loid). Figure 4-46 clearly shows that there has been a substantial change in the distribution of many of the metal(loid)s over the 16 weeks of incubation.

The iron fractionation data for this *Phragmites* treated sediment showed a slight increase in the soluble and exchangeable iron fraction (*$MgCl_2$*), and a decrease in both the hydrochloric acid (*HCl*) and citrate buffered dithionite (*CBD*) fractions over the 16 week period (Figure 4-46). The iron associated with the organic matter and residual fraction (*OM & Residual*) increased over the incubation period. As discussed previously, these results would therefore indicate that there has been a reduction of both poorly ordered and crystalline iron oxides to soluble and/or exchangeable iron and organically bound iron.

The surface water data indicated that both cobalt and nickel were released into solution partially as a consequence of the reductive dissolution of iron minerals (see Sections 4.2.1.9.6 and 4.2.1.9.10). Figure 4-46 does show an overall reduction in the cobalt and nickel associated with poorly ordered and crystalline iron oxide fractions (*HCl + CBD*) over the 16 week period. This was particularly evident with the nickel associated with crystalline iron oxides (*CBD*) which decreased from 0.20 µg/g to 0.03 µg/g over the 16 weeks. In addition, the soluble and exchangeable cobalt and nickel fractions (*$MgCl_2$*) were also readily mobilised into solution. Nickel also showed a substantial decrease in the *OM & Residual* fraction (i.e. from 0.85 µg/g to 0.48 µg/g) indicating that the nickel associated with this fraction was also released into solution; some of this nickel may have been associated with the *Phragmites*.

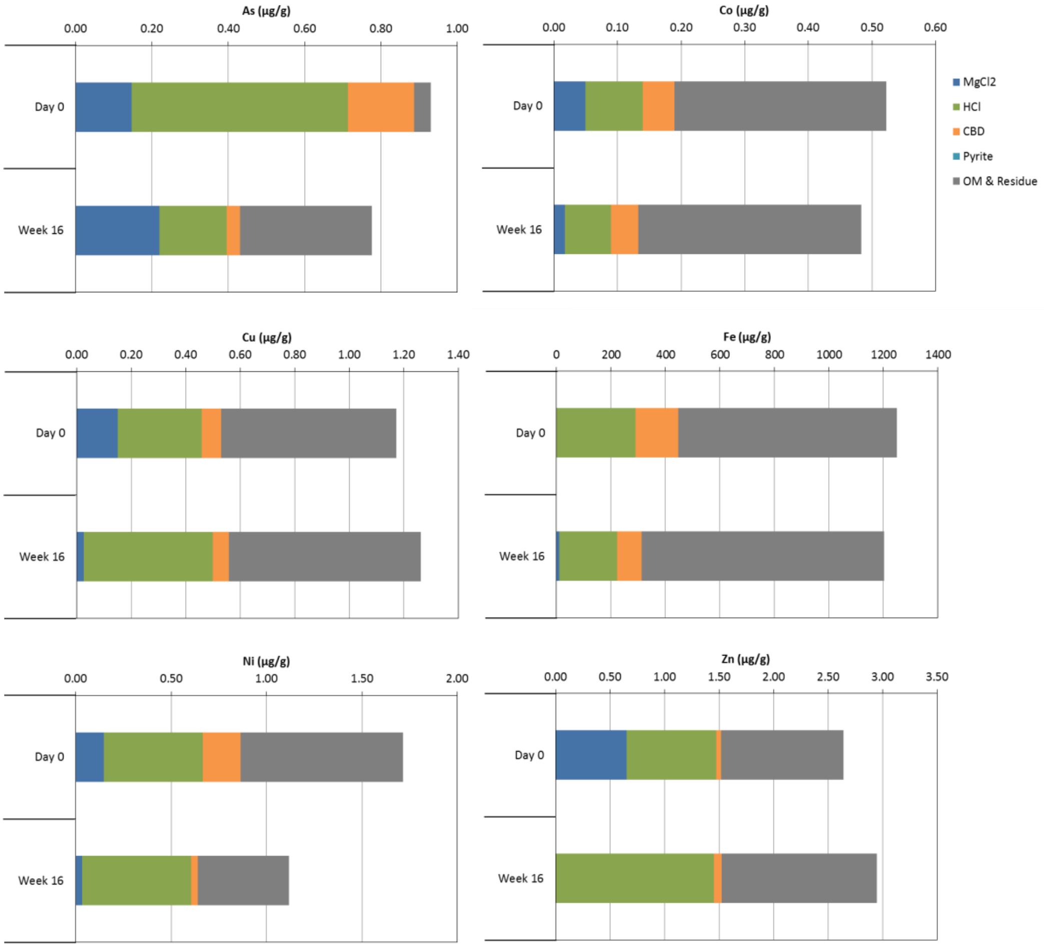

Figure 4-46. Waltowa surface (0-2.5 cm) sediment metal(loid) fractionation dynamics with the addition of *Phragmites*. [The sequential extraction procedure ranges from the soluble and exchangeable fraction (*MgCl$_2$*) with the greatest solubility through to the acid soluble fraction (*HCl*), crystalline oxide fraction (*CBD*), pyrite-bound fraction (*Pyritic*), and finally the least soluble acid/peroxide digestible fraction (*OM & Residual*)].

The fractionation of arsenic with the *Phragmites* treated sediment changed considerably over the 16 week incubation period (Figure 4-46). The arsenic associated with poorly ordered and crystalline iron oxides (*HCl + CBD*) decreased from 0.74 µg/g to 0.21 µg/g over the 16 weeks. A large proportion of the arsenic released from these iron oxide fractions also went to the organic matter and residual fraction (*OM & Residual*); this fraction increased from 0.04 µg/g to 0.35 µg/g over the 16 weeks. There was also a slight increase in the soluble and exchangeable arsenic fraction (*MgCl$_2$*). The data indicates that the increase in the surface water arsenic concentration observed with the Waltowa *Phragmites* treated surface sediment during incubation (see Figure 4-19) is largely caused by the loss of arsenic from the iron oxide fraction.

The change in the fractionation of copper and zinc over the 16 week incubation period both showed a similar trend (Figure 4-46). There was a substantial reduction in the soluble and exchangeable copper and zinc fractions (*MgCl$_2$*), and an increase in these metals associated with the poorly ordered iron oxides (*HCl*) and organic matter and residual fraction (*OM & Residual*). The amount of copper and zinc associated with the crystalline iron oxides (*CBD*) largely remained unchanged. The total sediment copper and zinc content also showed a slight increase as a result of the metals that were initially released into the surface water on Day 0 becoming associated with the sediment fraction on Week 16.

Summary of Section

The analysis of the sediment properties showed that RIS compounds (including pyrite, iron monosulfides and elemental sulfur) did not form in any of the sediments over the 16 week incubation period. The data indicates the low concentrations of dissolved sulfur (Figure 4-11) is one of the factors limiting RIS formation.

All sediments and vegetation treatments had low TAA values (< 7 mol H^+/t), no measurable ANC and no retained acidity. All sediments without the addition of vegetation had low carbon contents (~0.2% C). The surface (0-2.5 cm) sediments with the addition of vegetation showed a slight decrease in organic carbon over the 16 week incubation period (Figure 8-20, Appendix 7).

Mineralogical changes over the 16 week period were not observed with any of the treatments using XRD. This technique is limited to a detection limit of about 2%, and therefore, changes in the iron mineralogy (i.e. ≤ 0.22% Fe), if any, were below detection.

The iron (Fe) fractionation results showed an increase in the soluble and exchangeable ferrous iron fraction over 16 weeks (Figure 4-45). The iron fractionation results indicated that the addition of vegetation led to the reduction of poorly ordered and crystalline iron oxides to soluble and exchangeable iron, and also organically bound iron with the surface (0-2.5 cm) sediments. A greater concentration of less crystalline iron minerals (i.e. *HCl* fraction) were also detected in the surface (0-2.5 cm) sediments (Figure 8-23, Appendix 7).

Metal(loid) fractionation results for the *Phragmites* treated Waltowa surface (0-2.5 cm) sediment confirmed the release of cobalt (Co) and nickel (Ni) from iron oxides during incubation (Figure 4-46). This was particularly evident with the nickel associated with crystalline iron oxides (*CBD* fraction). The soluble and exchangeable cobalt and nickel fractions (*$MgCl_2$* fraction) were also readily mobilised into solution. Nickel showed a substantial decrease in the *OM & Residual* fraction indicating that the nickel associated with this fraction was also released into solution; some of this nickel may have been associated with the *Phragmites*.

Fractionation results also showed the arsenic (As) associated with poorly ordered and crystalline iron oxides (*HCl + CBD* fraction) was released into solution (Figure 4-46). The released arsenic was also found to be associated with the soluble and exchangeable (*$MgCl_2$* fraction) and organic matter and residual (*OM & Residual* fraction) fractions after 16 weeks of incubation.

The fractionation results for copper (Cu) and zinc (Zn) both showed a similar trend with a substantial reduction in the soluble and exchangeable fraction (*$MgCl_2$* fraction), and an increase in these metals associated with the poorly ordered iron oxides (*HCl* fraction) and organic matter and residual fraction (*OM & Residual* fraction) (Figure 4-46). The total sediment copper and zinc content also showed a slight increase as a result of the metals that were initially released into the surface water on Day 0 becoming associated with the sediment fraction on Week 16.

4.3 Laboratory Batch Experiment

The following sections present the changes that were observed in the surface water properties over a period of 12 weeks during the batch experiment. The sediment properties were only examined for the mesocosm experiment. In the batch experiment various types of organic matter were added to the Waltowa sub-surface sediment (2.5-10 cm) including glucose, acetate, humic acid, and the two vegetation types used in the mesocosm experiment (i.e. *Phragmites australis* and *Schoenoplectus validus)*. The two vegetation types were added at the same concentrations as used in the mesocosm experiment (i.e. 0.40 g per sample). The other three other organic compounds (i.e. glucose, acetate, humic acid) were added at the same organic carbon concentration (i.e. 227 mg C/L), but at a lower concentration to the vegetation used (see Section 4.2.3 for further details). The results often indicate that the three organic compounds were added at a sub-optimal rate when compared to the relatively abundant supply of decomposable organic matter available with the vegetation. This is also indicated in the initial surface water DOC concentrations and the fluorescence intensity data (see Section 4.3.7). As the two vegetation types often showed a different response during incubation to the other types of organic matter used due to the greater supply of decomposable organic matter, they therefore are usually discussed separately in the following sections.

4.3.1 pH

The change in surface water pH during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-47 and 4-48. Without the addition of organic matter (i.e. control) the surface water pH increased from pH 5.4 to pH 7.8 over the 12 weeks of incubation. The addition of acetate and humic acid showed similar behaviour to the control, although a higher final pH of 8.8 was reached with the acetate treatment (Figure 4-47). The addition of glucose, *Phragmites* and *Schoenoplectus* all showed similar pH behaviour, but did not show such a rapid pH increase; all three treatments had a pH of less than 6.5 after 12 weeks. The lower pH values with the glucose, *Phragmites* and *Schoenoplectus* treatments reflect the greater release of organic acids produced during bacterial decomposition.

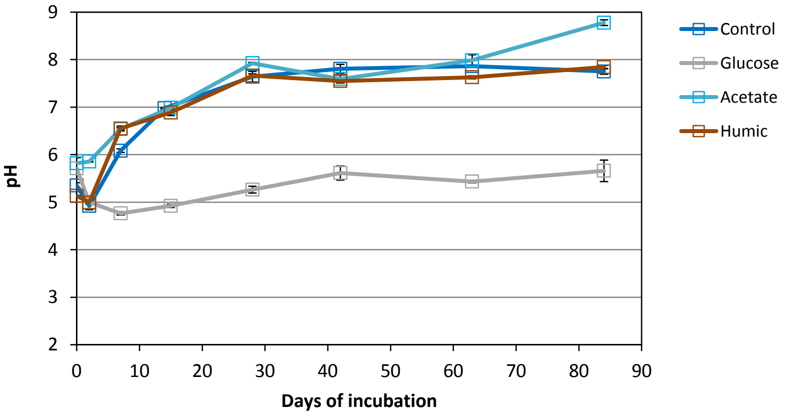

Figure 4-47. Waltowa (2.5 – 10 cm) surface water pH dynamics with and without the addition of glucose, acetate and humic acid.

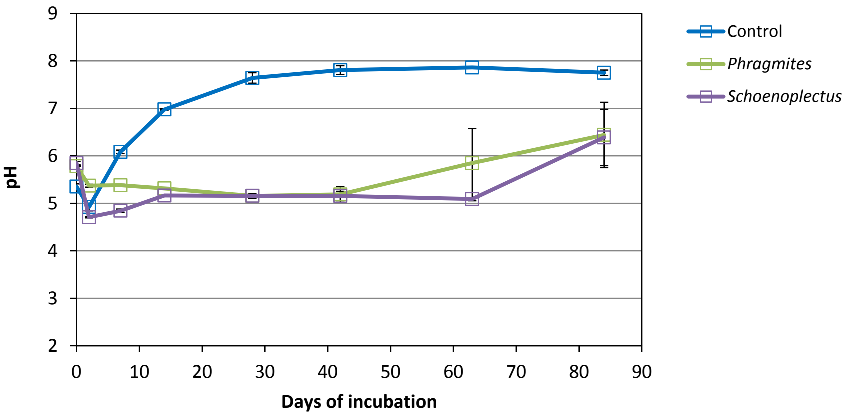

Figure 4-48. Waltowa (2.5 – 10 cm) surface water pH dynamics with and without the addition of vegetation.

The change in surface water pH during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-49. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) usually resulted in a substantially lower pH than the non-treated control. The decrease in pH during incubation with these jarosite and schwertmannite treatments indicates acidity is being released from the hydrolysis of these iron minerals. Where there is an increase in the pH, which was observed with the jarosite treatments, this indicates the alkalinity produced from the reductive dissolution is greater than the acidity being produced as a consequence of hydrolysis.

The addition of jarosite and schwertmannite to the vegetation treated sediments showed a different response (Figure 4-49). The addition of jarosite and schwertmannite to the vegetation treated sediments raised the pH higher than the sediments without these minerals. This also occurred at a faster rate with the schwertmannite treated vegetation sediments. This result indicates that far greater reductive dissolution occurred when the two vegetation types were added compared to the three organic compounds.

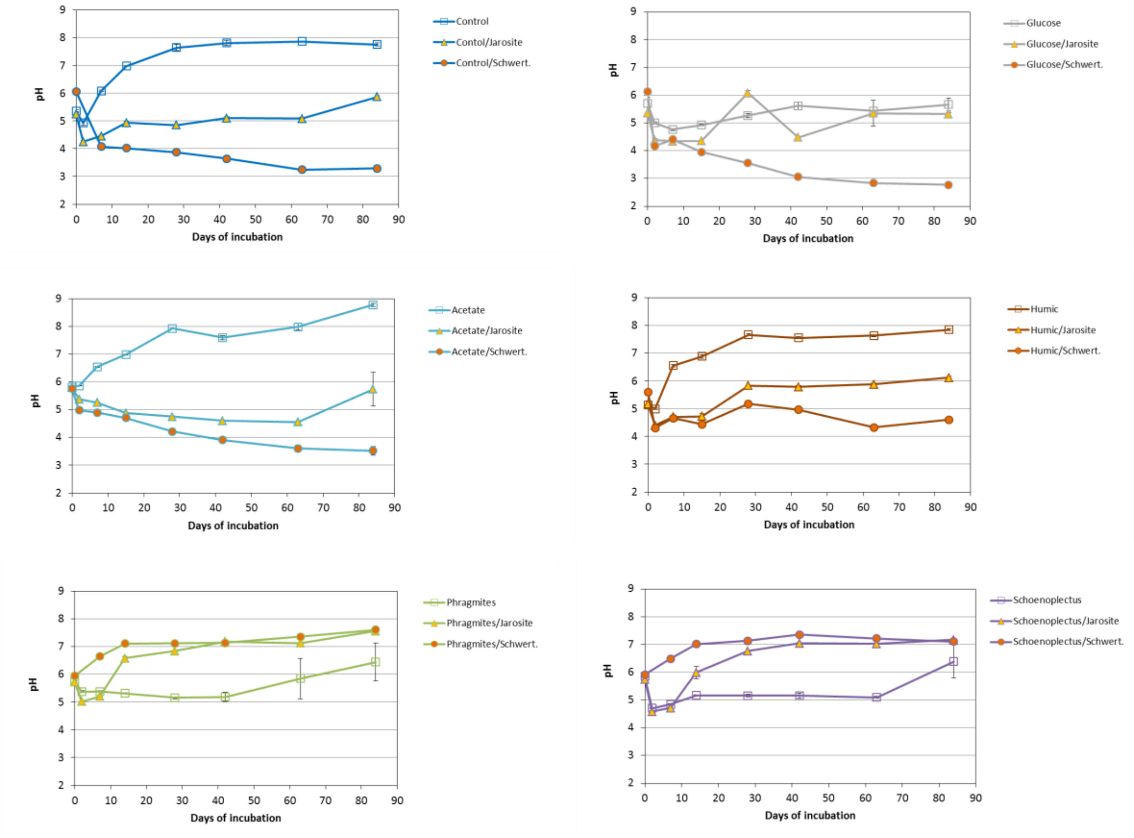

Figure 4-49. Waltowa (2.5 – 10 cm) surface water pH dynamics with and without the addition of organic matter, jarosite and schwertmannite.

4.3.2 Redox Potential (Eh)

The change in surface water Eh during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-50 and 4-51. The Eh of the control rapidly declined to less than -100 mV over the initial 28 days after which is started to increase. The Eh of all the organic treatments tended to decrease over the initial 2-7 days after which it often either stabilised or gradually increased. As observed in the mesocosm experiment the redox potential was the lower in the control when compared to the organic treatments.

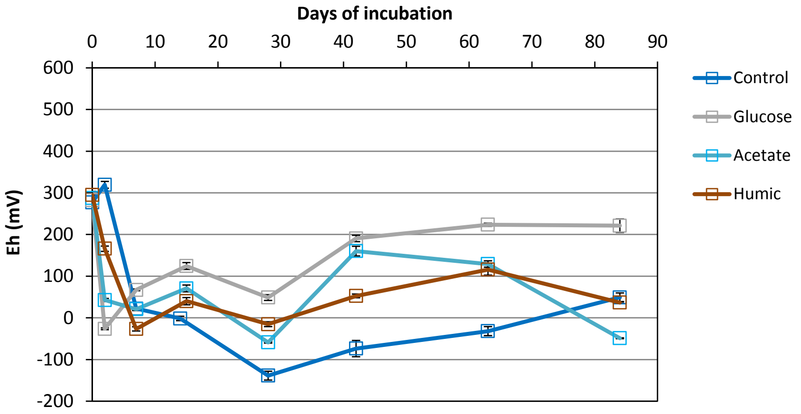

Figure 4-50. Waltowa (2.5 – 10 cm) surface water Eh dynamics with and without the addition of glucose, acetate and humic acid.

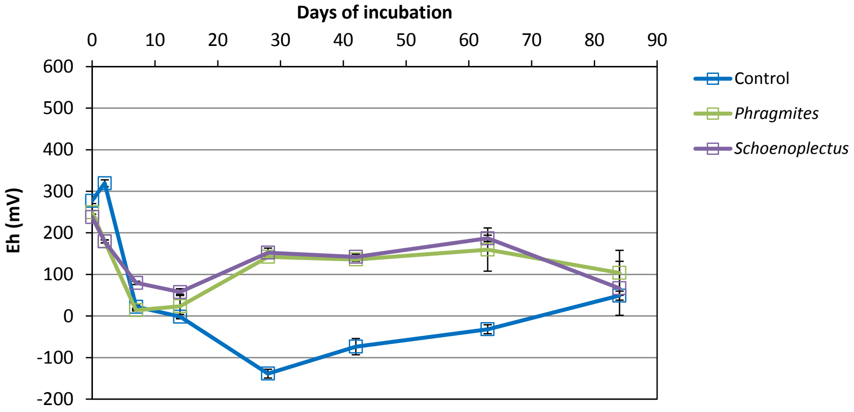

Figure 4-51. Waltowa (2.5 – 10 cm) surface water Eh dynamics with and without the addition of vegetation.

The change in surface water Eh during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-52. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) usually resulted in a substantially higher Eh than the non-treated control. The schwertmannite treatment had a higher Eh than the jarosite treatment. The addition of jarosite and schwertmannite to the vegetation treatment had the reverse effect with the lowest Eh observed in the schwertmannite treatment followed by the jarosite treatment with the vegetation only treatment having a substantially higher Eh. This again indicates that the addition of the vegetation to the jarosite and schwertmannite treatments resulted in substantial reductive dissolution of these minerals.

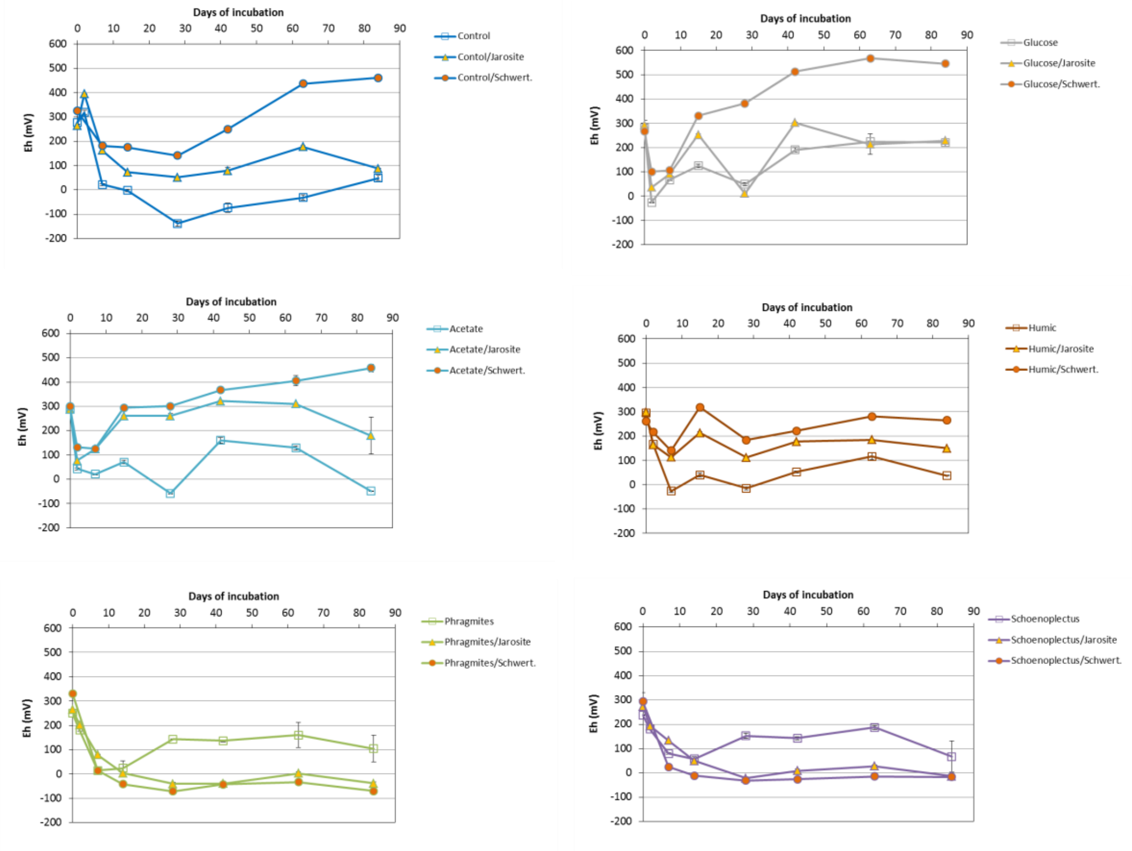

Figure 4-52. Waltowa (2.5 – 10 cm) surface water Eh dynamics with and without the addition of organic matter, jarosite and schwertmannite.

4.3.3 Electrical Conductivity (EC)

The change in surface water EC during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-53 and 4-54. The surface water EC of the control decreased slightly over the 12 week incubation period from 394 µS/cm to 332 µS/cm. The addition of glucose and humic acid to the sediment resulted in a slight increase in the EC when compared to the control. However, the addition of acetate resulted in a substantial increase in the surface water EC (i.e. > 1,000 µS/cm).

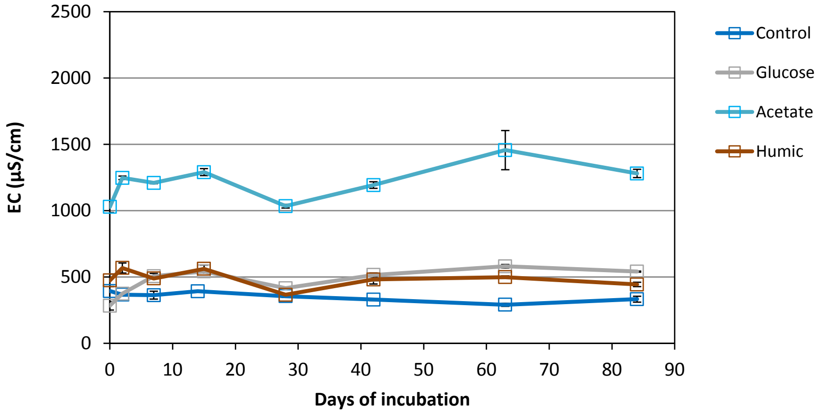

Figure 4-53. Waltowa (2.5 – 10 cm) surface water EC dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a substantial increase in the surface water EC when compared to the control (Figure 4-54). This behaviour was also observed in the mesocosm experiment (see Section 4.2.1.3 for further details). An increase in the surface water EC was observed over the initial 14 days for the vegetation treated samples.

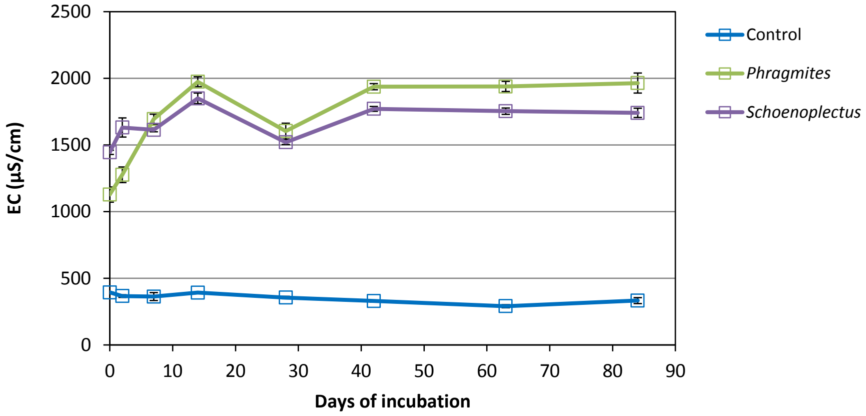

Figure 4-54. Waltowa (2.5 – 10 cm) surface water EC dynamics with and without the addition of vegetation.

The change in surface water EC during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-55. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in a substantially higher EC than the controls. Higher EC values were also usually observed with the schwertmannite treated sediments than the jarosite treated sediments; the schwertmannite treated sediments also had higher initial EC values (i.e. Day 0). The substantial increase in EC during incubation with the jarosite and schwertmannite treatments indicate ions are being released into the surface water from the hydrolysis and/or reductive dissolution of these iron minerals.

The addition of jarosite and schwertmannite to the vegetation treated sediment showed a similar response, although the jarosite treated sediment tended to have a higher EC than the schwertmannite treatment. The addition of jarosite and sometimes schwertmannite to the vegetation treated sediment tended to result in a higher EC when compared to the three organic compounds. The higher EC with the vegetation treated sediments often largely accounts for this difference (Figures 4-53 and 4-54), however, some of this difference may be due to the greater reductive dissolution observed with the vegetation treated sediments.

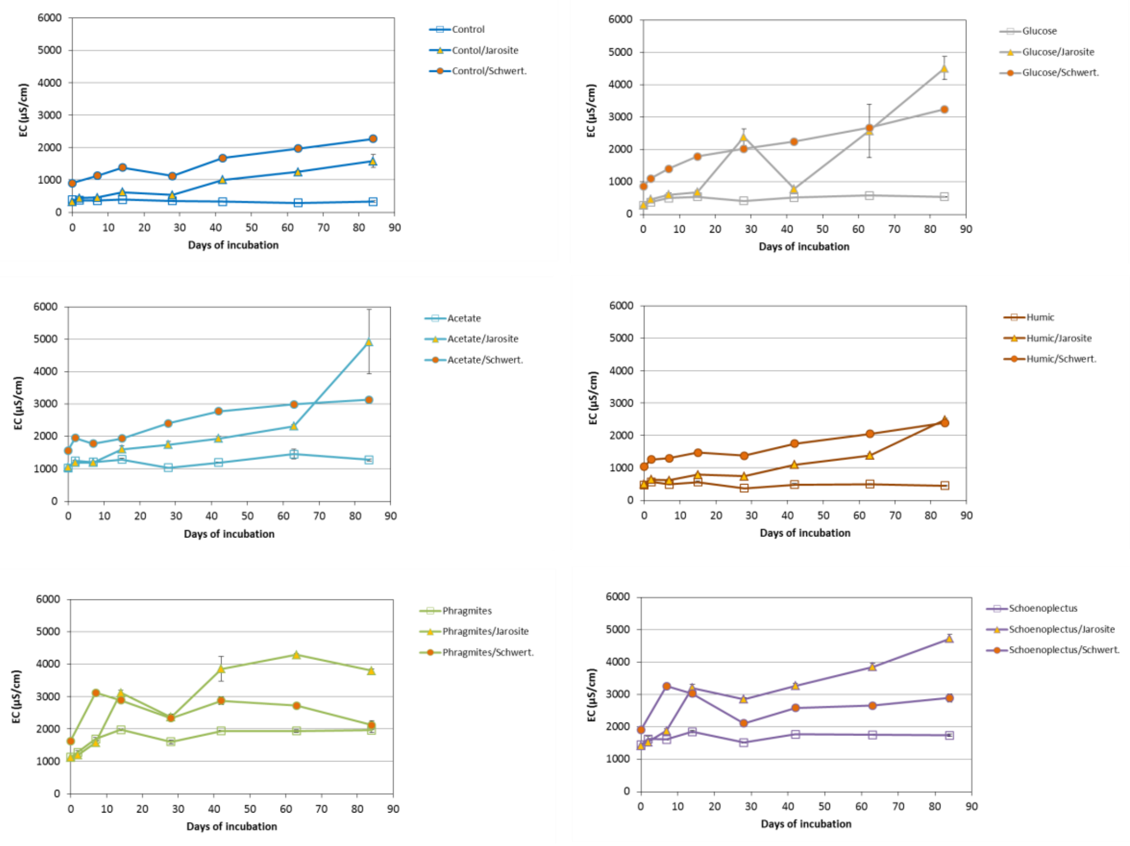

Figure 4-55. Waltowa (2.5 – 10 cm) surface water EC dynamics with and without the addition of organic matter, jarosite and schwertmannite.

4.3.4 Sulfur and Sulfide

4.3.4.1 Sulfur

The change in surface water sulfur concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-56 and 4-57. The initial surface water sulfur concentration for the sediments with and without the addition of the three organic compounds (i.e. glucose, acetate and humic acid) was low (<20 mg/L) (Figure 4-56). A slight increase in the surface water sulfur concentration was observed during the initial 2-7 days followed by a decrease; the decrease was more rapid with the three organic compound treatments than the control.

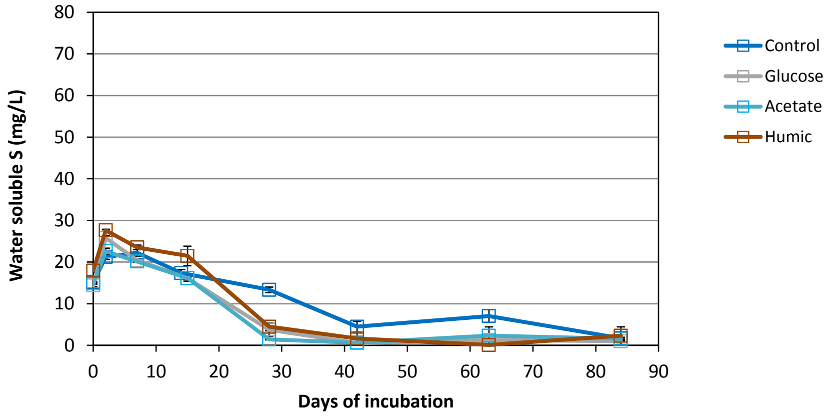

Figure 4-56. Waltowa (2.5 – 10 cm) surface water sulfur dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a higher initial surface water sulfur concentration when compared to the control (Figure 4-57), which was also observed in the mesocosm experiment (see Section 4.2.1.6 for further details). The decrease in the surface water sulfur concentration during incubations was also more rapid with the vegetation treated sediments than the control.

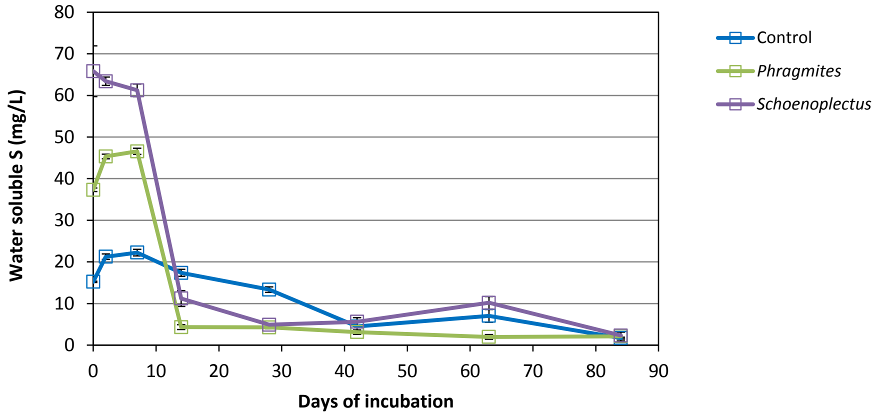

Figure 4-57. Waltowa (2.5 – 10 cm) surface water sulfur dynamics with and without the addition of vegetation.

The change in surface water sulfur concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-58. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in substantially higher sulfur concentrations than the non-treated control. Higher sulfur concentrations were also usually observed with the schwertmannite treated sediments; the schwertmannite treated sediments also had higher initial sulfur concentrations (i.e. Day 0).

When jarosite and schwertmannite were added the humic acid treatment the sulfur concentration was often similar to the treated control; the sulfur concentration of the glucose and acetate treatments were higher than the treated control. The substantial increase in sulfur concentration during incubation with the jarosite and schwertmannite treatments also indicates sulfate is being released into the surface water from the hydrolysis and reductive dissolution of these iron minerals.

The addition of jarosite and schwertmannite to the vegetation treatments resulted in a different behaviour depending on which iron mineral was added (Figure 4-58). The addition of jarosite to the vegetation treatments largely showed an increase in the sulfur concentration during the incubation. However, the addition of schwertmannite to the vegetation treatments showed a rapid decline in the sulfur concentration after 7 days of incubation. The decline was particularly rapid with the *Phragmites* treated sediment which had a low sulfur concentration (i.e. < 12 mg/L) by Day 14. The decrease in the iron concentrations also observed with these treatments would indicate the formation of iron sulfide minerals (see Figure 4-65).

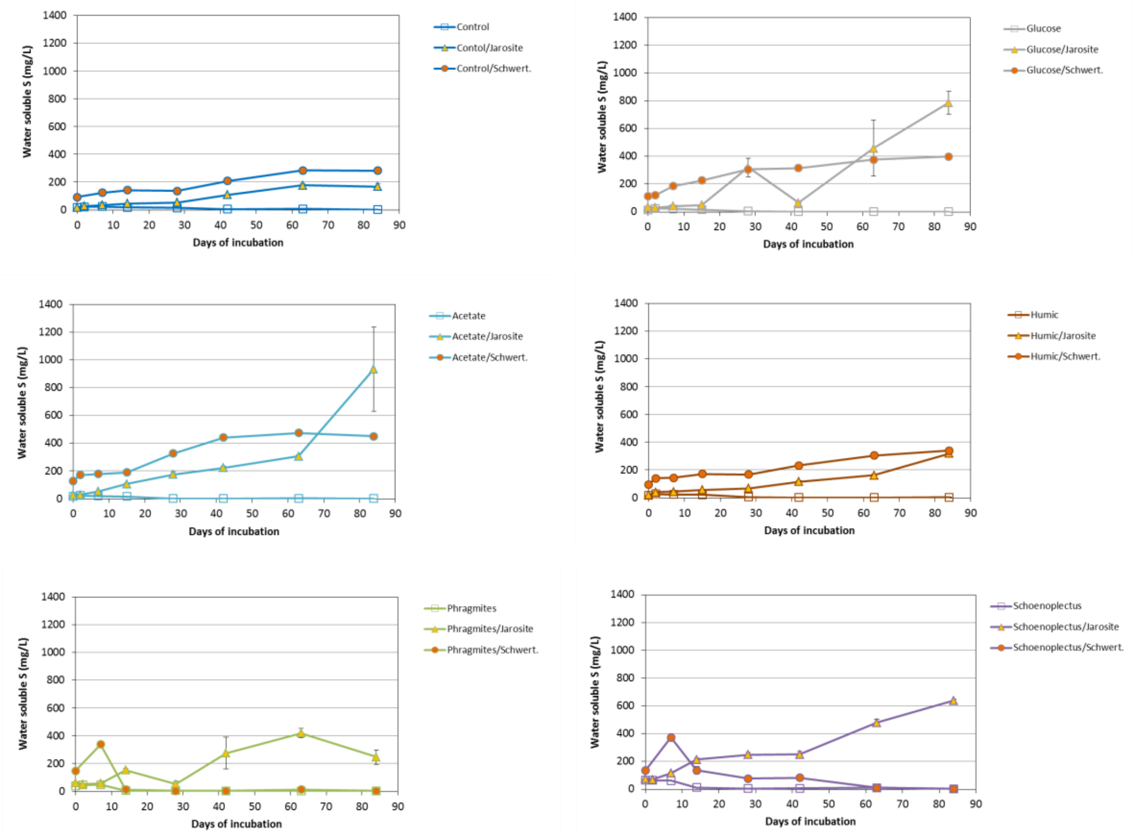

Figure 4-58. Waltowa (2.5 – 10 cm) surface water sulfur dynamics with and without the addition of organic matter, jarosite and schwertmannite.

Visual indications, particularly a black mineral forming on the sides of the centrifuge tubes, also suggested the formation of iron sulfides (i.e. iron monosulfides) with many of the schwertmannite and/or jarosite treatments. This was particularly evident when these iron minerals were added to the vegetation treated sediments (e.g. Figure 4-59).

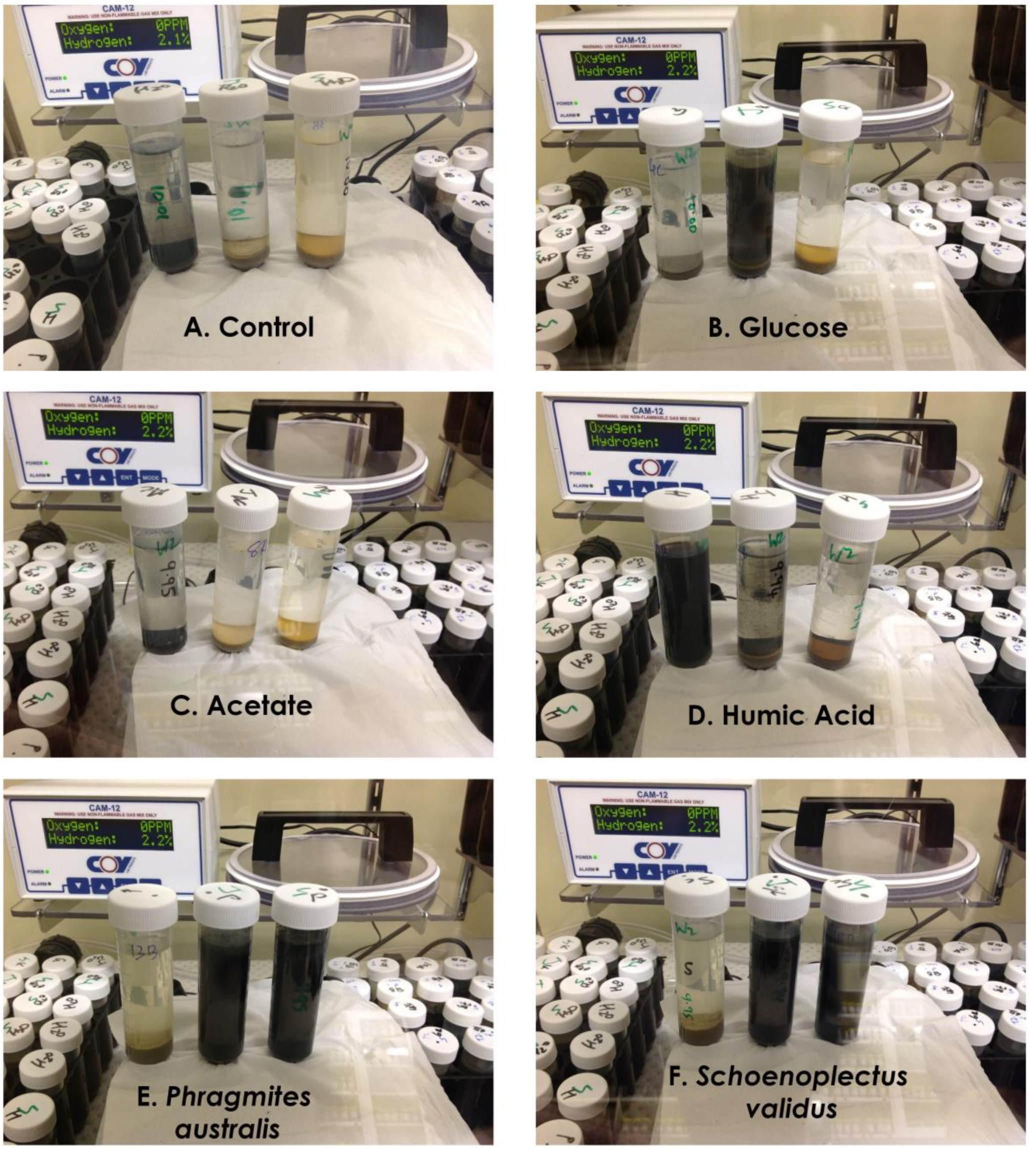

Figure 4-59. Waltowa sediments (2.5-10 cm) after 47 days of incubation (*left tube* - sediment only; *middle tube* - sediment + jarosite; *right tube* - sediment + schwertmannite).

4.3.4.2 Sulfide

The change in surface water sulfide concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-60 and 4-61. Without the addition of organic matter (i.e. control) the surface water sulfide was only detected on Day 7 and Day 63 (Figure 4-60). The addition of acetate showed a similar trend, although slightly more sulfide (~350 µg/L) was observed on Day 7. The addition of glucose resulted in substantially more sulfide being released into solution over the initial 28 days (up to ~650 µg/L) indicating greater sulfate reduction than the other treatments. Unfortunately, it was not possible to quantify the sulfide produced during incubation with the humic acid treatment due to the colour interference with the method used.

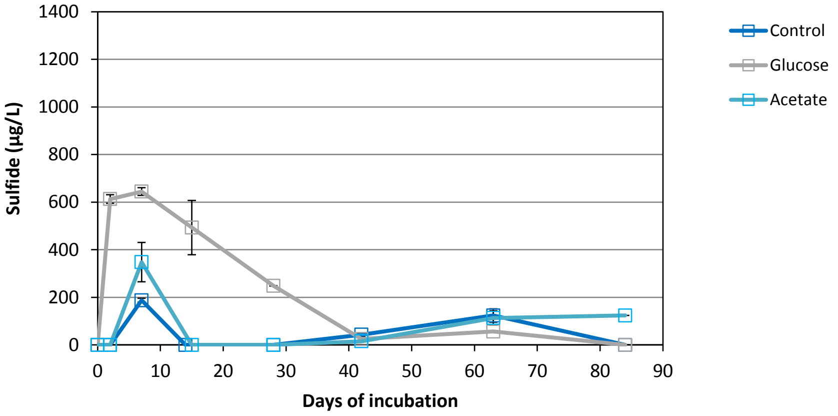

Figure 4-60. Waltowa (2.5 – 10 cm) surface water dissolved sulfide dynamics with and without the addition of glucose and acetate.

The addition of vegetation resulted in a substantial increase in the surface water sulfide concentration when compared to the control (Figure 4-61). The addition of vegetation resulted in more sulfide being released into solution than the glucose treatment, with approximately 770 µg/L and 970 µg/L of sulfide being released from the *Phragmites* and *Schoenoplectus* treatments, respectively.

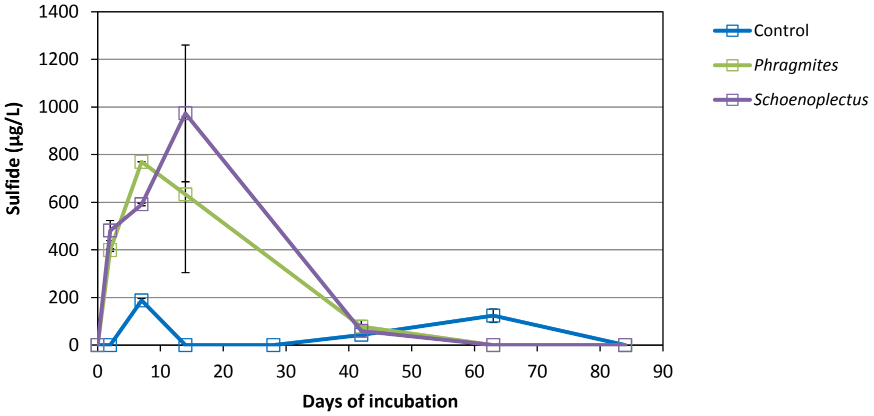

Figure 4-61. Waltowa (2.5 – 10 cm) surface water dissolved sulfide dynamics with and without the addition of vegetation.

The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) usually resulted in minimal sulfide formation (e.g. Figure 4-62). Whilst the addition of jarosite to the vegetation treated sediments showed similar sulfide behaviour to the vegetation treated sediments without jarosite (see Figures 4-61 and 4-62), no sulfide was detected with the addition of schwertmannite to these sediments (Tables 8-8 – 8-15, Appendix 3). The lack of dissolved sulfide with the addition of schwertmannite to the vegetation treated sediments (despite evidence of hydrolysis and reductive dissolution of schwertmannite) indicates the rapid formation of sulfide minerals; rapid formation of sulfide minerals with this treatment was also indicated by the sulfur data (see Section 4.3.4.1).

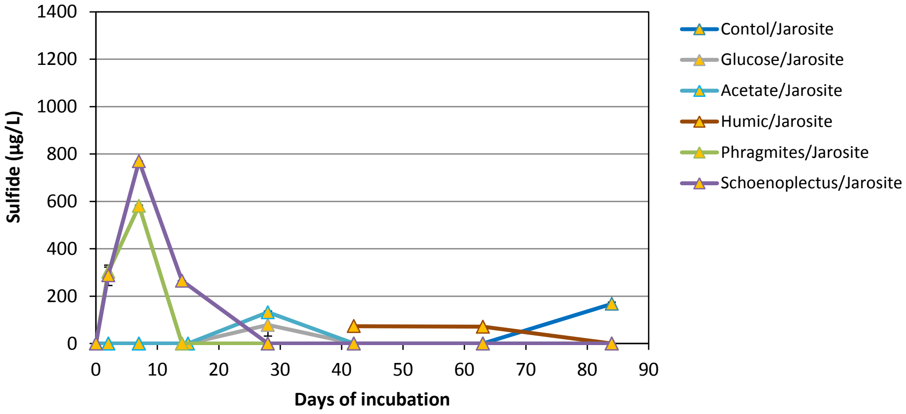

Figure 4-62. Waltowa (2.5 – 10 cm) surface water sulfide dynamics with the addition of jarosite.

4.3.5 Summary of Surface Water Parameter Trends

A summary table was created to gain an understanding of some of the high level trends/relationships with the surface water parameters discussed in Sections 4.3.1 to 4.3.4 (see Table 4-3). Table 4-3 compares the rank of the maximum value/concentration (where 1 represents the highest value and 6 represents the lowest value) for each treatment (i.e. control, glucose, acetate, humic acid, *Phragmites*, *Schoenoplectus*) during the 16 week incubation period. For example, the *Phragmites* treatment which had the highest EC (see Figures 4-53 and 4-54) is ranked 1, and the control had the lowest maximum value is ranked 6 (see Figures 4-53 and 4-54).

Table 4-3. Summary of the rank of the maximum parameter values/concentrations.

Treatment	**Parameter**				
	pH	**Eh***	**EC**	**Sulfur**	**Sulfide**
Control	2	1	6	5	5
Glucose	6	3	4	4	3
Acetate	1	2	3	5	4
Humic Acid	2	3	4	3	n.a.
Phragmites	4	5	1	2	2
Schoenoplectus	4	6	2	1	1

* *Eh decreased with time and therefore minimum value compared.*

Highest Value/ Concentration	1	2	3	4	5	6	Lowest Value/ Concentration

Table 4-3 highlights the fact that the addition of *Phragmites* and *Schoenoplectus* to the Waltowa sub-surface (2.5-10 cm) sediment resulted in higher surface water EC, soluble sulfur and sulfide concentrations than the other treatments. The addition of the three organic compounds (i.e. glucose, acetate, humic acid) usually resulted in an increase in these parameters when compared to the control. The addition of organic matter to the sediments also tended to result in a lower pH and higher Eh than the control.

A summary of the surface water parameter trends (including the jarosite and schwertmannite treated sediments) is provided in the following 'Summary of Section'.

Summary of Section

In the batch experiment various organics and two commonly found acid sulfate soil minerals (jarosite and schwertmannite) were added to Waltowa sub-surface (2.5-10 cm) sediment to examine their effect on the rate of recovery and mobilisation of metal(loid)s. The organics added included two plant materials (*Phragmites australis* and *Schoenoplectus validus*) and three organic compounds (acetate, glucose, and humic acid) which can form during the microbial degradation of plant material. As observed with the mesocosm experiment, with the addition of *Phragmites* and *Schoenoplectus* to the sediment the parameters showed a similar response. The response often varied between the addition of the organic compounds, jarosite and schwertmannite.

A similar pH response to the untreated control was observed with the addition of acetate and humic acid to the sediments, reaching a neutral pH after approximately 14 days (Figure 4-47). The addition of glucose, *Phragmites* and *Schoenoplectus* initially resulted in some acidification followed by a slow recovery; the pH was less than 6.5 after 12 weeks with these treatments (Figures 4-47 and 4-48). The addition of jarosite and schwertmannite to the control and the organic compound treatments usually resulted in a substantially lower pH than the non-treated control (Figure 4-49), indicating acidity is being released from the hydrolysis of these iron minerals. The addition of jarosite and schwertmannite to the vegetation treated sediments raised the pH higher than the sediments without these minerals, and occurred at a faster rate with the schwertmannite treated sediments (Figure 4-49). This indicates that far greater reductive dissolution and acid neutralisation occurred when jarosite and schwertmannite were added to the two vegetation types.

As expected, the surface water redox potential (Eh) initially decreased with all treatments (Figures 4-50, 4-51 and 4-52). The untreated control had a lower Eh than the organic treated sediments (Figures 4-50 and 4-51). The addition of jarosite and schwertmannite increased the Eh compared to the organic treated controls, except when added to the vegetation treated sediments where the Eh was substantially lower after 4 weeks (Figure 4-52).

As observed with the mesocosm experiment, the addition of vegetation resulted in a substantial initial increase in the surface water electrical conductivity (EC) when compared to the control (Figure 4-54). The addition of jarosite and schwertmannite to all treatments also resulted in substantially higher EC values than the controls. This indicates ions are being released into the surface water from the hydrolysis and/or reductive dissolution of these iron minerals.

The water soluble sulfur concentrations were low with the untreated control and the organic treated sediments (i.e. < 70 mg/L), and decreased substantially within the initial 2-4 weeks (Figures 4-56 and 4-57). The decrease in the water soluble sulfur concentration was enhanced when organic matter was added. The addition of jarosite and schwertmannite to the control and the organic compound treatments resulted in substantially higher sulfur concentrations than the non-treated control (Figure 4-58). The addition of jarosite to the vegetation treatments showed a similar response, however, the addition schwertmannite showed a rapid decline in the sulfur concentration after 7 days of incubation (Figure 4-58); the decline was particularly rapid with the *Phragmites* treatment. A decline in the surface water iron concentration was also observed with these treatments (Figure 4-65), and would indicate the formation of iron sulfide minerals. Visual indications of a black mineral forming also suggested the formation of iron monosulfides with many of the schwertmannite and/or jarosite treatments (e.g. Figure 5-59).

The addition of organic matter resulted in an increase in the surface water sulfide concentration over the initial 4 weeks (Figures 4-60 and 4-61). The addition of glucose resulted in greater sulfide concentrations than the addition of acetate (Figure 4-60), and the addition of vegetation led to further increases in the sulfide concentration (Figure 4-61). The addition of jarosite and schwertmannite to the control and the organic compound treatments usually resulted in minimal sulfide formation (e.g. Figure 4-62). Whilst the addition of jarosite to the vegetation treated sediments showed similar sulfide behaviour to these sediments without jarosite (see Figures 4-61 and 4-62), no sulfide was detected following the addition of schwertmannite, indicating the rapid formation of sulfide minerals.

As observed in the mesocosm experiment, the results showed the addition of vegetation substantially slowed the rate of recovery of the Waltowa sub-surface sediment (due to the formation of organic acids). The addition of glucose showed similar response, and both acetate and humic acid had a minimal effect on the pH recovery of the sediments. The presence of jarosite and schwertmannite often resulted in further acidification (due acidity being released from the hydrolysis of these iron minerals) and a slow recovery. However, a rapid recovery was observed in the presence of vegetation suggesting that acidity was rapidly consumed by the reductive dissolution of these iron minerals; the formation of sulfide minerals was also indicated visual indications and by the decrease in the soluble sulfur and sulfide concentrations.

4.3.6 Selected Metal(loid)s

In this section the batch experiment surface water results for selected metal(loid)s including iron (Fe), manganese (Mn), arsenic (As), cobalt (Co), copper (Cu), nickel (Ni), potassium (K) and zinc (Zn) are presented. These metal(loid)s were selected as they were the primary metal(loid)s that were released into solution during the mesocosm experiment (see Section 4.2.1.9). Potassium has also been included as it was released into solution as a consequence of jarosite dissolution.

4.3.6.1 Iron (Fe)

The change in surface water iron concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-63 and 4-64. A comparison of the Fe^{2+} and total iron concentrations showed that the water soluble iron fraction was virtually entirely in the Fe^{2+} form (Figure 8-24, Appendix 7). Without the addition of organic matter (i.e. control) the surface water iron concentration increased slightly over the initial 14 days to a maximum concentration of 4.1 mg/L and then decreased (Figure 4-63). The addition of acetate and humic acid showed a similar trend with the release of slightly more iron released than the control (up to 13.6 mg/L with the humic acid treatment). The addition of glucose resulted in substantially more iron being released into solution (up to 37.4 mg/L) indicating greater reductive dissolution of iron minerals than the other treatments.

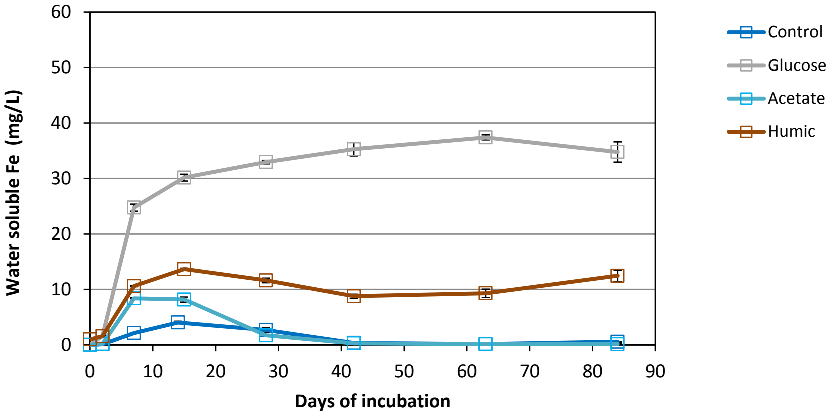

Figure 4-63. Waltowa (2.5 – 10 cm) surface water iron dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a substantial increase in the surface water iron concentration (Figure 4-64) as observed in the mesocosm experiment (see Section 4.2.1.9.1 for further details). The addition of vegetation resulted in more iron being released into solution than the glucose treatment, with approximately 50 mg/L of iron being released.

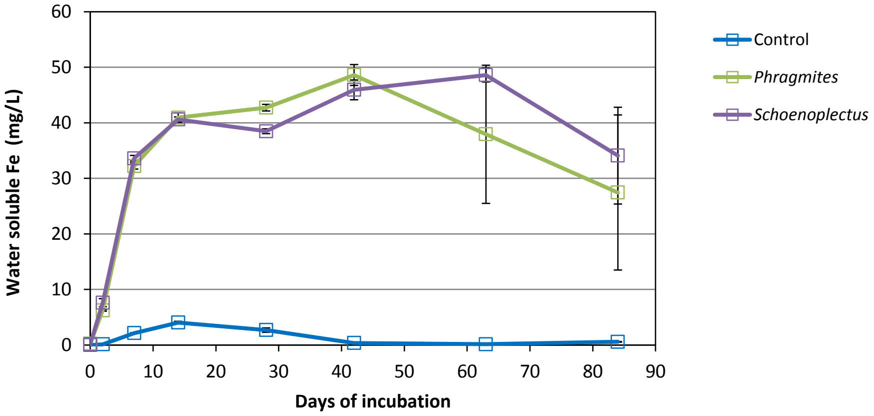

Figure 4-64. Waltowa (2.5 – 10 cm) surface water iron dynamics with and without the addition of vegetation.

The change in surface water iron concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-65. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in a substantial increase in the dissolved iron concentration, particularly after 4 weeks of incubation. The addition of jarosite and schwertmannite to the glucose treatment showed the highest release in dissolved iron, and this was closely followed by the acetate treatment. The addition of jarosite and schwertmannite to humic acid treatment largely showed a similar response to the control treated with the iron minerals.

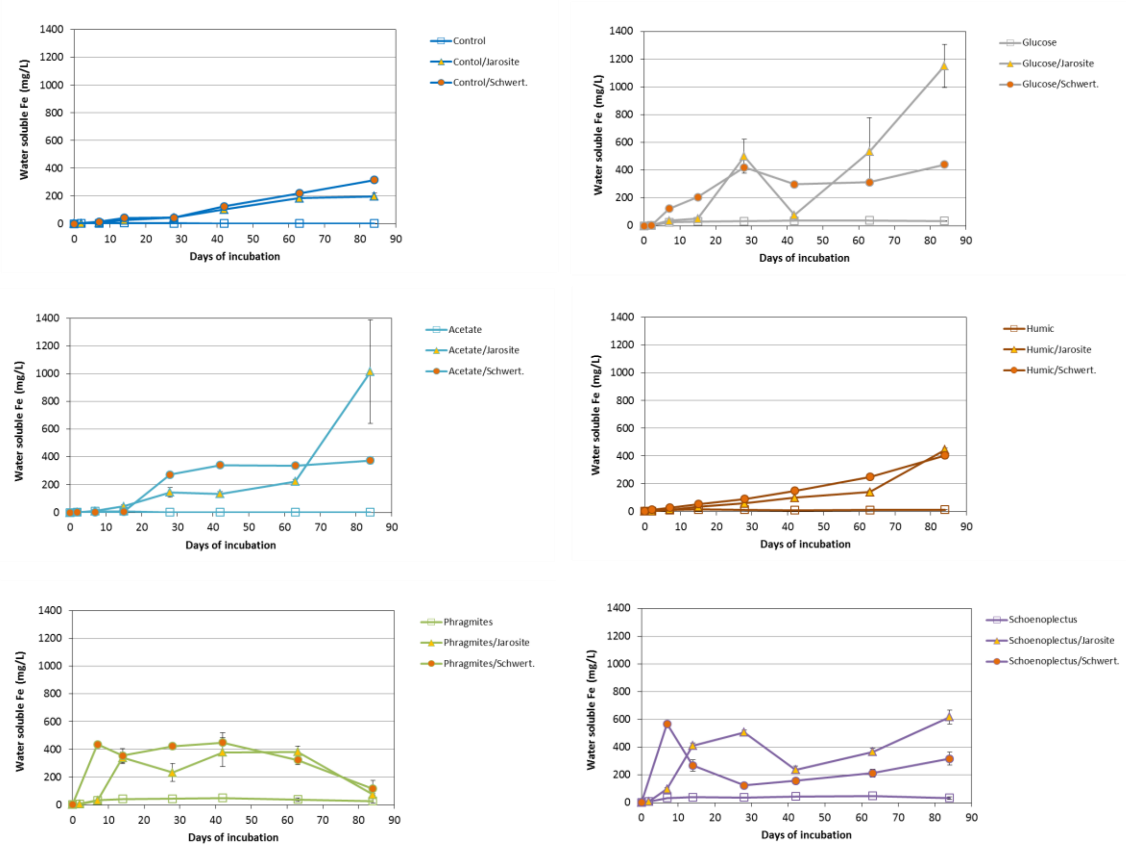

Figure 4-65. Waltowa (2.5 – 10 cm) surface water Fe dynamics with and without the addition of organic matter, jarosite and schwertmannite.

As discussed earlier (see Section 4.3.1), the data suggests that the increase in iron is both from the hydrolysis and reductive dissolution of the added iron minerals. There may also be greater reduction of the iron minerals associated with the sediment. The addition of jarosite and schwertmannite to the vegetation treated sediment showed a much earlier response (particularly with the schwertmannite treatment), suggesting a quicker onset of reductive dissolution. In addition, a decrease in the iron concentration was also observed, and along with a decrease in the sulfur concentration (see Section 4.3.4.1), the data would indicate the decrease was the result of iron sulfide formation.

The pH and redox potential for the batch experiment have been plotted on an iron pE/pH diagram (Figure 4-66); note the stability fields have been estimated for the experimental conditions. As with the mesocosm experiment most of the data is in the Fe^{2+} stability field.

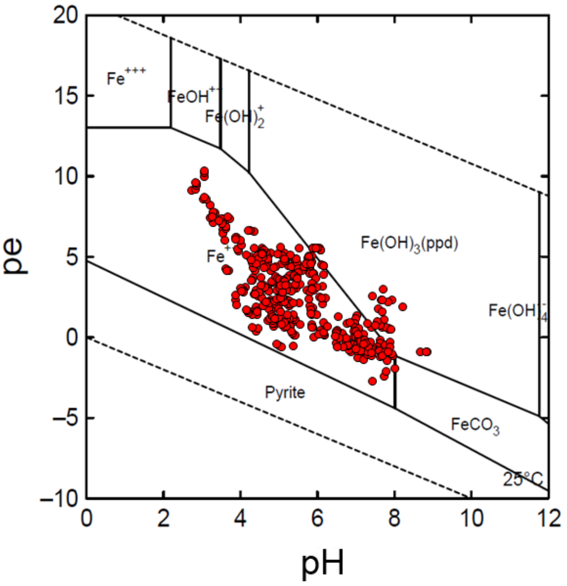

Figure 4-66. Iron pE/pH diagram for batch surface waters.

4.3.6.2 Manganese (Mn)

The change in surface water manganese concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-67 and 4-68. Without the addition of organic matter (i.e. control) the surface water manganese concentration increased slightly over the initial 7 days and then steadily decreased (Figure 4-67). The addition of the three organic compounds (i.e. glucose, acetate and humic acid) showed the same response as iron (see Figure 4-63), with glucose showing the greatest increase as a result of reductive dissolution.

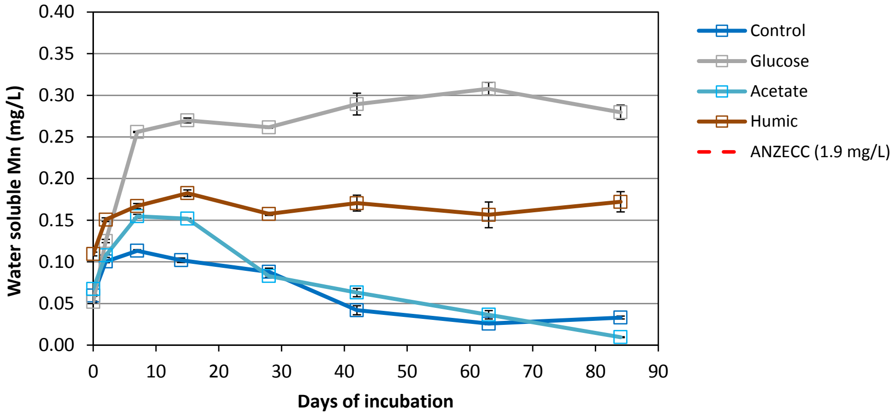

Figure 4-67. Waltowa (2.5 – 10 cm) surface water manganese dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a substantial increase in the surface water manganese concentration (Figure 4-68) as observed in the mesocosm experiment (see Section 4.2.1.9.2 for further details). The addition of vegetation resulted in substantially more manganese being released into solution than the glucose treatment, with up to approximately 1.5 mg/L of manganese being released. The manganese concentration in the surface waters did not exceed the ANZECC water quality guideline with all treatments.

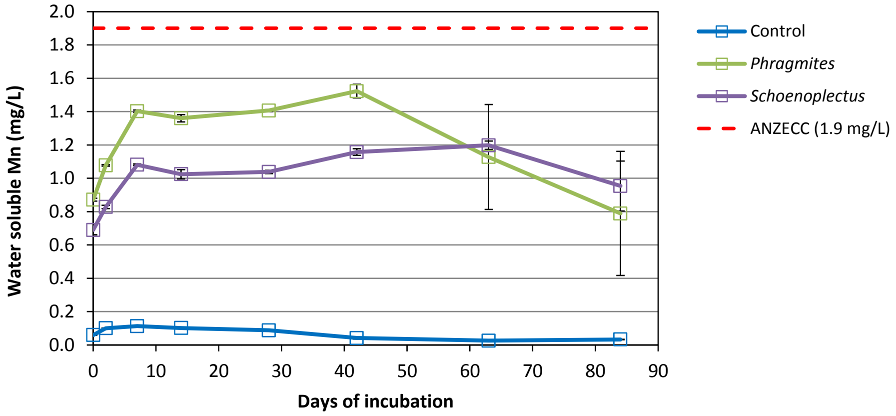

Figure 4-68. Waltowa (2.5 – 10 cm) surface water manganese dynamics with and without the addition of vegetation.

A summary of the change in surface water manganese concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-69 and 4-70. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in a steady increase in the manganese concentration. The addition of jarosite to the glucose and acetate treatments showed a slightly greater release of dissolved manganese when compared to the jarosite treated control (Figure 4-69). The addition of schwertmannite to the glucose treatment also showed a slightly greater release of dissolved manganese when compared to the treated control

(Figure 4-69). The data suggests that the increase in manganese is from the reductive dissolution of manganese minerals present in the sediment (i.e. manganese oxides and oxyhydroxides).

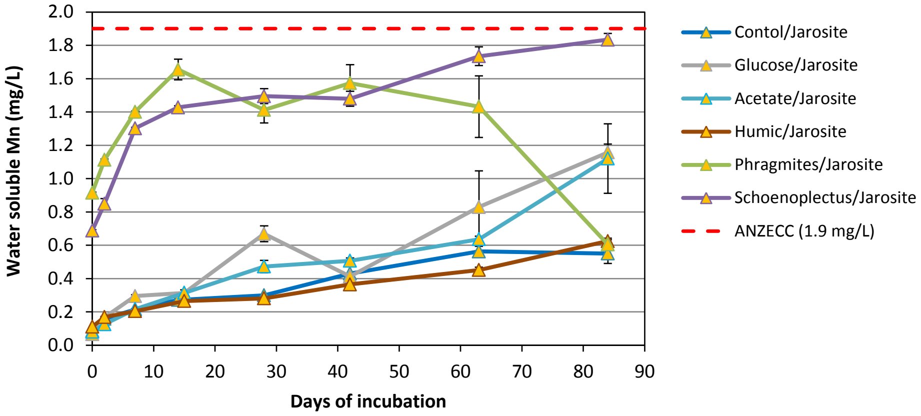

Figure 4-69. Waltowa (2.5 – 10 cm) surface water manganese dynamics with the addition of jarosite.

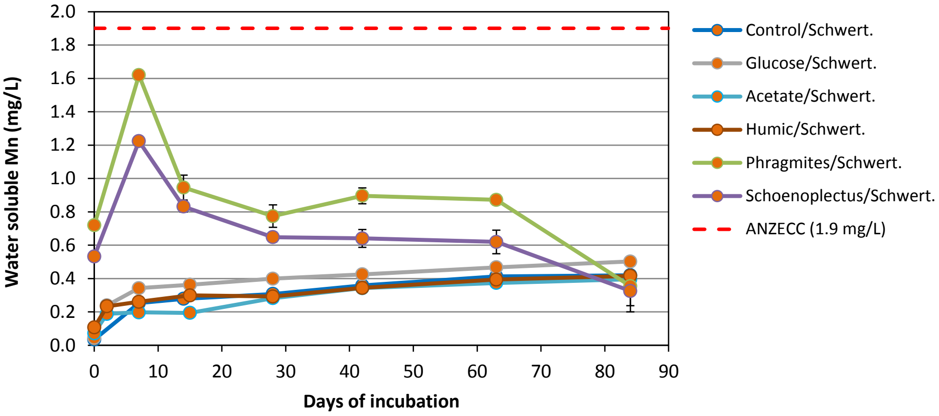

Figure 4-70. Waltowa (2.5 – 10 cm) surface water manganese dynamics with the addition of schwertmannite.

The addition of jarosite and schwertmannite to the vegetation treated sediment showed a much earlier and greater response, indicating the rapid onset of reductive dissolution. The addition of schwertmannite showed a maximum manganese concentration of 1.62 mg/L in the *Phragmites* and 1.22 mg/L in the *Schoenoplectus* treatments after 7 days of incubation (Figure 4-70).

4.3.6.3 Arsenic (As)

The change in surface water arsenic concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-71 and 4-72. A rapid increase in the surface water arsenic concentration was observed over the initial 7-14 days with the control and the three organic compound treatments (Figure 4-71). The addition of glucose resulted in substantially less arsenic being released into the surface water. The release of arsenic also shows the same trend as that observed with the pH (see Figure 4-47) and a strong correlation with pH (Figure 8-25, Appendix 7). This behaviour suggests that arsenic is in the form of arsenate (As V), which is much more strongly sorbed at low pH.

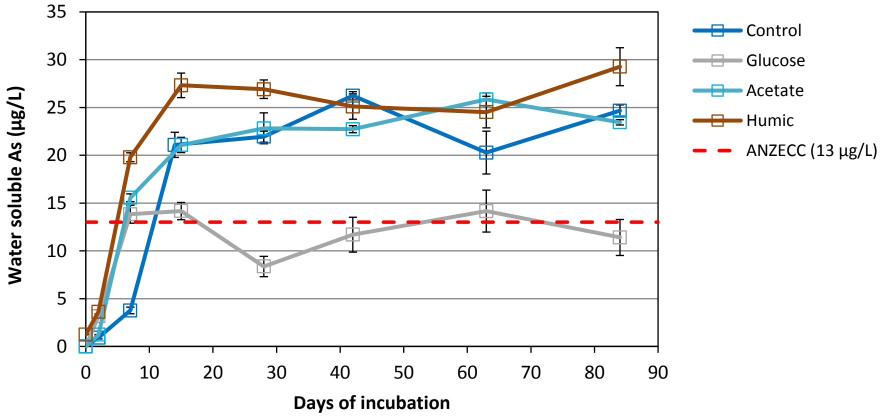

Figure 4-71. Waltowa (2.5 – 10 cm) surface water arsenic dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation suppresses the release of arsenic into the surface water (Figure 4-72) as observed in the mesocosm experiment (see Section 4.2.1.9.4 for further details).

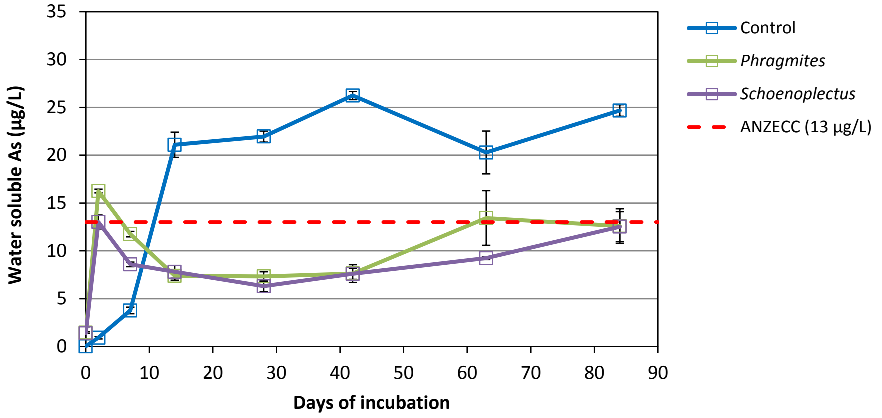

Figure 4-72. Waltowa (2.5 – 10 cm) surface water arsenic dynamics with and without the addition of vegetation.

The change in surface water arsenic concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-73. The data clearly shows that the release of arsenic was substantially suppressed when the sediment was treated with schwertmannite. The data would suggest that when schwertmannite was added to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) the low pH resulted in the sorption of arsenate (As V) to the mineral surface of schwertmannite (e.g. Burton *et al.* 2009). However, when schwertmannite was added to the vegetation treated samples the stronger reducing conditions may have resulted in the reduction of arsenate (As V) to arsenite (As III) which is sorbed at the near-neutral pH of these treatments (see Figure 4-49). The level of arsenic in the jarosite treatments seems to reflect the surface water pH.

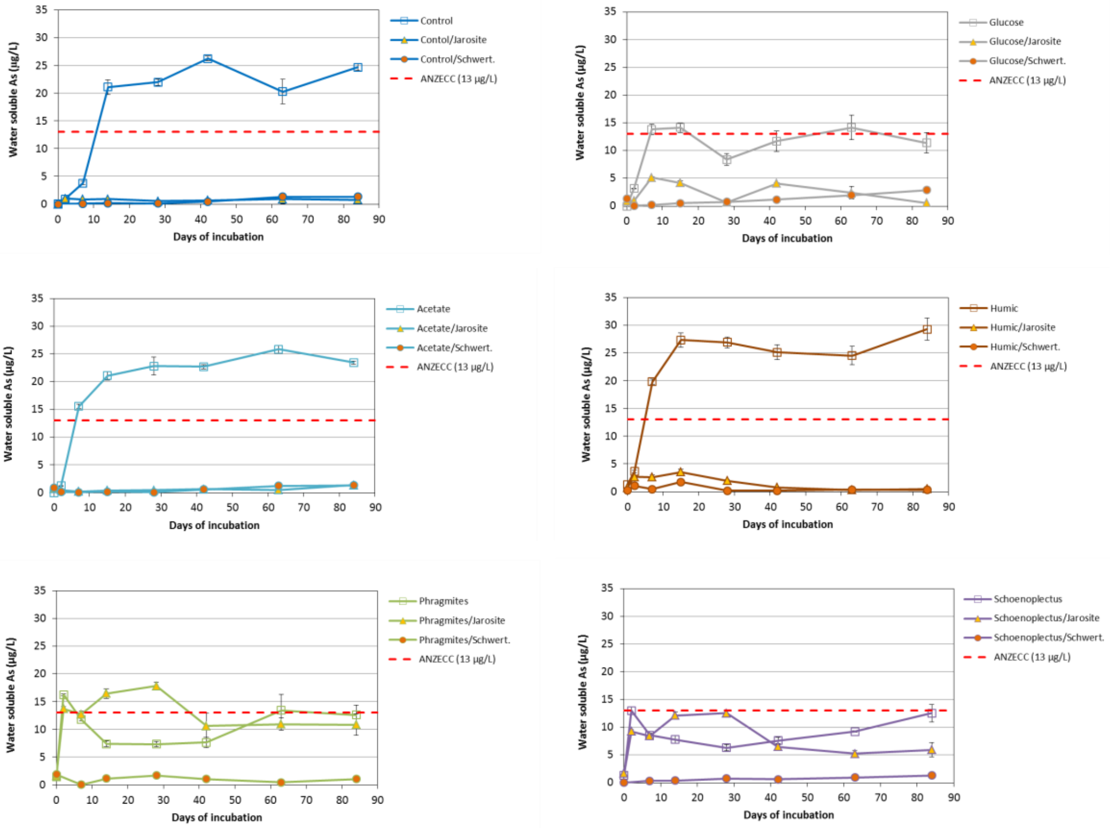

Figure 4-73. Waltowa (2.5 – 10 cm) surface water arsenic dynamics with and without the addition of organic matter, jarosite and schwertmannite.

While the ANZECC water quality guideline for arsenic was often exceeded with the organic matter treatments, the addition of jarosite and schwertmannite clearly reduced the arsenic concentrations and was only exceeded with the *Phragmites*/jarosite treatment (Figure 4-73).

4.3.6.4 Cobalt (Co)

The change in surface water cobalt concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-74 and 4-75. Without the addition of organic matter (i.e. control) the surface water cobalt concentration increased slightly over the initial 7 days and then rapidly decreased (Figure 4-74). The addition of humic acid substantially increased the surface water cobalt concentration from Day 0 indicating that the cobalt is derived from the humic acid. While the acetate treatment showed a similar trend to the control, the addition of glucose clearly increased the cobalt surface water concentration. As with the mesocosm experiment, the release of cobalt data suggests that the release of cobalt is associated with the reduction of iron and manganese minerals in the sediment (see Section 4.2.1.9.6).

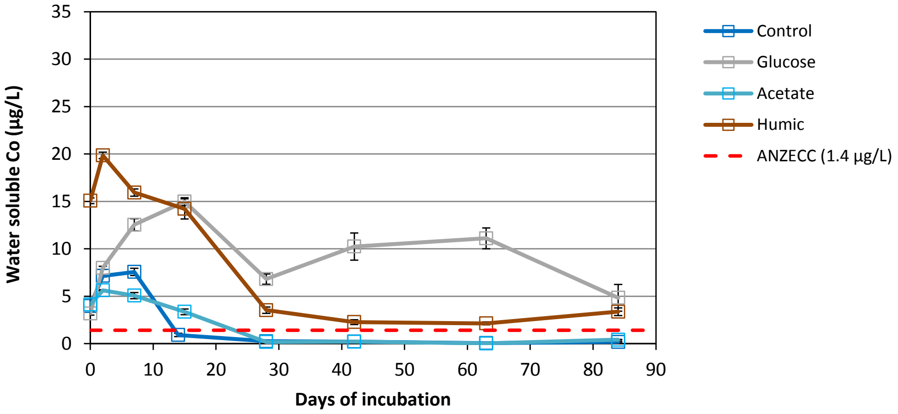

Figure 4-74. Waltowa (2.5 – 10 cm) surface water cobalt dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a substantial increase in the surface water cobalt concentration (Figure 4-75) as observed in the mesocosm experiment (see Section 4.2.1.9.6 for further details). The addition of vegetation resulted in more cobalt being released into solution than with the glucose treatment.

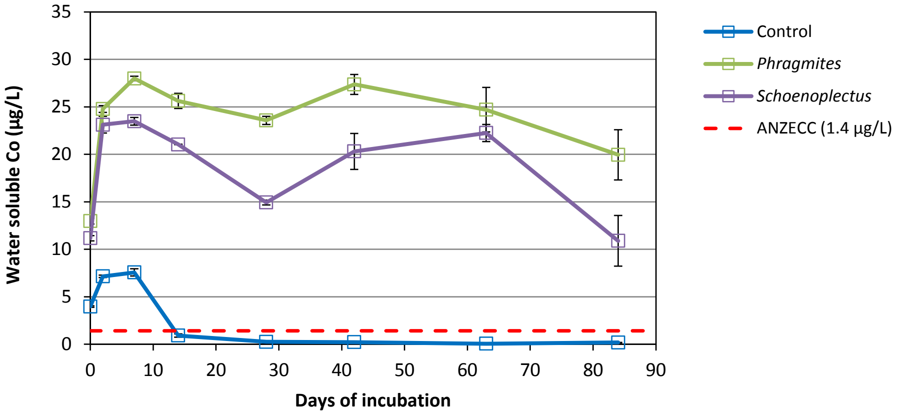

Figure 4-75. Waltowa (2.5 – 10 cm) surface water cobalt dynamics with and without the addition of vegetation.

The change in surface water cobalt concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-76. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in a substantial increase in the dissolved cobalt concentration (Figure 4-76). However, there was a substantial reduction in the cobalt concentration by Week 12 with the jarosite treated sediments. The addition of jarosite and schwertmannite to the vegetation treated samples showed the cobalt concentration rapidly diminished during the incubation experiment (Figure 4-76).

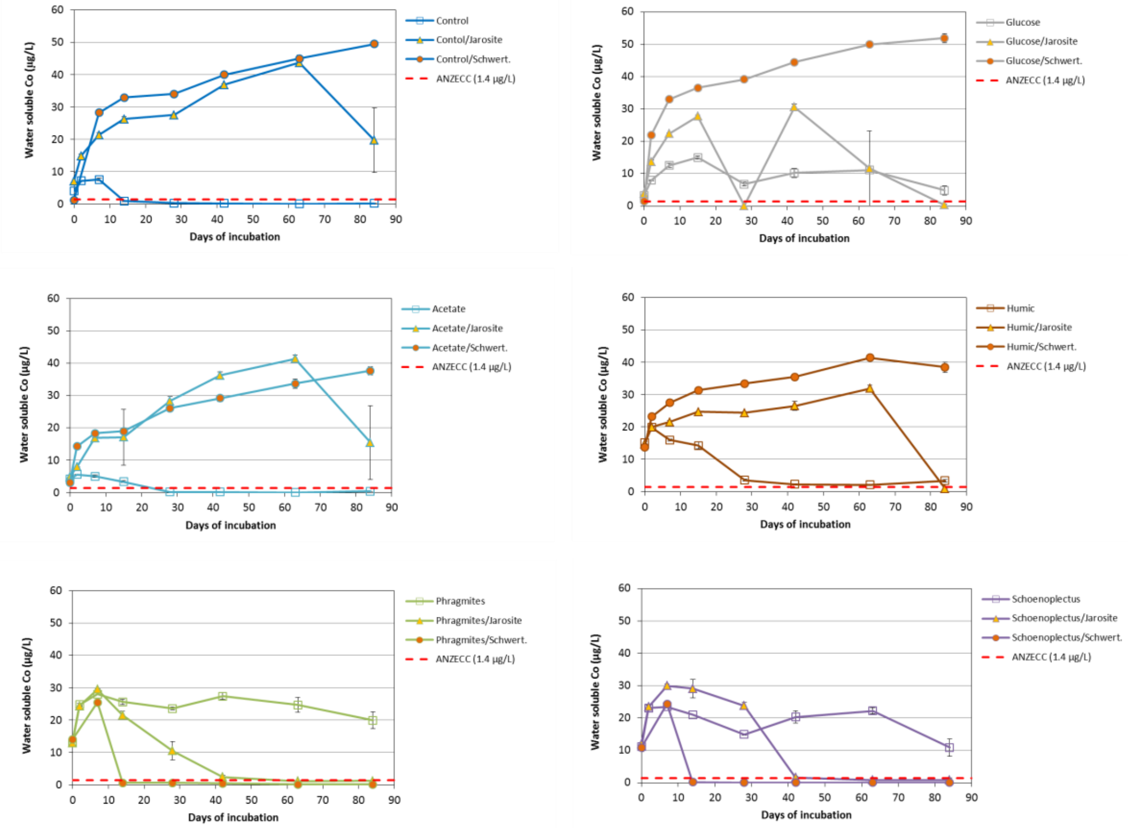

Figure 4-76. Waltowa (2.5 – 10 cm) surface water cobalt dynamics with and without the addition of organic matter, jarosite and schwertmannite.

The data indicates that the change in the surface water cobalt concentration is largely related to the effect these minerals have on the pH of the surface water (see Figures 8-26 and 8-27, Appendix 7). As the pH increases cobalt becomes less soluble; this relationship is particularly clear with the schwertmannite treated samples (Figure 8-27, Appendix 7). However, a closer examination of the data for the sediments treated with both *Phragmites* and *Schoenoplectus* and jarosite/schwertmannite shows that the removal of cobalt from solution at around pH 7 is clearly not only due to the surface water pH (see Figures 8-28 and 8-29, Appendix 7). It is most likely that cobalt is being precipitated as a sulfide; there also may be some cobalt adsorption by the added iron minerals.

4.3.6.5 Copper (Cu)

The change in surface water copper concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-77 and 4-78. The results clearly show that the humic acid standard used had relatively high copper concentrations (Figure 4-77). Low copper concentrations (i.e. ≤ 1 µg/L) were observed throughout the incubation with the control and the addition of both glucose and acetate to the sediment.

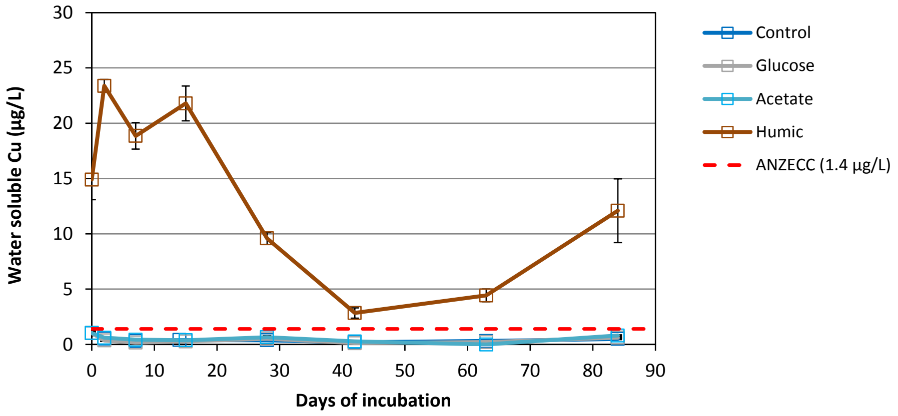

Figure 4-77. Waltowa (2.5 – 10 cm) surface water copper dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in an initial increase in the surface water copper concentration (Figure 4-78) as observed in the mesocosm experiment (see Section 4.2.1.9.7 for further details). The addition of vegetation resulted in less copper being released into solution than with the humic acid treatment.

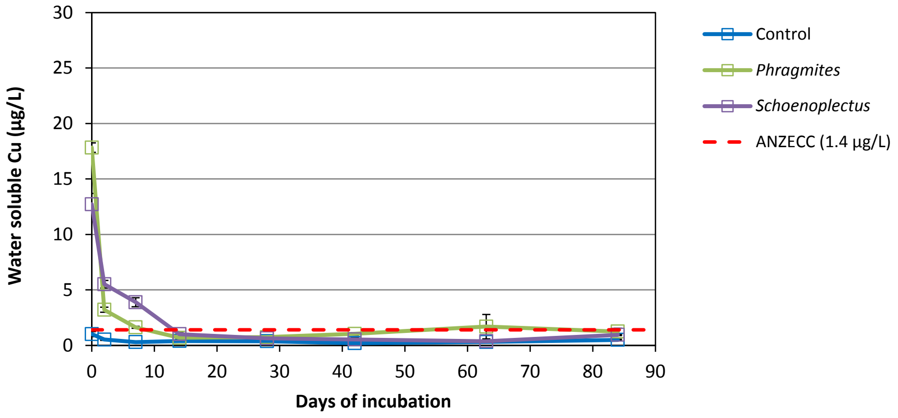

Figure 4-78. Waltowa (2.5 – 10 cm) surface water copper dynamics with and without the addition of vegetation.

The change in surface water copper concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-79. The addition of jarosite and schwertmannite to the control and the acetate treated sediments resulted in minimal change in the copper concentration (Figure 4-79). The addition of jarosite and schwertmannite to the glucose treated sediment also showed a similar trend, except there was an increase in the copper concentration with the glucose/schwertmannite treated sediments from Week 6. This increase in copper is due to the low pH (i.e. pH ≤ 3) of the surface water from this period (see Figure 4-49). The addition of jarosite and schwertmannite to the humic acid treated sediments showed a decrease during incubation probably due to adsorption by organic matter. The addition of jarosite and schwertmannite to the vegetation treated samples showed the copper concentration rapidly diminished during the incubation experiment (Figure 4-79); the trend was similar to that observed with the vegetation treated sediments without the addition of jarosite and schwertmannite.

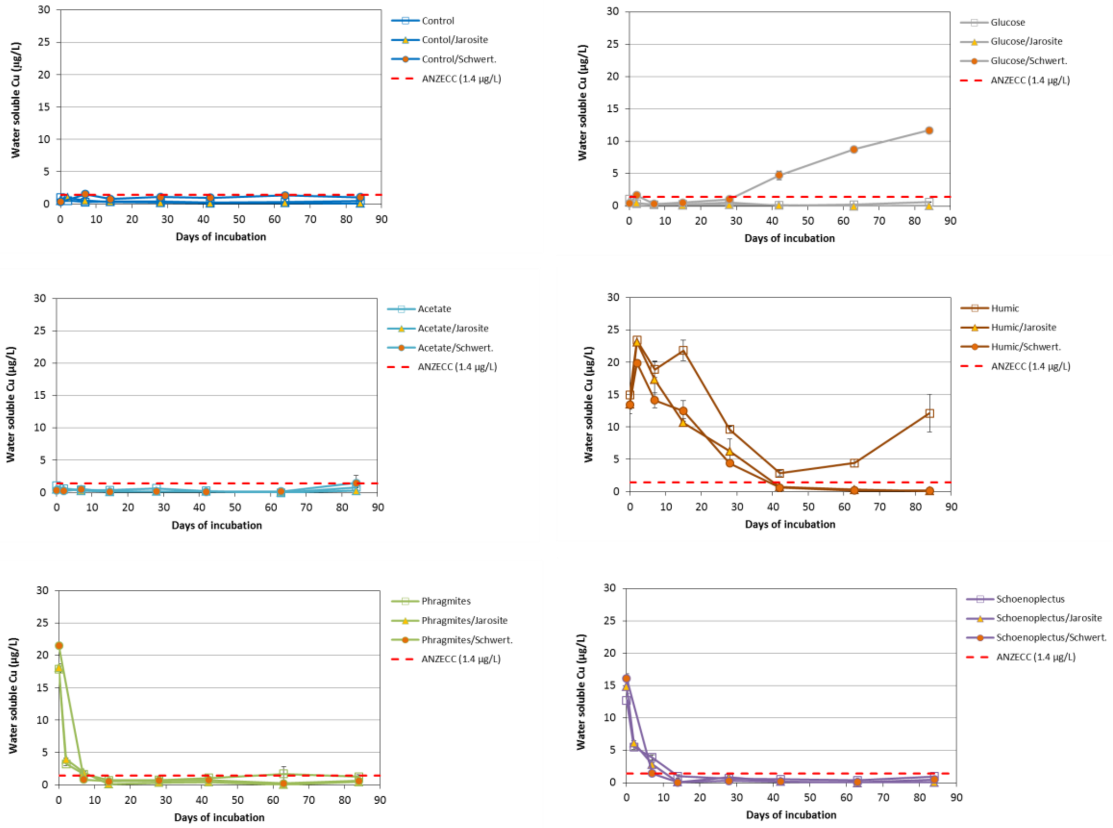

Figure 4-79. Waltowa (2.5 – 10 cm) surface water copper dynamics with and without the addition of organic matter, jarosite and schwertmannite.

4.3.6.6 Nickel (Ni)

The change in surface water nickel concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-80 and 4-81. As also observed in the mesocosm experiment, the behaviour of nickel and cobalt were strongly related (see Section 4.2.1.9.10). Without the addition of organic matter (i.e. control) the surface water nickel concentration initially increased slightly over the initial 7 days and then rapidly decreased (Figure 4-80). The addition of humic acid substantially increased the surface water nickel concentration from Day 0 indicating that the nickel is derived from the humic acid. While the acetate treatment showed a similar trend to the control, the addition of glucose clearly increased the nickel surface water concentration. As with the mesocosm experiment, the release of nickel data suggests that the release of nickel is associated with the reduction of iron and manganese minerals in the sediment (see Section 4.2.1.9.10).

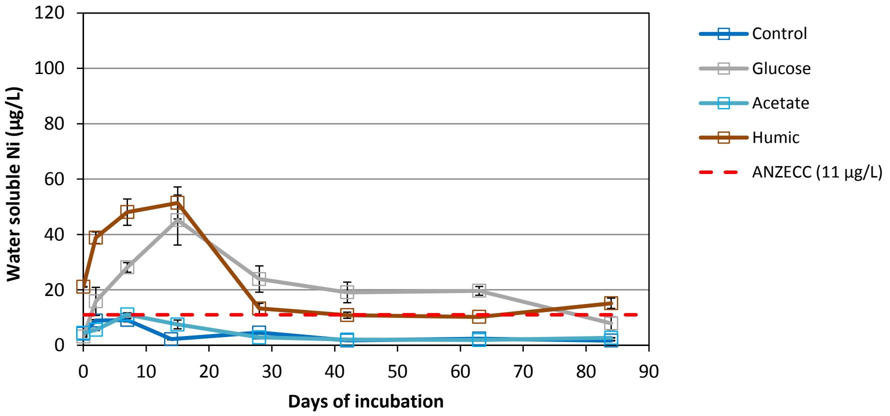

Figure 4-80. Waltowa (2.5 – 10 cm) surface water nickel dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation resulted in a substantial increase in the surface water nickel concentration (Figure 4-81) as observed in the mesocosm experiment (see Section 4.2.1.9.10 for further details). The addition of vegetation resulted in more nickel being released into solution than with the glucose treatment.

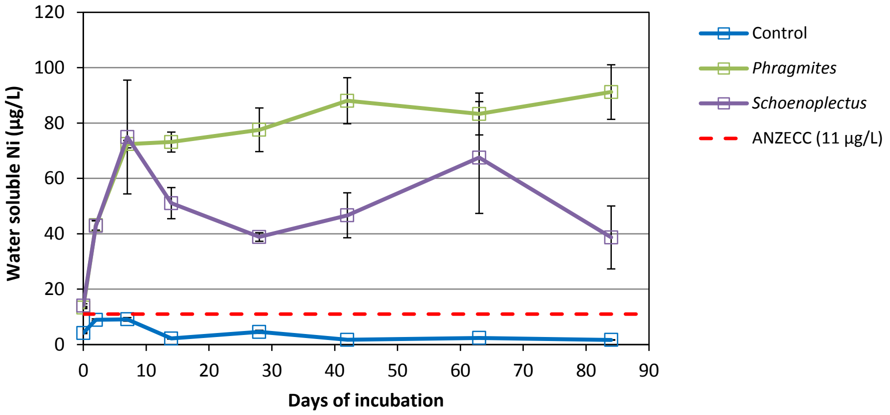

Figure 4-81. Waltowa (2.5 – 10 cm) surface water nickel dynamics with and without the addition of vegetation.

The change in surface water nickel concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-82. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) resulted in a substantial increase in the dissolved nickel concentration (Figure 4-82). However, there was a substantial reduction in the nickel concentration by Week 12 with the jarosite treated sediments. The addition of jarosite and schwertmannite to the vegetation treated samples showed the nickel concentration rapidly reduced during the incubation experiment (Figure 4-82).

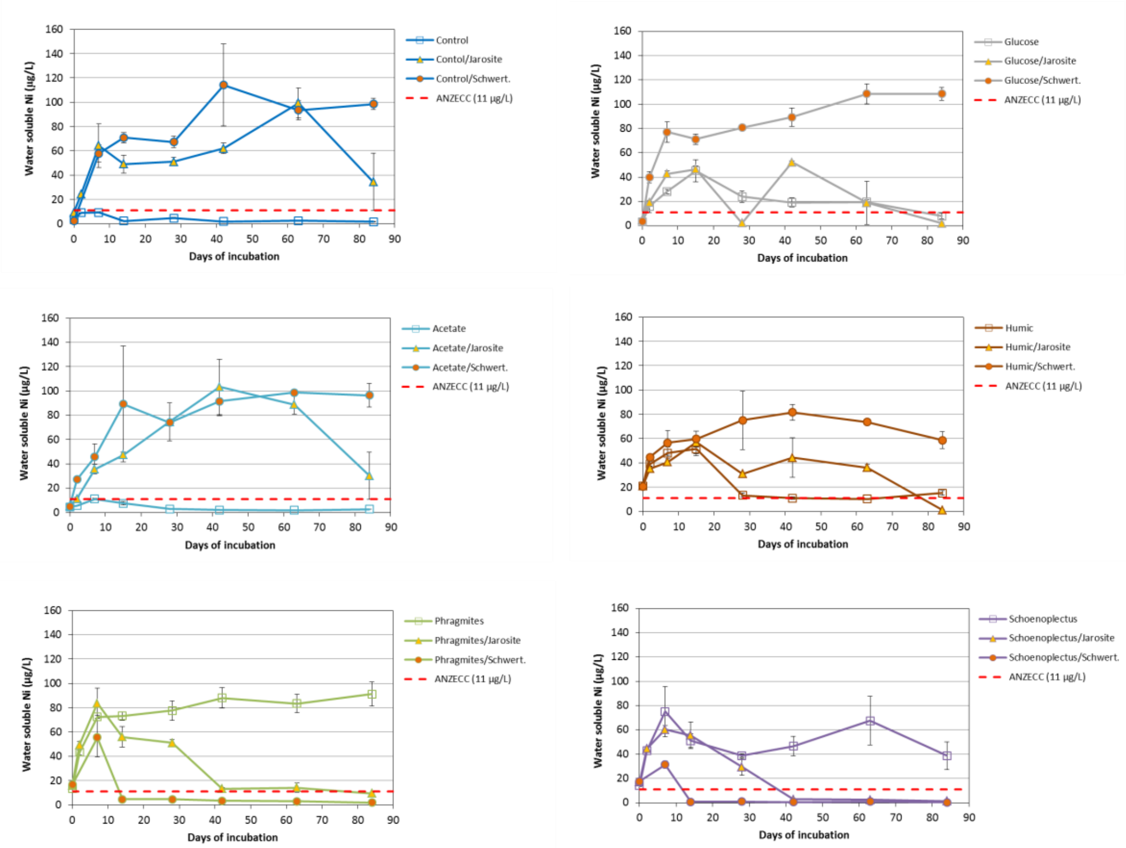

Figure 4-82. Waltowa (2.5 – 10 cm) surface water nickel dynamics with and without the addition of organic matter, jarosite and schwertmannite.

The data indicates that the change in the surface water nickel concentration (like cobalt) is largely related to the effect these minerals have on the pH of the surface water (see Figures 8-30 and 8-31, Appendix 7). As the pH increases nickel becomes less soluble; this relationship is particularly clear with the schwertmannite treated samples (Figure 8-31, Appendix 7). However, a closer examination of the data for the sediments treated with both *Phragmites* and *Schoenoplectus* and jarosite/schwertmannite shows that the removal of nickel from solution at around pH 7 is clearly not only due to the surface water pH (see Figures 8-32 and 8-33, Appendix 7). It is most likely that nickel (like cobalt) is being precipitated as a sulfide; there also may be some nickel adsorption by the added iron minerals.

4.3.6.7 Potassium (K)

The change in surface water potassium concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-83.
Low surface water potassium concentrations were observed in the three organic compounds treatments (i.e. glucose, acetate and humic acid) and in the surface water without the addition of organic matter (i.e. control). As observed with the mesocosm, the addition of vegetation substantially increased the cation and anion concentrations, including potassium (see Section 4.2.1.3).

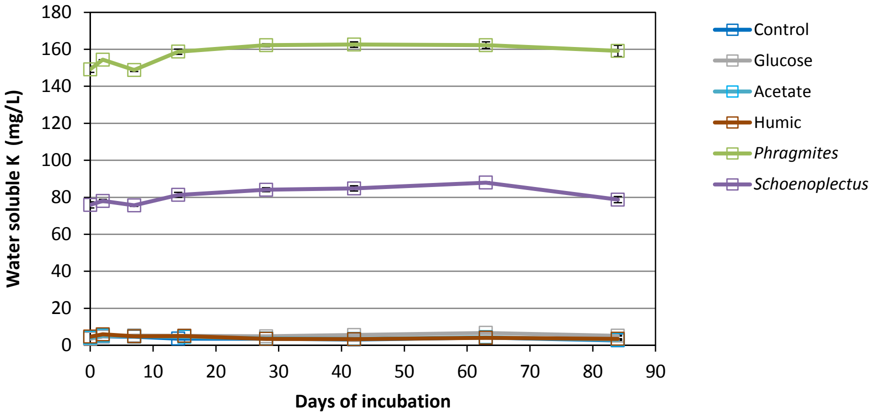

Figure 4-83. Waltowa (2.5 – 10 cm) surface water potassium dynamics with and without the addition of organic matter.

The addition of jarosite (a potassium containing mineral) to each of the treatments caused a substantial increase in the water soluble potassium concentrations as a result of jarosite dissolution. Figure 4-84 below shows the effect of the various organic treatments on the dissolution of jarosite. As indicated by the previous data the addition of vegetation resulted in the greatest dissolution, followed by the addition of glucose.

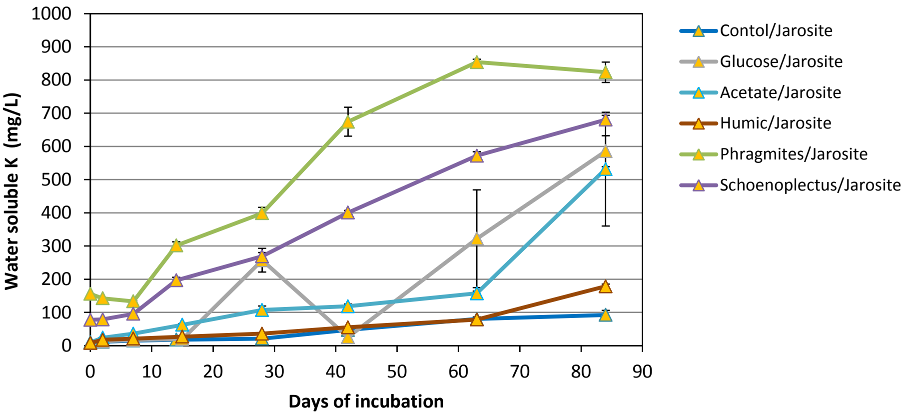

Figure 4-84. Waltowa (2.5 – 10 cm) surface water potassium dynamics jarosite treatment with and without the addition of organic matter.

4.3.6.8 Zinc (Zn)

The change in surface water zinc concentration during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5 -10 cm) is shown in Figures 4-85 and 4-86. The results clearly show that the humic acid standard used had relatively high zinc concentrations (Figure 4-85). The addition of acetate only resulted in a slight increase in the zinc concentration over the early stages of the incubation (i.e. 2 days), with the addition of glucose resulting in a steady increase over the initial 4 weeks.

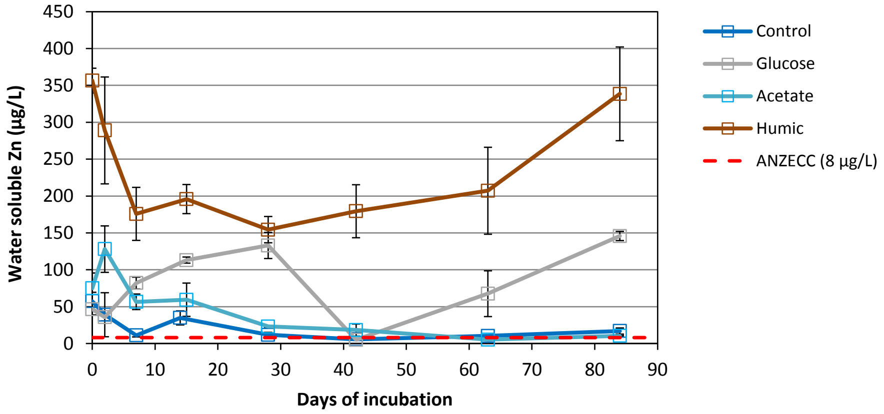

Figure 4-85. Waltowa (2.5 – 10 cm) surface water zinc dynamics with and without the addition of glucose, acetate and humic acid.

The addition of vegetation clearly increased the surface water zinc concentration, and as discussed previously is largely derived from the vegetation (see Section 4.2.1.9.13). The addition of vegetation resulted in more zinc being released into solution than with the glucose treatment.

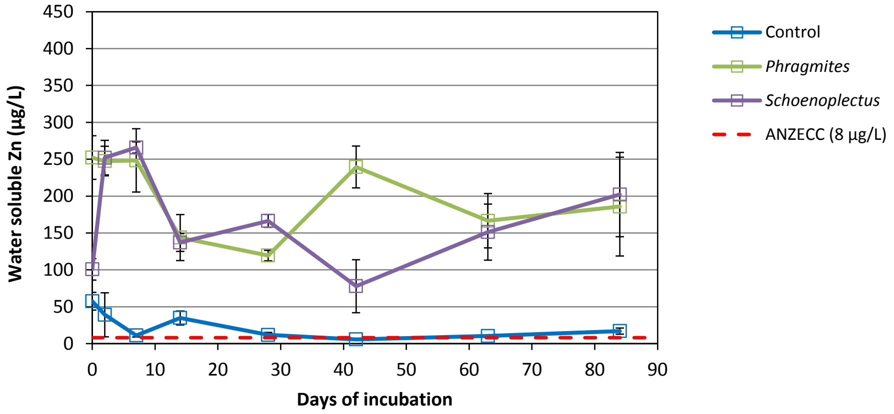

Figure 4-86. Waltowa (2.5 – 10 cm) surface water zinc dynamics with and without the addition of vegetation.

The change in surface water zinc concentration during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-87. The addition of jarosite and schwertmannite to the control and the non-vegetation organic matter treatments (i.e. glucose, acetate and humic acid) often resulted in an increase in the dissolved zinc concentration (Figure 4-87). The addition of jarosite and schwertmannite to the vegetation treated samples showed the zinc concentration rapidly reduced over the initial 2 weeks and was lower than the control during the incubation (Figure 4-87).

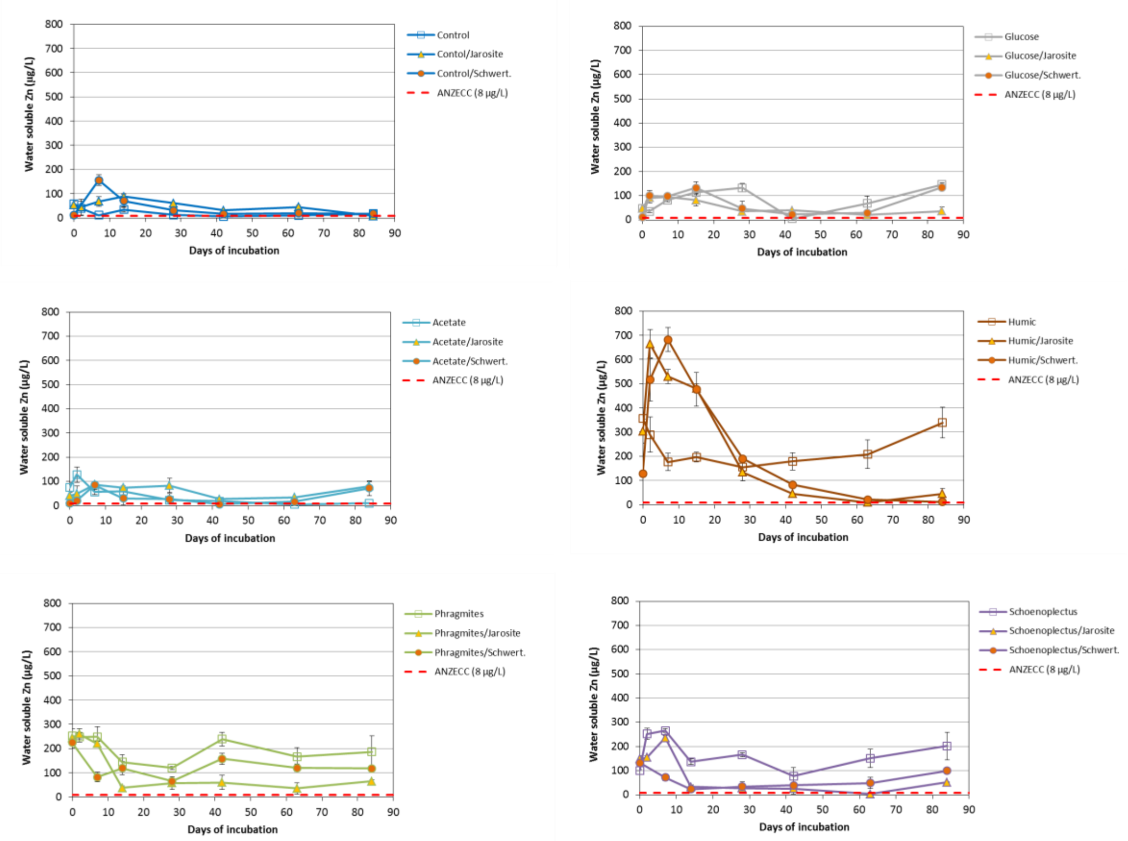

Figure 4-87. Waltowa (2.5 – 10 cm) surface water zinc dynamics with and without the addition of organic matter, jarosite and schwertmannite.

The data indicates that the change in the surface water zinc concentration (like cobalt and nickel) is largely related to the effect these minerals have on the pH of the surface water (see Figures 8-34 and 8-35, Appendix 7). As the pH increases zinc becomes less soluble; this relationship is particularly clear with the jarosite treated samples (Figure 8-34, Appendix 7). With the vegetation treated sediments the precipitation of zinc sulfide or adsorption of zinc by the added iron minerals may also play a role.

The addition of all types of organic matter, jarosite and schwertmannite resulted in the surface water zinc concentration greatly exceeding the ANZECC water quality guideline value.

4.3.6.9 Summary of Metal(loid) Trends

A summary table was created to gain an understanding of some of the high level trends/relationships with the surface water metal(loid) concentrations observed in the batch experiment (see Table 4-4). Table 4-4 compares the rank of the maximum concentration (where 1 represents the highest concentration and 6 represents the lowest concentration) for each treatment (i.e. control, glucose, acetate, humic acid, *Phragmites*, *Schoenoplectus*) during the 16 week incubation period. For example, the *Phragmites* treatment which had the highest manganese concentration (see Figures 4-67 and 4-68) is ranked 1, and the control had the lowest maximum concentration is ranked 6 (see 4-67 and 4-68).

Table 4-4. Summary of the rank of the maximum metal(loid) concentrations.

Treatment	**Metal(loid)**							
	Fe	**Mn**	**As**	**Co**	**Cu**	**Ni**	**K**	**Zn**
Control	6	6	**2**	**5**	4	6	6	**6**
Glucose	3	3	**5**	**4**	4	**4**	3	**4**
Acetate	5	5	**2**	**6**	4	**5**	5	**4**
Humic Acid	4	4	**1**	**3**	**1**	**3**	4	**1**
Phragmites	1	1	**4**	**1**	**2**	**1**	1	**2**
Schoenoplectus	1	2	**6**	**2**	**3**	**2**	2	**2**

Bold red values *indicate that the concentration exceeded ANZECC Guideline Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems (ANZECC/ARMCANZ 2000).*

Highest concentration	1	2	3	4	5	6	Lowest concentration

The addition of organic matter to the Waltowa sub-surface (2.5-10 cm) sediment often resulted in an increase in the mobilisation of metal(loid)s (Table 4-4). Many of the metal(loid)s examined were at their lowest concentration in the surface water without the addition of organic matter. The surface water arsenic (As) concentration tended to be higher without the addition of organic matter due to the more favourable pH/Eh conditions for arsenic release (see Section 4.2.1.9.4 for further details).

The highest surface water concentration of many of the metal(loid)s occurred when vegetation (i.e. *Phragmites* and *Schoenoplectus)* was added to sediments (Table 4-4). As observed in the mesocosm experiment, the metal(loid)s concentration was often greater with the *Phragmites* treated sediment. The copper (Cu) and zinc (Zn) concentrations were highest with the humic acid treatment as the standard used had relatively high concentrations of these metals (Figures 4-77 and 4-85). With the three organic compound treatments (i.e. glucose, acetate, humic acid), the addition of glucose consistently resulted in the greatest mobilisation of iron and manganese.

Under the experimental conditions, the ANZECC water quality guidelines for the metal(loid)s were often exceeded when organic matter was added (Table 4-4). The surface water guideline for manganese (Mn) was not exceeded with any of the organic matter treatments.

A summary of the surface water metal(loid) trends (including the jarosite and schwertmannite treated sediments) is provided in the following 'Summary of Section'.

Summary of Section

As observed with the mesocosm experiment, the addition of *Phragmites* and *Schoenoplectus* to the Waltowa sub-surface (2.5-10 cm) sediment often resulted in an increase in the mobilisation of metal(loid)s; the increase was also slightly greater with the *Phragmites* treated sediment (see Table 4-4). Enhanced metal(loid) mobilisation was also usually observed with the addition of the organic compounds, jarosite and schwertmannite, although the magnitude of the response often varied between the treatments.

The addition of organic matter resulted in greater iron (Fe) and manganese (Mn) mobilisation to the surface waters than the untreated control, however, the magnitude of release varied depending on the treatment. The addition of acetate only resulted in a slight increase in the iron and manganese concentrations over the initial 2 weeks (Figures 4-63 and 4-67). Iron and manganese mobilisation increased progressively with the addition of humic acid, glucose and vegetation, respectively (Figures 4-63, 4-64, 4-67 and 4-68). The addition of glucose clearly resulted in greater reductive dissolution of both iron and manganese minerals than the addition of either humic acid or acetate.

The addition of jarosite and schwertmannite to all sediments resulted in a substantial increase in the dissolved iron concentration (Figure 4-65). It is expected that the increase in the iron is derived from the hydrolysis and reductive dissolution of the added iron minerals and dissolution of iron associated with the sediment. The addition of jarosite and schwertmannite also enhanced the reductive dissolution of manganese minerals associated with the sediment, particularly when vegetation was added (Figures 4-69 and 4-70). The earlier response observed with the addition of vegetation suggests a quicker onset of reductive dissolution (Figures 4-65, 4-69 and 4-70). A decrease in the iron concentration was also observed with the addition of vegetation to the jarosite/schwertmannite treatments (Figure 4-65), and along with a decrease in the sulfur concentration (see Section 4.3.4.1), would indicate this is due to iron sulfide formation.

As observed in the mesocom experiment, the addition of vegetation resulted in the mobilisation of many other metals including cobalt (Co), copper (Cu), nickel (Ni) and zinc (Zn) (Figures 4-75, 4-78, 4-81 and 4-86). Whilst the vegetation may be a source of some of these metals (particularly with copper and zinc), the reduction of iron and manganese minerals is also an important source (e.g. Co, Ni). The addition of humic acid to the sediment initially increased the surface water concentration of many of the metals compared to the other organic compound treatments (e.g. Co, Cu, Ni, Zn), indicating the metals are derived from the added humic acid (Figures 4-74, 4-77, 4-80 and 4-85). Whilst the addition of glucose enhanced the mobilisation of some of these metals (e.g. Co, Ni, Zn), metal mobilisation associated with the addition of acetate was often similar to that of the untreated control (e.g. Co, Cu, Ni).

The addition of jarosite and schwertmannite to the control and the organic compound treatments also resulted in the mobilisation of cobalt, nickel and zinc (Figures 4-76, 4-82 and 4-87); enhanced mobilisation of copper was only observed with the glucose/schwertmannite treatment (Figure 4-79). The data indicates that the mobilisation of these metals is often largely due to the acidification of the surface waters (e.g. Figure 8-27, Appendix 7). The addition of jarosite and schwertmannite to vegetation treated sediments resulted in the immobilisation of cobalt, nickel and zinc compared to the control (Figures 4-76, 4-82 and 4-87). It is most likely that these metals precipitated as sulfides, although there also may have been some adsorption by the added iron minerals.

As observed with the mesocosm experiment, the release of arsenic (As) was found to be strongly related to surface water pH, with less mobilisation at low pH values (Figure 8-25, Appendix 7). The addition of the acetate and humic acid showed a similar increase in the arsenic concentration over the initial 14 days to that observed with the control (Figure 4-71). The addition of glucose, vegetation jarosite and schwertmannite suppressed arsenic mobilisation compared to the untreated control (Figures 4-71, 4-72 and 4-73). Arsenic mobilisation was suppressed to a greater extent when the sediment was treated with schwertmannite due to greater sorption (Figure 4-73).

The increase in the water soluble potassium (K) concentration during incubation with the jarosite treatments provided an insight into the kinetics of jarosite dissolution (Figure 4-84). The addition of vegetation clearly resulted in the quickest rate of jarosite dissolution, with the addition of humic acid showing a similar rate to the jarosite treated control.

Under the experimental conditions, the ANZECC water quality guidelines for the metal(loid)s were often exceeded when organic matter was added (see Table 4-4). The surface water guideline for manganese was not exceeded with any of the treatments.

4.3.7 Natural Organic Matter (NOM)

4.3.7.1 Dissolved Organic Carbon (DOC)

The dissolved organic carbon contents of the surface waters were determined at the start (i.e. after 10 minutes) and at the end (i.e. after 12 weeks) of the batch experiment (see Table 4-5). The addition of vegetation to the sediment resulted in a much greater initial surface water DOC concentration when compared to the three organic compounds. The vegetation treatments had an initial DOC of approximately 460 mg/L compared to approximately 220 mg/L with the organic compounds.

The DOC of the control without the addition of organic matter showed a slight increase as observed in the mesocosm experiment. The DOC of the organic matter treated sediments generally decreased over the 12 week incubation period. It is expected that the large decrease in the DOC with the humic acid treatments when jarosite and schwertmannite are present is due to the lack of solubility of humic acid at the pH values observed, rather than a breakdown of the humic acid over the 12 week incubation period.

Table 4-5. Summary of the mean DOC contents (mg/L) of the surface waters at the start and end of the batch experiment. Standard deviation of replicate samples is given in brackets.

Treatment	Day 0		Week 12		Change in DOC after 12 weeks
None	3.7	(±0.4)	22	(±2.4)	+18
None/Jarosite	1.1	(±0.1)	4.0	(±0.4)	+2.9
None/Schwertmannite	0.9	(±0.1)	4.1	(±0.3)	+3.2
Glucose	224	(±14)	148	(±8.1)	-76
Glucose/Jarosite	236	(±1.5)	4.7	(±0.3)	-231
Glucose/Schwertmannite	235	(±0.8)	128	(±4.6)	-107
Acetate	224	(±3.1)	120	(±17)	-104
Acetate/Jarosite	225	(±0.8)	105	(±99)	-120
Acetate/Schwertmannite	199	(±2.4)	196	(±2.7)	-3.7
Humic Acid	208	(±18)	64	(±4.0)	-144
Humic Acid/Jarosite	195	(±11)	7.7	(±1.0)	-187
Humic Acid/Schwertmannite	161	(±21)	6.0	(±0.7)	-155
Phragmites	464	(±11)	561	(±230)	+97
Phragmites/Jarosite	464	(±4.6)	62	(±8.8)	-403
Phragmites/Schwertmannite	446	(±17)	297	(±164)	-149
Schoenoplectus	456	(±5.2)	359	(±147)	-97
Schoenoplectus/Jarosite	468	(±0.6)	33	(±6.0)	-436
Schoenoplectus/Schwertmannite	463	(±0.9)	490	(±112)	+27

4.3.7.2 Fluorescence Intensity

The change in surface water T_1 fluorescence intensity during incubation with and without the addition of organic matter for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figures 4-88 and 4-89. Fluorescence analysis of the tryptophan-like peak (T_1; excitation/emission wavelength region 275/340 nm) has previously been found to provide an accurate indication of the presence and relative proportions of bioavailable organic material present (Hudson *et al.* 2008). As expected the addition of both glucose and acetate increased surface water T_1 fluorescence intensity compared to the control due to more bioavailable organic material being present (Figure 4-88); humic acid is not included on the graph as it had an intensity of zero. The surface water T_1 fluorescence intensity tended to increase at a quicker rate in the early stages (i.e. 14 days) with these three sediments, possibly as a result of the rapid breakdown of easily decomposable organic compounds.

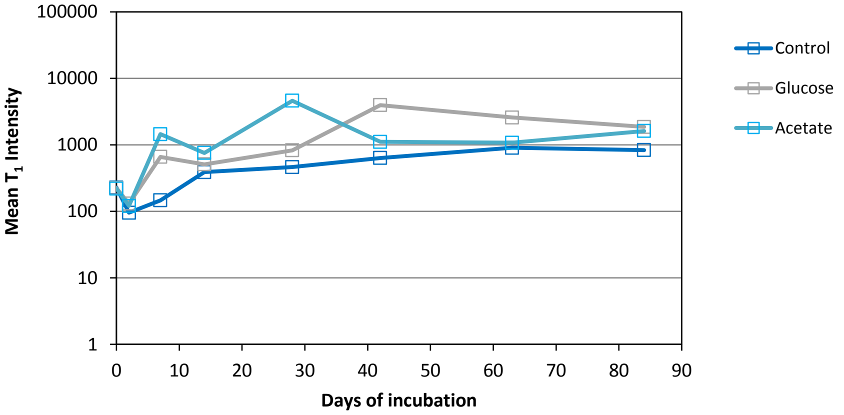

Figure 4-88. Waltowa (2.5 – 10 cm) surface water T_1 fluorescence intensity dynamics with and without the addition of glucose and acetate (Humic acid treatment had an intensity of zero and therefore is not shown on the graph).

The addition of vegetation resulted in a substantial increase in the surface water T_1 fluorescence intensity as observed in the mesocosm experiment (Figure 4-89) (see Section 4.2.1.10.2 for further details).

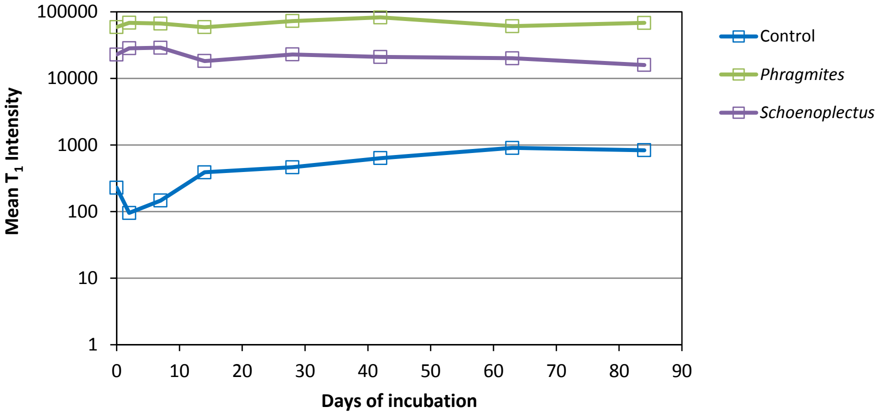

Figure 4-89. Waltowa (2.5 – 10 cm) surface water T_1 fluorescence intensity dynamics with and without the addition of vegetation.

4.3.7.3 Optical Properties

The change in surface water optical properties during incubation with and without the addition of organic matter, jarosite and schwertmannite for the Waltowa sub-surface sediment (2.5-10 cm) is shown in Figure 4-90. The change in the optical properties of the control and the vegetated samples is discussed in Section 4.2.1.10.3. Compared to the control treatment, the addition of acetate and glucose did not substantially change the optical properties due to their own weak UV-Vis absorption characteristics. It is interesting to note that surface water with the humic acid/iron minerals treatments showed the minimal UV-Vis absorbance after 12 weeks, probably due to precipitation of humic acid at the low pH values, rather than a complete decomposition over the 12 week incubation period. There were no obvious changes in the optical properties of the humic acid control treatment during incubation, indicating the stability of humic acid at slightly alkaline pH. With addition of jarosite and schwertmannite to the vegetation, a substantial decrease in surface water absorbance was observed within the region of 200-400 nm. This clearly indicates there was substantial decomposition of dissolved organic species from the vegetation during the reductive dissolution of jarosite and schwertmannite.

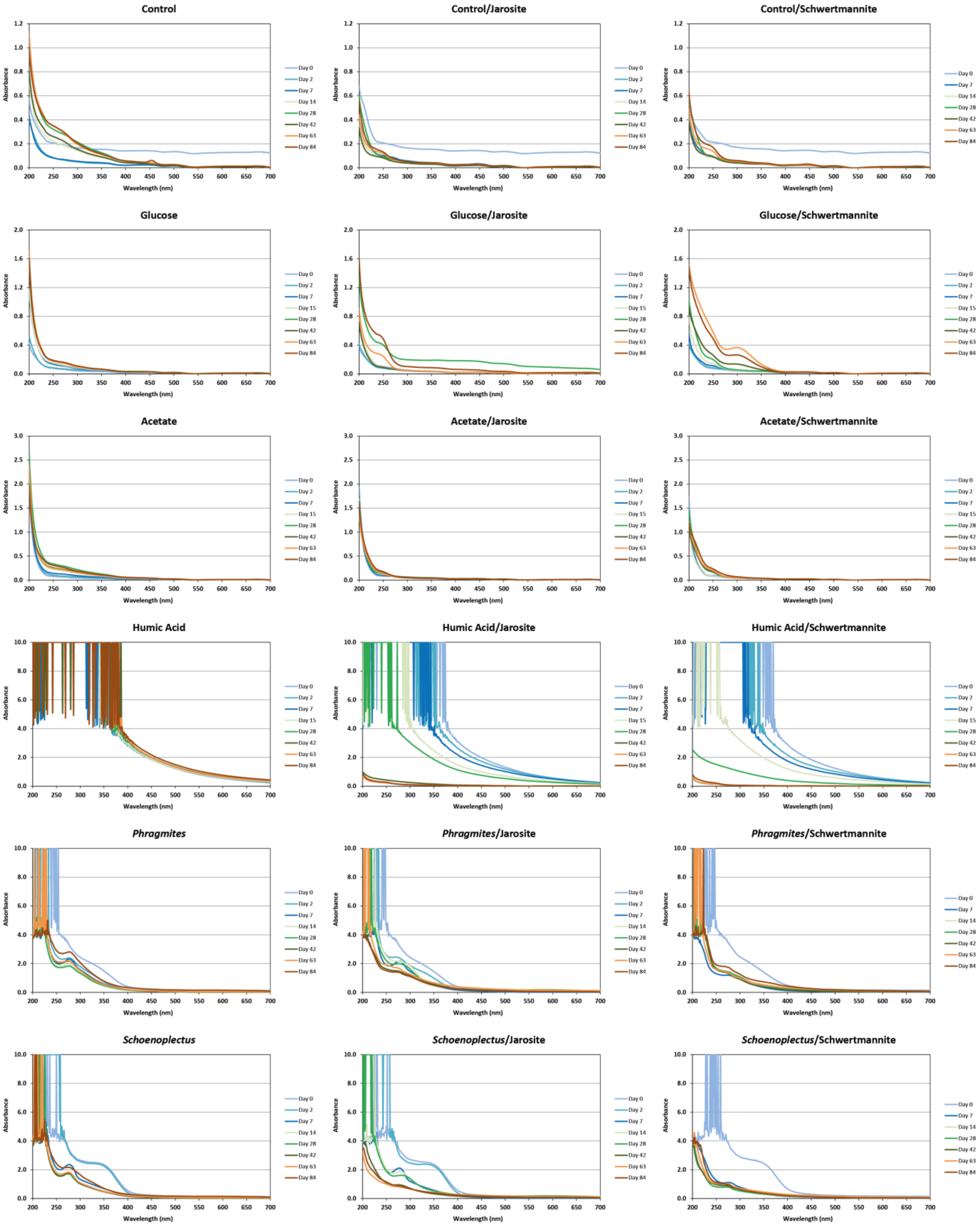

Figure 4-90. Waltowa (2.5 – 10 cm) surface water optical property dynamics with and without the addition of organic matter, jarosite and schwertmannite.

Summary of Section

The addition of vegetation to the sediment resulted in a much greater initial surface water dissolved organic carbon (DOC) concentration when compared to the three organic compounds (i.e. glucose, acetate, humic acid). While the DOC of the control showed a slight increase over the 12 week incubation period, the DOC of the organic matter treated sediments generally decreased (Table 4-5).

Fluorescence analysis of the tryptophan-like peak (T_1) showed the addition of both glucose and acetate increased the surface water T_1 fluorescence intensity compared to the control due to more bioavailable organic material being present (Figure 4-88). The addition of vegetation resulted in a substantial increase in the surface water T_1 fluorescence intensity compared to the three organic compounds (Figure 4-89).

UV-visible spectrophotometry showed the addition of acetate and glucose to the sediment did not substantially change the surface water optical properties compared to the control (Figure 4-90). There were no obvious changes in the optical properties of the humic acid control treatment during incubation, indicating the stability of humic acid at slightly alkaline pH. A substantial decrease in surface water absorbance (within the region of 200-400 nm) was observed with the addition of jarosite and schwertmannite to the vegetation treatments. This decrease in absorbance indicates there was substantial decomposition of dissolved organic species during the reductive dissolution of these iron minerals.

4.4 Metal(loid) Concentrations in Vegetation

A component of this project was to continue to examine the likely mobility and uptake by vegetation of metals from the formerly acidified lake sediments. High metal concentrations in the vegetation of the Lower Lakes have the potential to impact on the food web of the ecosystem. Previous studies have shown that acidic sediment layers had pore-water nickel and zinc concentrations that greatly exceeded the respective water quality guidelines for ecosystem protection (e.g. Sullivan *et al.* 2011). More recently some of the shoreline vegetation at the Lower Lakes has been found to contain high concentrations of nickel (Sullivan *et al.* 2012a, 2013).

A summary of the metal(loid) concentrations measured in the *Phragmites australis* (stem and leaf) and *Schoenoplectus validus* (stem only) at Tolderol and Waltowa is presented below in Table 4-6; further details of the concentrations at each site are given in Tables 8-35 and 8-36, Appendix 5. As previously observed, high concentrations of some of the metals (particularly iron (Fe), aluminium (Al) and manganese (Mn)) were measured in some of the vegetation samples. Consistently low concentrations of arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), nickel (Ni), selenium (Se) and silver (Ag) were found in the vegetation samples analysed; the concentrations of these metals were often below the detection limits of between 0.1 and 1.0 mg/kg depending on the metal(loid) analysed. The metal concentrations observed in this study are similar to those previously reported by Sullivan *et al.* (2012a, 2013). The only exception is the concentration of nickel in the leaves and stems which are often considerably lower than those previously reported.

Table 4-6. Summary of metal(loid) concentrations (mg/kg) observed in vegetation at the Tolderol and Waltowa sites (October 2013).

Metal(loid)	***Phragmites australis***		***Schoenoplectus validus***	**Concentration Range**
	Stem Concentration	**Leaf Concentration**	**Stem Concentration**	
Aluminium (Al)	<50 – 613	<50 – 1,064	234 – 684	<50 – 1,064
Arsenic (As)	0.2 – 0.5	<0.1 – 0.7	0.6 – 0.8	<0.1 – 0.8
Cadmium (Cd)	<0.5	<0.5	<0.5	<0.5
Chromium (Cr)	<1 – 1.4	<1 – 1.6	1.2 – 2.0	<1 – 2.0
Cobalt (Co)	<0.1 – 0.2	<0.1 – 0.2	<0.1 – 0.2	<0.1 – 0.2
Copper (Cu)	<1 - 2	2 - 4	3 - 5	<1 - 5
Iron (Fe)	36 – 565	102 – 919	197 – 493	36 – 919
Lead (Pb)	<1	<1	<1	<1
Manganese (Mn)	37 – 104	108 – 459	108 – 256	37 – 459
Nickel (Ni)	<1 – 2.3	<1 – 2.4	1.1 – 2.0	<1 – 2.4
Selenium (Se)	<0.1 – 0.8	<0.1	1.4 – 2.0	<0.1 – 2.0
Silver (Ag)	<1	<1	<1	<1
Zinc (Zn)	9 - 42	18 - 35	11 - 16	9 - 42

The distributions of the dominant metals observed in the vegetation at each site are presented in Figures 4-91 and 4-92. Aluminium, iron and manganese were usually observed to be at the highest concentrations. Figure 4-91 initially indicates that the highest concentrations of aluminium and iron are found in the *Phragmites* leaves at the Tolderol site. Lower concentrations of aluminium and iron were usually observed in the vegetation at Waltowa, with the *Schoenoplectus* stems tending to have the highest concentrations (Figure 4-92).

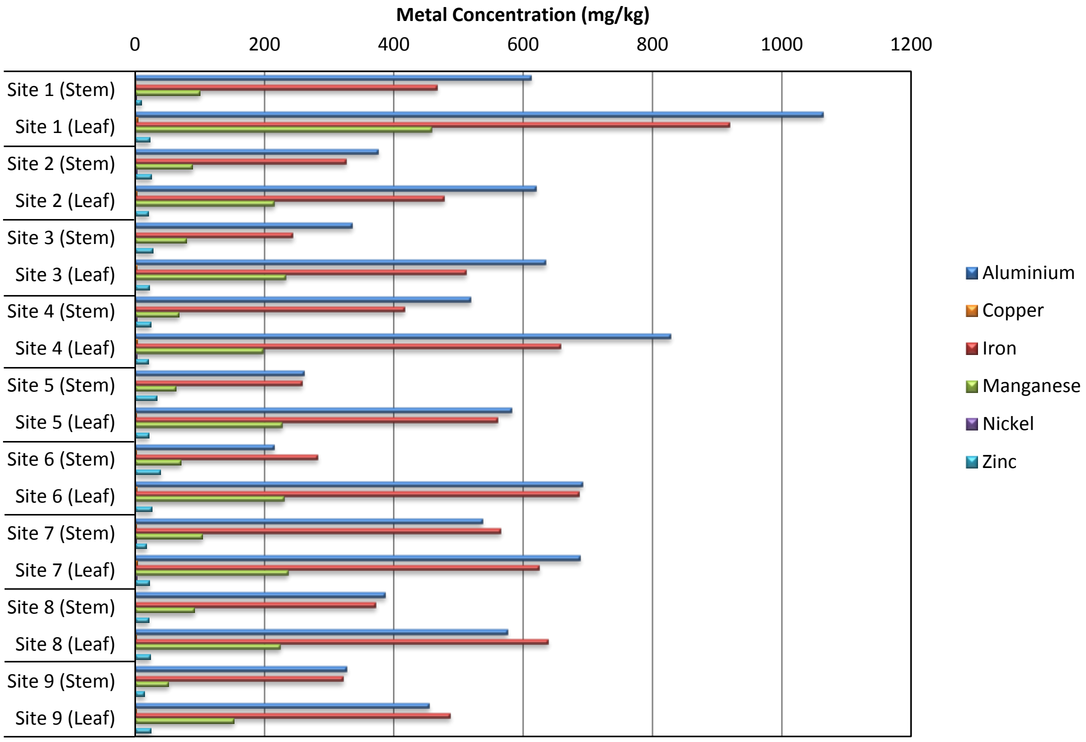

Figure 4-91. Concentration of aluminium, copper, iron, manganese, nickel and zinc in the leaves and stems of *Phragmites* sampled at Tolderol.

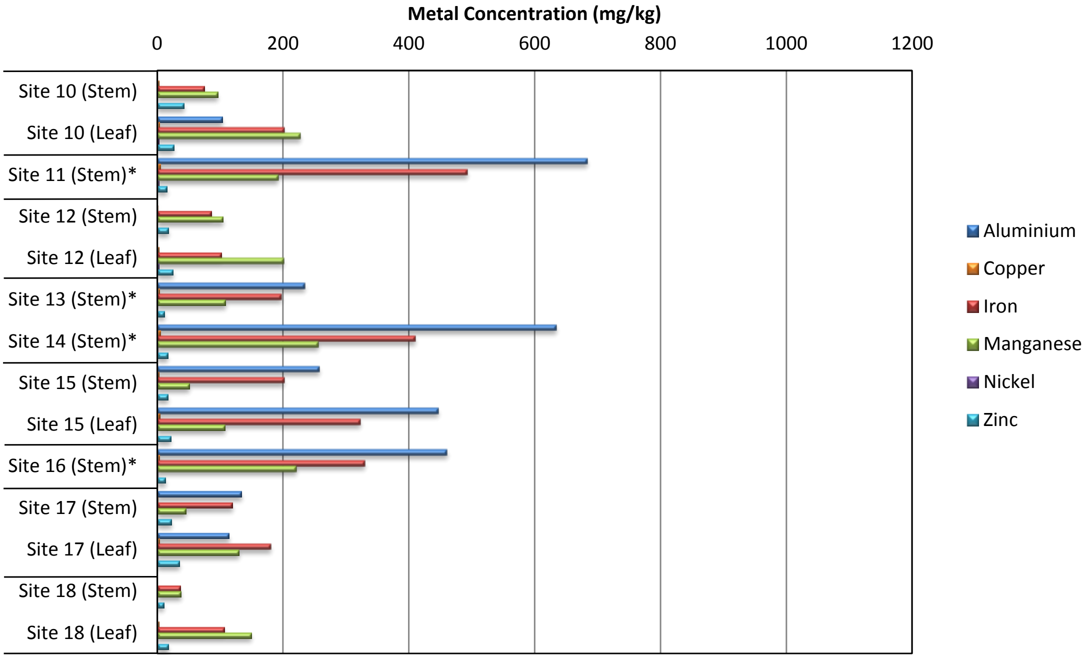

Figure 4-92. Concentration of aluminium, copper iron, manganese, nickel and zinc in the leaves and stems of vegetation sampled at Waltowa (* indicates *Schoenoplectus Validus* sample).

Further examination of the metal concentrations in the *Phragmites* leaf, *Phragmites* stem *and Schoenoplectus* stem at both sites are presented below in Figure 4-93. This confirms that the *Phragmites* leaves tend to have higher concentrations of aluminium, iron and manganese than the *Phragmites* stems, and this was also observed in the study by Sullivan *et al.* (2013). The limited number of *Schoenoplectus* stems also indicates that the concentration of these metals is higher than observed in the *Phragmites* stems. Minimal differences in the zinc concentration were observed between *Phragmites* leaf, *Phragmites* stem *and Schoenoplectus* stem.

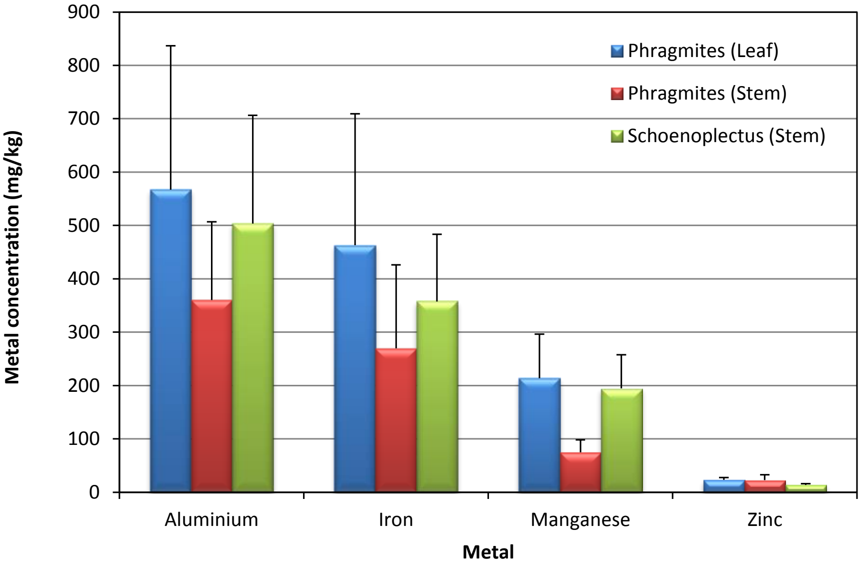

Figure 4-93. Average metal concentrations found in the leaves and stems at the Tolderol and Waltowa sites. (The error bars indicate the standard deviation).

Further examination of the dominant metals in the *Phragmites* leaves and stems at the two sites is presented below in Figure 4-94. This clearly shows the higher average concentrations of aluminium, iron and manganese in the *Phragmites* leaves at the Tolderol site when compared to the Waltowa site. The average concentration of the dominant metals in the *Phragmites* stems is similar at both sites.

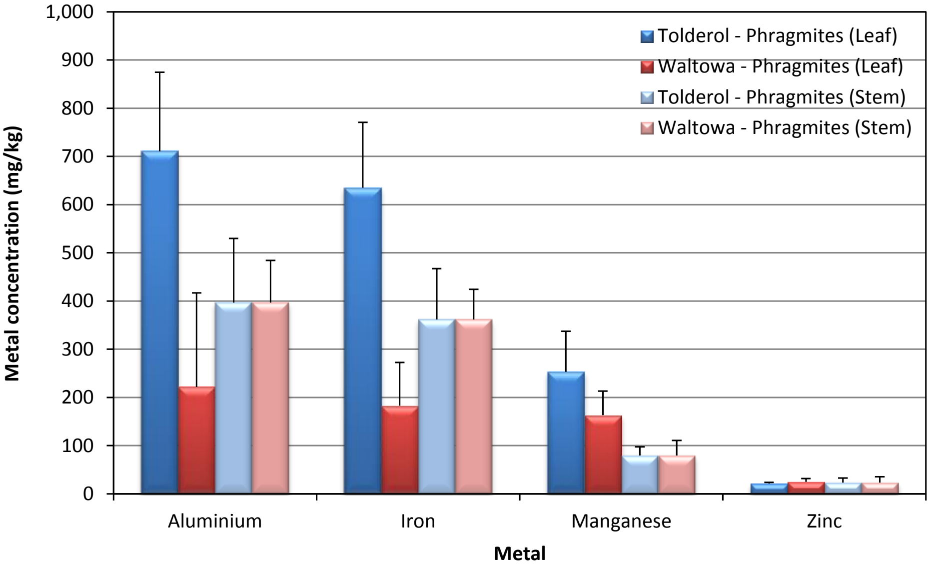

Figure 4-94. Average metal concentrations found in the leaves and stem of *Phragmites australis* at the Tolderol and Waltowa sites. (The error bars indicate the standard deviation).

Both of these sites experienced acidification during the recent drought (e.g. Sullivan *et al.* 2013) resulting in the potential mobilisation of metals. The higher concentration of some of the metals (i.e.

Al, Fe, Mn) in the *Phragmites* leaves at the Tolderol probably reflects the difference in the background concentration of these metals at the sites. For example, the previous study by Sullivan *et al.* (2013) did observe higher iron concentrations in the porewater at the Tolderol scald site when compared to the Waltowa *Cotula* site.

Summary of Section

The concentration of many of the metal(loid)s examined in the *Phragmites australis* and *Schoenoplectus validus* plant materials was generally low (Table 4-6).

High concentrations of aluminium (Al), iron (Fe) and manganese (Mn) were measured in some of the vegetation samples (Figures 4-91 and 4-92).

The metal concentrations are similar to those previously reported by Sullivan *et al.* (2012a, 2013), except for nickel (Ni) which are often considerably lower.

Differences were observed in the uptake and accumulation of some of the metals (i.e. Al, Fe, Mn) by the two vegetation types. The *Schoenoplectus* stems consistently had higher concentrations of these metals than the *Phragmites* stems (Figure 4-93). The *Phragmites* leaves at Tolderol were found to have higher aluminium, iron and manganese concentrations than those in the *Phragmites* leaves at Waltowa (Figure 4-94). The higher concentration of these metals in the *Phragmites* leaves at the Tolderol probably reflects the difference in the background concentration of these metals at the two sites.

4.5 Discussion

4.5.1 Recovery of the Acidified Sediment Layers

Sediments usually undergo a series of sequential redox reactions when the redox status changes from oxic to anoxic as a consequence of inundation. The major redox reactions include denitrification, manganese [Mn(IV)] reduction, ferric iron [Fe(III)] reduction, sulfate reduction and methanogensis (e.g. Du Laing *et al.* 2009; Bethke *et al.* 2011). It is well known that these microbial reduction processes which use organic carbon as an energy source consume acidity (e.g. Figure 4-95).

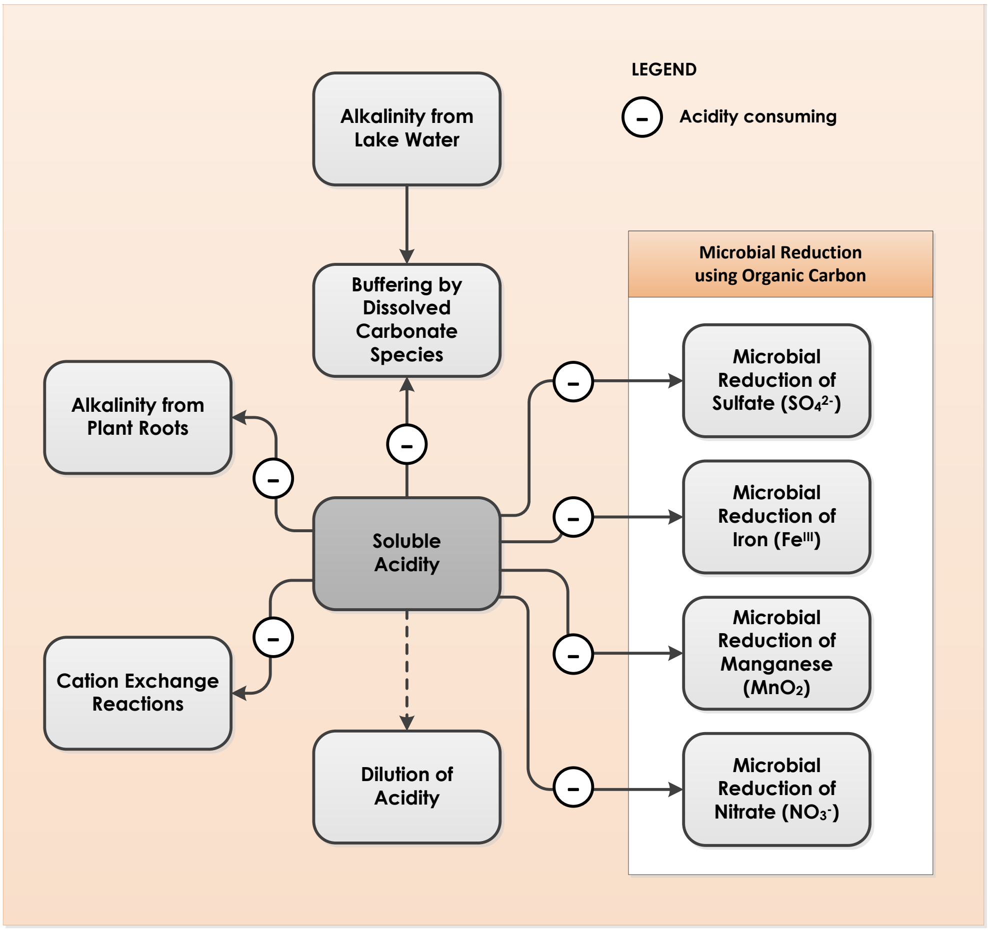

Figure 4-95. A flowchart summarising the potential acid consuming processes that may occur in the Lower Lakes following lake filling (source: Ward *et al.* 2013).

In this study the rate of recovery of the sediments was similar at both the Tolderol and Waltowa sites, although the behaviour differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. The pH of the surface water recovered to near-neutral as a consequence of reduction processes within 4 to 8 weeks with all the acidic sediments without the addition of organic carbon (Figure 4-5). The addition of vegetation (*Phragmites* and *Schoenoplectus*) to the surface (0-2.5 cm) sediments initially resulted in acidification, although a near-neutral pH was still reached within 8 weeks (Figure 4-5). However, the addition of vegetation to the sub-surface (2.5-10 cm) sediments resulted in acidification for at least 8 weeks, and a near-neutral pH was not reached within the timeframe of the mesocosm experiment (i.e. 16 weeks).

Further examination confirmed that the organic acids produced from the breakdown of the added vegetation were the cause of the acidification. Three low molecular weight (LMW) organic acids were identified in the surface water including malonic acid ($CH_2(COOH)_2$), formic acid (HCOOH)and oxalic acid ($H_2C_2O_4$); benzoic acid ($C_7H_6O_2$) was also detected after 16 weeks of incubation. It is possible that other LMW organic acids may have formed (particularly acetic acid), but these organic acids were not detected as they may have been broken down within the initial 4 weeks of incubation.

Formic acid was identified as the most important LWM organic acid affecting the recovery of the sediments when both vegetation types were added (Figure 4-42). Formic acid was also found to show a similar trend to that observed with titratable acidity (Figure 4-8). Whilst the presence of formic acid explains the difference in the rate of recovery between the surface and sub-surface sediments, the reason why formic acid was able to persist in the sub-surface sediments for a longer period of time is currently not clear. One possible explanation is that the surface and sub-surface sediments have different bacterial populations, and there are sufficient suitable bacteria in the surface sediments that are able to rapidly breakdown the formic acid. It is important to note that whilst the presence of organic acids resulted in significantly higher titratable acidities when vegetation was added to the sediments, the titratable acidities were low (i.e. ≤ 504 mg/L $CaCO_3$ or ≤ 0.01 mol H^+/L) when compared to the sulfuric and sulfidic acidities previously reported within the sediments in the Lower Lakes (e.g. Fitzpatrick *et al.* 2008). The sediments examined in this study also had very low titratable actual acidity (TAA) values (i.e. < 7 mol H^+/t).

The techniques used in this study provided further information on the nature of the organics released into solution during the incubation of the Tolderol and Waltowa sediments. In addition to identifying the LMW organic acids present (and benzoic acid), high-performance liquid chromatography (HPLC) showed the formation of additional organic compounds, including an unknown phenolic and other aromatic compounds. UV-visible spectrophotometry also indicated the formation of total aromatic compounds after 4 weeks of incubation with the addition of vegetation. The technique indicated that more labile structures (e.g. carbohydrates, amino acids, etc.) were then destroyed, and more thermodynamically stable aromatic and polyaromatic structures formed. Fluorescence analysis of the surface water tryptophan-like peak (T_1) indicated an increase in the amount of bioavailable organic material during the incubation without the addition of vegetation, and the addition of vegetation substantially increased the amount of bioavailable organic material. Finally, Differential Pulse Voltammetry (DPV) showed there were distinct differences in the reducing dissolved organic matter content between the *Phragmites* and *Schoenoplectus* treatments. These techniques clearly showed there were significant changes in the nature of the organics present during the 16 week incubation experiment.

The organic compounds present in the vegetation, and produced during their breakdown, provided an energy source for the microbial reduction processes. The low surface water nitrate concentrations (≤ 0.14 mg/L N) suggested that denitrification was not a major redox process consuming acidity in these sediments. However, manganese, iron and sulfate reduction were found to be important acidity consuming processes with all sediments. The addition of organic matter clearly enhanced the rate of reduction of both iron and manganese minerals, substantially increasing the concentration of these metals in the surface waters compared to the sediments without organic matter (Figures 4-13 and 4-15). The rates of iron and manganese reduction were also greater with the surface sediments than the sub-surface sediments. Iron fractionation data confirmed that the reduction of both poorly ordered and crystalline iron oxides occurred over the 16 week incubation period (Figure 4-45).

The surface water sulfate levels were low with all sediments without the addition of vegetation (i.e. < 15 mg/L S), and the addition of vegetation resulted in initial increases in the water soluble sulfur concentrations (i.e. ≤ 52 mg/L S) (Figure 4-11). Whilst there was a rapid decrease in the water soluble sulfur concentration over the initial 4 weeks when vegetation was added (indicating sulfate reduction), the low levels of sulfate under the experimental conditions of the mesocosm experiment prevented the accumulation of detectable levels of iron sulfides (i.e. <0.01% S).

The addition of the two vegetation types to the sediments usually resulted in a similar behaviour. The only clear exception was with the ammonia concentration, where the addition of *Phragmites* resulted in substantially higher concentrations (Figure 4-10). Whether the high ammonia levels measured under the conditions in the mesocosm experiment with *Phragmites* would potentially lead to the development of algal blooms is dependent on the rate of ammonia flux from the sediments, dilution within the lakes and other processes (e.g. nitrification/denitrification). In addition to ammonia, Sullivan *et al.* (2012b) also showed that the uppermost sediments under *Phragmites* at Waltowa appeared likely to act as sources of soluble phosphate.

The addition of *Phragmites* and *Schoenoplectus* to the sediments also resulted in substantial increases in the surface water electrical conductivities (Figure 4-7). The data clearly showed the dissolution of salts associated with the vegetation was the cause of the EC increase (e.g. Figures 8-11 - 8-15, Appendix 7).

In addition to *Phragmites* and *Schoenoplectus*, the batch experiment examined the effect of various organics (including acetate, glucose and humic acid) that potentially form during the microbial degradation of plant material on the rate of recovery. The results often indicated that the three organic compounds were added at a sub-optimal rate when compared to the relatively abundant supply of decomposable organic matter available with the vegetation. The difference in response emphasises the importance of the supply of sufficient organic material for a rapid recovery to occur.

The addition of both acetate and humic acid did not affect the rate of pH recovery when compared to the untreated control (Figure 4-47). However, as observed with the vegetation treatment the addition of glucose resulted in initial acidification due to the formation of organic acids, and this was followed by a slow recovery. It is expected that glucose was readily broken down as many bacteria possess the enzymes required for the degradation and oxidation of this sugar (e.g. Rohan *et al.* 2013). While acetate is also easily broken down by bacteria (and there is clearly a decrease in the DOC with this treatment over the 12 weeks of incubation (Table 4-5)), it is broken down to carbon dioxide (CO_2) and therefore does not directly influence the pH.

The addition of the three potential degradation products clearly had an effect on the rate of iron and manganese reduction when compared to the untreated control, although the effect varied depending on the treatment (Figures 4-63 and 4-67). The addition of glucose clearly showed the greatest release of iron and manganese into solution (Figures 4-63 and 4-67), although somewhat less than when vegetation was added (Figures 4-64 and 4-66). The addition of acetate only enhanced the release of iron and manganese over the initial 2 weeks when compared to the control. The addition of the three organic compounds resulted in a similar rate of sulfate reduction which was slightly enhanced when compared to the untreated control (Figure 4-56).

The batch experiment was also used to examine the effect of two common acid sulfate soil minerals (i.e. schwertmannite and jarosite) on carbon utilisation and recovery. The addition of jarosite and schwertmannite to the control and the organic compound treatments usually resulted in a substantially lower pH than the non-treated control (Figure 4-49). The lower pH observed with the addition of jarosite and schwertmannite is due to the liberation of acidity from the hydrolysis of these iron minerals (e.g. Equation 4.1).

$$KFe_3(SO_4)_2(OH)_6 + 3\,H_2O \rightarrow 3\,Fe(OH)_3 + 2\,SO_4^{2-} + 3\,H^+ + K^+ \qquad [4.1]$$

Hydrolysis occurs as these minerals only tend to be stable under acidic oxidising conditions (e.g. Regenspurg *et al.* 2004). The addition of jarosite and schwertmannite to the vegetation treated sediments raised the pH higher than the sediments without these minerals, and occurred at a faster rate with the schwertmannite treated sediments (Figure 4-49). This response indicates that there is a rapid onset of reductive dissolution when vegetation is added, and this is also indicated by the rapid initial increase in the sulfur and iron concentrations with the vegetation treatments (Figures 4-58 and 4-65). The faster pH recovery observed with the schwertmannite treated sediments is due to the quicker onset of sulfate and iron reduction (Figures 4-58 and 4-65). This finding clearly shows that when there is sufficient available carbon the reductive dissolution of jarosite and schwertmannite is able to increase the rate of recovery compared to sediments without these minerals. While there is an increase in the rate of recovery with the presence of these iron minerals there is also the associated increase in the mobilisation of metal(loid)s (see Section 4.5.2 for further details). The data and visual indications also suggested the formation of iron monosulfides with the addition of jarosite and schwertmannite (e.g. Figure 5-59).

In summary, the addition of vegetation and glucose slowed the rate of recovery of the sediments due to the formation of organic acids. The addition of both acetate and humic acid had a minimal effect on the pH recovery of the sediments. The addition of vegetation to the surface (0-2.5 cm) sediments resulted in a faster rate of recovery when compared to the sub-surface (2.5-10 cm) sediments. Whilst the reason for this difference is not clear, it is likely that differences in the bacterial populations between the two layers affect the rate of breakdown of the organic acids present. The presence of jarosite and schwertmannite often resulted in further acidification and a slow recovery, due acidity being released from the hydrolysis of these iron minerals. However, a rapid recovery was observed in the presence of vegetation suggesting that acidity was rapidly consumed by the reductive dissolution of these iron minerals.

4.5.2 Metal(loid) Mobilisation-Immobilisation

Previous studies have demonstrated the potential for metal(loid) mobilisation from sediments in the Lower Lakes (e.g. Simpson *et al.* 2008, 2009, 2010; Sullivan *et al.* 2008, 2010; Hicks *et al.* 2009; Shand *et al.* 2012). Whilst the release of metal(loid)s from the acid sulfate soils has often been attributed to sulfide oxidation, metal(loid)s can also be mobilised when these sediments are subject to prolonged inundation. A summary of the potential metal(loid) mobilisation-immobilisation processes that may occur following inundation is presented in Figure 4-96. This study has illustrated the importance of organic carbon on these metal(loid) mobilisation-immobilisation processes with sediments from the Lower Lakes.

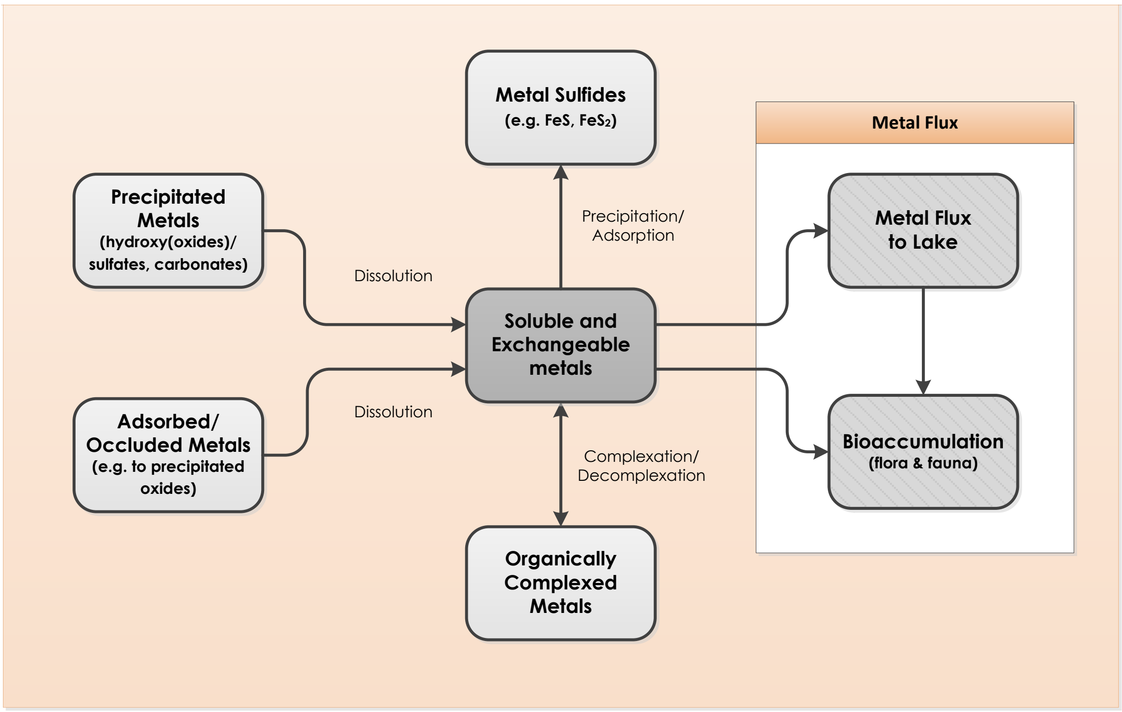

Figure 4-96. A flowchart summarising the potential metal(loid) mobilisation-immobilisation processes that may occur in the Lower Lakes following inundation (source: Ward *et al.* 2013).

The results of this study have shown that addition of NOM (including *Phragmites*, *Schoenoplectus,* acetate, glucose and humic acid) to sediments from the Lower Lakes has often resulted in an increase in the mobilisation of metal(loid)s when compared to the NOM-depleted sediments (see Tables 4-2 and 4-4). The addition of either *Phragmites* or *Schoenoplectus* to each of the sediments usually showed a similar metal(loid) behaviour (e.g. Figure 4-13). However, some metal concentrations (e.g. Co, Cu, Mn, Ni, Zn) were found to be slightly higher in the surface water associated with the *Phragmites* treated sediments, despite the two vegetation types usually having similar total metal contents (Table 8-35 and 8-36, Appendix 5). Whilst enhanced metal(loid) mobilisation was also usually observed with the three organic compound treatments, the magnitude of the response often varied between the treatments (e.g. Figure 4-63). The highest surface water metal(loid) concentrations usually occurred when vegetation was added to sediments (see Table 4-4).

The addition of organic carbon clearly enhanced the reduction of iron and manganese oxides/oxyhydroxides present in the sediments. An increase in the surface water iron and manganese concentrations was observed following the addition of organic carbon to all sediments compared to the untreated controls (e.g. Figures 4-13, 4-15, 4-63 and 4-67). Iron fractionation data also clearly showed that there had been the dissolution of poorly ordered and crystalline iron minerals in the presence of vegetation over the incubation period (Figure 4-45). The magnitude of iron and manganese release varied depending on the nature of the organic matter. The addition of vegetation resulted in the greatest iron and manganese mobilisation (Figures 4-64 and 4-68). Whilst the addition of glucose resulted in greater iron and manganese dissolution than the humic acid treatment, the addition of acetate only enhanced the release of these metals over the initial 2 weeks when compared to the control (Figures 4-63 and 4-67).

A similar behaviour in the soluble iron and manganese fractions was observed between the sites and when either vegetation type was added, however, the behaviour differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments (Figures 4-13 and 4-15). The reduction of the iron and manganese minerals occurred at a faster rate with the surface sediments, and the water soluble concentrations declined after 4 weeks. Iron fractionation data did show the surface sediments had a greater concentration of more easily reducible less crystalline iron minerals (i.e. *HCl* fraction) which may explain the difference observed (Figure 8-23, Appendix 7). Iron fractionation data suggested that decline in the surface water iron concentration with the surface sediments was due to iron becoming organically bound (Figure 4-45).

The addition of organic carbon to the sediments also resulted in an increase in the surface water cobalt and nickel concentrations (e.g. Figures 4-23 and 4-28, 4-74 and 4-80). Higher surface water cobalt and nickel concentrations were observed when vegetation was added to the Waltowa sediments compared to the Tolderol sediments; this may be due the greater sorption capacity of the Tolderol sediments. The surface water trends suggested that a significant proportion of the cobalt and nickel released into solution was associated with the dissolution of the iron and manganese minerals. Metal(loid) fractionation data for the *Phragmites* treated Waltowa surface sediment confirmed the release of cobalt and nickel from iron oxides during incubation (Figure 4-46). However, the data also showed that the soluble and exchangeable cobalt and nickel fractions (*$MgCl_2$* fraction) were readily mobilised into solution. Nickel showed a substantial decrease in the *OM & Residual* fraction indicating that the nickel associated with this fraction was also released into solution; some of this nickel may have been associated with the *Phragmites*. The initial increase the surface water cobalt and nickel concentrations with the addition of humic acid indicated these metals are derived from humic acid itself (Figures 4-74 and 4-80); this was also observed with copper and zinc.

The arsenic behaviour varied between the sites, sediment depths and organic matter type added (Figures 4-19, 4-71 and 4-72). All sediments and treatments showed an increase in the arsenic concentration during the incubation period. As the adsorption of arsenic is both redox sensitive and pH dependent, the arsenic concentration was observed to increase as the Eh decreased and pH increased (e.g. Figures 4-20 and 4-21). Whilst the addition of vegetation did not have a consistent effect with the surface (0-2.5 cm) sediments at the two sites, the addition of vegetation to the sub-surface (2.5-10 cm) sediments clearly supressed the release of arsenic (Figure 4-19); this is most likely due to the relatively low pH associated with these sediments. Metal(loid) fractionation data for the *Phragmites* treated sediment clearly showed that the arsenic associated with poorly ordered and crystalline iron oxides (*HCl + CBD* fraction) was released into solution (Figure 4-46). The addition of acetate and humic acid showed a similar arsenic response to the untreated sediment, however, the addition of glucose suppressed the release of arsenic due to the relatively low pH of this treatment (Figure 4-71).

An increase in the surface water copper concentrations at the start of the incubation experiments with all sediments treated with vegetation indicated the vegetation being the source (Figures 4-25 and 4-78). The copper fractionation data for the *Phragmites* treated sediment also showed the soluble and exchangeable fraction (*$MgCl_2$* fraction) was mobilised into solution (Figure 4-46). The surface water copper concentration rapidly decreased, and copper fractionation data showed it became associated with the poorly ordered iron oxides (*HCl* fraction) and organic matter and residual fraction (*OM & Residual* fraction) (Figure 4-46). Whilst the addition of humic acid resulted in an increase in the copper concentration due to its relatively high copper content, the addition of glucose and acetate had minimal effect (Figure 4-77).

The data also indicated that the added vegetation and humic acid were sources of the elevated surface water zinc concentrations (Figures 4-32, 4-85 and 4-86). The zinc fractionation data for the *Phragmites* treated sediment also showed the soluble and exchangeable fraction (*$MgCl_2$* fraction) was mobilised into solution (Figure 4-46). The zinc fractionation data showed it became associated with the poorly ordered iron oxides (*HCl* fraction) and organic matter and residual fraction (*OM & Residual* fraction) (Figure 4-46). The addition of acetate and glucose also increased the surface water zinc concentration compared to the control (Figure 4-85).

The batch experiment was also used to examine the effect of two common acid sulfate soil minerals (schwertmannite and jarosite) on metal(loid) mobilisation. The addition of jarosite and schwertmannite to the sediments resulted in a substantial increase in the dissolved iron concentration (Figure 4-65). It is expected that the increase in the iron is derived from the hydrolysis and reductive dissolution of the added iron minerals and dissolution of iron associated with the sediment. The addition of jarosite and schwertmannite also enhanced the reductive dissolution of manganese minerals associated with the sediment, particularly when vegetation was added (Figures 4-69 and 4-70). The earlier response observed with the addition of vegetation indicates a quicker onset of reductive dissolution (Figures 4-65, 4-69 and 4-70). A decrease in the iron concentration was also observed with the addition of vegetation to the jarosite/schwertmannite treatments (Figure 4-65), and along with a decrease in the sulfur concentration (see Section 4.3.4.1), would indicate this is due to iron sulfide formation.

The addition of jarosite and schwertmannite to the control and the organic compound treatments also resulted in the mobilisation of cobalt, nickel and zinc (Figures 4-76, 4-82 and 4-87); enhanced mobilisation of copper was only observed with the glucose/schwertmannite treatment (Figure 4-79). The data indicates that the mobilisation of these metals is often largely due to the acidification of the surface waters (e.g. Figures 8-27, 8-31 and 8-34, Appendix 7). The addition of jarosite and schwertmannite to vegetation treated sediments resulted in the immobilisation of cobalt, nickel and zinc compared to the control (Figures 4-76, 4-82 and 4-87). It is most likely that these metals precipitated as sulfides, although there also may have been some adsorption by the added iron minerals. The addition jarosite and schwertmannite usually suppressed arsenic mobilisation compared to the untreated control (Figure 4-73). Arsenic mobilisation was suppressed to a greater extent when the sediment was treated with schwertmannite due to greater sorption (Figure 4-73).

Recent studies in the Lower Lakes indicate that the general changes in sediment redox status towards more reducing conditions and pH from acidic to neutral have begun to drive the reductive dissolution of iron minerals such as jarosite (Sullivan *et al.* 2012b). Whilst the synthetic minerals used in this study had low metal contents, in the field these minerals are potentially significant sinks for metal(loid)s which may be released to a greater extent as a consequence of reductive dissolution.

The magnitude of metal(loid) mobilisation from sediments is affected by many factors in addition to the abundance and lability of organic matter and include but are not exclusive to: pH; the abundance and form of metal(loid); the abundance and reactivity of iron minerals; availability of sulfate; acid/alkalinity buffering capacity; salinity; clay content; microbial activity; temperature; and porosity (e.g. Gambell 1994; Du Laing *et al.* 2009; MDBA 2010). Previous studies on sediments from the Lower Lakes have shown the importance of pH on the magnitude of release of dissolved metals from the sediments (e.g. Simpson *et al.* 2010). In this study there is often a weak relationship between the pH of the surface water and the metal(loid) concentration (e.g. Figure 8-36, Appendix 7). Whilst pH is often an important control on the magnitude of metal(loid) release, processes (such as desorption from iron oxides and sorption by organic matter) have also been shown to play an important role when NOM is added. A stronger relationship between pH and the magnitude of metal(loid) release was sometimes observed in the batch experiment, particularly when lower pH values (i.e. pH < 4) were reached (e.g. Figures 8-27 and 8-31; Appendix 7).

Under the experimental conditions, many of the metal(loid)s examined in this study were found to exceed the ANZECC Ecosystem Protection Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems (ANZECC/ARMCANZ 2000) (see Tables 4-2 and 4-4). With many of the metals (e.g. Co, Cu, Cr, Ni, Mn, Zn) the ANZECC water quality guidelines were exceeded to a greater extent when organic matter (particularly vegetation) was added to the sediments. While mesocosm and batch experiment results give an indication of the magnitude of metal(loid) release from the sediment, the overlying water will rarely have the concentration measured in solution due to dilution in the receiving waters. Degree of hazard thresholds have been developed for the potential release of metal(loid)s from acid sulfate soils in the Murray Darling Basin (MDB) based on the level of exceedance of the ANZECC guideline threshold (see Table 4-7). It is important to note that the contaminant metal(loid) dynamics method used in the MDB studies involved adding 5 g of field moist soil to 100 ml water, resulting in at least a 1:20 soil:water ratio (MDBA 2010). In this study a 1:5 soil:water ratio was used, which would result in less dilution of the metal(loid)s. However, the guideline thresholds were largely developed to identify which metal(loid)s released from the sediment were of particular concern.

Table 4-7. Summary of the degree of hazard associated with the measured metal(loid) concentrations in the mesocosm experiment (adapted from Ward *et al.* 2011).

Degree of Hazard	Guideline Threshold	Metal(loid)
No Hazard	Value below ANZECC guideline threshold.	Cd, Se
Low Hazard	Value exceeds ANZECC guideline threshold, but is less than 10x exceedance.	Ag, Al*, As, Cr, Pb, Mn
Moderate Hazard	Value exceeds ANZECC guideline threshold by 10x or more, but is less than 100x exceedance.	Co, Cu, Ni, Zn
High Hazard	Value exceeds ANZECC guideline threshold by 100x or more.	None

** Based on aluminium being soluble – at pH > 5.5 this is unlikely.*

It can be assumed that if a metal(loid) concentration did not exceed the ANZECC water quality guideline it does not represent an environmental hazard. Under the conditions of the mesocosm experiment, two of the metals examined (i.e. cadmium (Cd) and selenium (Se)) were not found to exceed the ANZECC water quality guidelines during 16 weeks of incubation (Table 4-7). A total of ten of the metal(loid)s were found to exceed the ANZECC water quality guidelines during the mesocosm inundation experiment and represent a low-moderate hazard (Table 4-7). None of the metal(loid) concentrations measured represent a high hazard.

With the exception of nickel (Ni) and manganese (Mn), all of the metal(loid)s which exceeded the ANZECC water quality guideline, exceeded the guideline with and without the addition of vegetation (Table 4-2). The nickel and manganese ANZECC water quality guidelines were only exceeded when vegetation was added; manganese was only exceeded when vegetation was added to the Waltowa surface (0-2.5 cm) sediment (Figure 4-15).

It is important to note that some of the metal(loid)s were only potentially a low or moderate hazard for a short timeframe, or only with limited sediments and treatments. For example, copper (Cu) was only a moderate hazard for the vegetation treated sediments when measured on Day 0 (Figure 4-25), cobalt (Co) was also only a moderate hazard when vegetation was added to the Waltowa sediments (Figure 4-23), and nickel was only moderate hazard when *Phragmites* was added to the Waltowa sediments (Figure 4-28).

In summary, the addition of NOM (including *Phragmites*, *Schoenoplectus,* acetate, glucose and humic acid) to sediments from the Lower Lakes has often resulted in an increase in the mobilisation of metal(loid)s when compared to the NOM-depleted sediments. The rapid reductive dissolution of iron and manganese minerals in the presence of organic matter and the release of associated metal(loid)s (e.g. As, Co, Ni) clearly plays an important role controlling the magnitude of metal(loid) mobilisation. The type and amount of NOM clearly also has had an effect on the magnitude of metal(loid) mobilisation from the sediments. Whilst under the conditions of this experiment the ANZECC guidelines were often exceeded, numerous factors (including the rate of metal(loid) flux from the sediments and dilution in the receiving waters) will determine the potential impacts of the increased metal(loid) mobilisation on the surrounding aquatic environment.

4.5.3 Metal(loid) Concentrations in Lake Vegetation

The concentration of many of the metal(loid)s examined in the *Phragmites australis* and *Schoenoplectus validus* plant materials collected was generally low (see Table 4-6), and below the published elevated level criteria for most plants. However, whilst universally accepted critical metal contents for wetland vegetation are currently not available, the data clearly shows elevated concentrations of some metals analysed in the vegetation growing in the formerly acidified sediments.

The manganese concentrations in the plant tissue (with a mean concentration of 151 mg/kg and maximum of 459 mg/kg) were well above the published criteria for the limit for most plants of 50 mg/kg, "above which toxicity may be observed and if it is taken above this level by animals via food chain is hazardous" (Jarvis and Whitehead 1981).

As previously observed by Sullivan *et al.* (2012a, 2013), the aluminium concentrations in the plant tissue (with a mean concentration of 473 mg/kg and maximum of 1,064 mg/kg) were often well above the published criteria for the limit for most plants of 200 mg/kg. In addition, the iron concentrations in the plant tissue (with a mean concentration of 365 mg/kg and maximum of 919 mg/kg) were also high, but within the published ranges for fodder plants of 18 to 1,000 mg/kg. The zinc concentrations observed in the vegetation at the two sites (i.e. 9 – 42 mg/kg) is not unusual; normal levels of zinc in most crops and pastures range from 10 mg/kg to 100 mg/kg (WHO 2001).

Sullivan *et al.* (2012a, 2013) previously reported elevated nickel concentrations in some of the vegetation surrounding the lakes. In this study, the nickel concentrations in the plant tissue (with a mean concentration of 1.6 mg/kg and maximum of 2.4 mg/kg) were within the published ranges in most natural vegetation (0.05 to 5 mg/kg dry weight; NAS 1975) and for fodder (1 to 10 mg/kg; NAS 1975).

Differences were observed in the uptake and accumulation of some of the metals (i.e. Al, Fe, Mn) by the two vegetation types (Figure 4-93), and the *Phragmites* leaves at Tolderol were found to have higher concentrations of these metals than those in the *Phragmites* leaves at Waltowa (Figure 4-94). The higher concentration of these metals in the *Phragmites* leaves at the Tolderol probably reflects the difference in the background concentration of these metals at the two sites.

5.0 Conclusions

This project reports the outcomes of the final investigation of a series of investigations over the past three years into the recovery of acid sulfate soils in the Lower Lakes (Sullivan *et al.* 2011, 2012b, 2013). The importance of organic carbon in mitigating impacts and triggering in situ geochemical recovery of the sediment and improvement to water quality has merged as a key theme for future management. This study has reached a deeper understanding of the role of organics in bioremediation, and will improve the capacity to predict the recovery of acid sulfate soils.

The key findings of this study are:

1) The addition of organic carbon (i.e. *Phragmites australis* and *Schoenoplectus validus*) to the surface and sub-surface sediments (0-10 cm) from Tolderol and Waltowa slowed the rate of recovery due to the release of organic acids from the vegetation.

2) The addition of *Phragmites* and *Schoenoplectus* showed a similar recovery response, although the rate of recovery differed between the surface (0-2.5 cm) and sub-surface (2.5-10 cm) sediments. The surface sediments recovered at a faster rate due to the rapid breakdown of organic acids, particularly formic acid.

3) The effect of various organics (including acetate, glucose and humic acid) on the rate of recovery varied. Whilst the addition of both acetate and humic acid had minimal effect on the rate of recovery, the addition of glucose slowed the rate of recovery (due the formation of organic acids).

4) The hydrolysis of schwertmannite and jarosite led to acidification of the surface water, however, the presence of sufficient organic matter led to a rapid rate of recovery as a consequence of the reductive dissolution of these minerals.

5) The addition of NOM to both the Waltowa and Tolderol sediments resulted in an increase in the mobilisation of many of the metal(loid)s. The addition of either *Phragmites* or *Schoenoplectus* to each of the sediments often resulted in a similar metal(loid) behaviour, although slightly higher metal concentrations were often found associated with the *Phragmites* treated sediments (e.g. Co, Cu, Mn, Ni, Zn).

6) The addition of NOM enhanced the reduction of iron and manganese oxides and oxyhydroxides in the sediment to more soluble forms (i.e. Fe^{2+}, Mn^{2+}). The magnitude of iron and manganese release varied depending on NOM type added, with the addition of vegetation resulting in the greatest release.

7) Trace metals including arsenic (As), cobalt (Co) and nickel (Ni) associated with these iron and manganese minerals were also released into the surface water. Elevated levels of copper (Cu) and zinc (Zn) were associated with both *Phragmites* and *Schoenoplectus*.

8) The surface water arsenic (As) concentration increased with all sediments as the conditions became more reducing and the pH increased. The addition of *Phragmites* and *Schoenoplectus* suppressed arsenic mobilisation in the sub-surface sediments (2.5-10 cm) compared to the untreated sediments due to the relatively low pH of these sediments.

9) The hydrolysis and reductive dissolution of jarosite and schwertmannite led to metal(loid) mobilisation, although in the presence of vegetation immobilisation was sometimes observed (possibly as the result of the precipitation of sulfides). The presence of schwertmannite was particularly effective in suppressing the release of arsenic due to arsenic sorption.

10) The concentration of many of the metal(loid)s in the surface waters exceeded the ANZECC water quality guidelines under the experimental conditions. The magnitude of metal(loid) mobilisation suggest the levels measured represent a low to moderate hazard. However, the potential impacts of the metal(loid) concentrations measured in this study on the surrounding aquatic environment is dependent on numerous factors (such as the rate of metal(loid) flux from the sediments and dilution in the receiving waters).

11) The addition of *Phragmites australis* to all sediments led to very high ammonia levels in the surface waters (up to 66 mg/L). Elevated ammonia levels were not observed when *Schoenoplectus validus* was added to the sediments. Whether the high ammonia levels measured under the conditions in the mesocosm experiment would potentially lead to the development of algal blooms is dependent on the rate of ammonia flux from the sediments, dilution within the lakes and other processes (e.g. nitrification/denitrification).

12) Although universally accepted critical metal(loid) contents for wetland vegetation are not available, this study has clearly shown elevated levels of some metals (i.e. Mn, Al) in the vegetation growing in the formerly acidified sediments. Such elevated metal concentrations are important as even moderate concentrations of metals have been shown to disrupt aquatic ecologies.

6.0 Recommendations

1) The results of the batch experiment have clearly shown that the carbon concentration has had an effect on the rate of recovery and release of metal(loid)s from the sediments. It is recommended that the effect of the organic carbon concentration on these processes is examined in detail using this experimental approach.

2) Whilst the reductive dissolution of the iron minerals added to the batch experiments (i.e. jarosite and schwertmannite) lead to an increase in the sulfate concentration and likely sulfide formation, the role of sulfate reduction on metal immobilisation was not directly assessed. The formation of sulfide minerals in these sediments (especially iron monosulfides) is potentially capable of strong metal immobilisation. In the mesocosm experiment there was a limited availability of sulfate resulting negligible sulfidisation. It is recommended that the effect of sulfate concentration is examined in detail using this experimental approach.

3) High surface water ammonia concentrations were observed under the conditions of this study following the addition of *Phragmites* to the sediments. Whether the high ammonia levels measured under the conditions in the mesocosm experiment would potentially lead to the development of algal blooms in the Lower Lakes is dependent on the rate of ammonia flux from the sediments, dilution within the lakes and other processes (e.g. nitrification/denitrification). Sullivan *et al.* (2012b) also showed that the uppermost sediments under *Phragmites* at Waltowa appeared likely to act as sources of soluble phosphate that could lead to increased nutrient flux/accumulation to lake water. It is recommended that the impact of *Phragmites* on the lake margins on the nutrient dynamics within the lakes is further examined.

7.0 References

Ahern C.R., L.A. Sullivan, and A.E. McElnea. 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=SearchByChemical

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

Baron D. and C.L. Palmer. 1996. Solubility of jarosite at 4-35^{o}C. Geochim. Cosmochim. Acta 60: 185-195.

Bi R., T. Yuan, Q. Lu, Y. Yuan, and S. Zhou. 2013. Electron donor capacity of reducing dissolved organic matter from crop residue decomposition as probed by chronoamperometry. Chemosph. 93: 1665-1671.

Burton E.D., R.T. Bush, S.G. Johnston, K.M. Watling, R.K. Hocking, L.A. Sullivan, and G.K. Parker. 2009. Sorption of arsenic (V) and arsenic (III) to schwertmannite. Env. Sci. Tech. 43: 9202-9207.

Burton E.D., R.T. Bush, L.A. Sullivan, S.G. Johnston, and D.R.G. Mitchell. 2008. Mobility of arsenic and selected metals during re-flooding of iron- and organic-rich acid-sulfate soil. Chem. Geol. 253: 64-73.

Burton E.D., R.T. Bush, L.A. Sullivan, and D.R.G. Mitchell. 2007. Reductive transformation of iron and sulfur in schwertmannite-rich accumulations associated with acidified coastal lowlands. Geochim. Cosmochim. Acta 71: 4456 - 4473.

Burton E.D. and S.G. Johnston. 2012. Impact of silica on the reductive transformation of schwertmannite and the mobilization of arsenic. Geochim. Cosmochim. Acta 96: 134-153.

Chacon N., W.L. Silver, E.A. Dubinsky and D.F. Cusack. 2006. Iron reduction and soil phosphorus solubilisation in humid tropical forests soils: the roles of labile carbon pools and an electron shuttle compound. Biogeochem. 78: 67-84.

Claff S.R., E.D. Burton, L.A. Sullivan, and R.T. Bush. 2011a. Metal partitioning dynamics during the oxidation and acidification of sulfidic soil. Chem. Geol. 286: 146-157.

Claff S.R., L.A. Sullivan, E.D. Burton, and R.T. Bush. 2010. A sequential extraction for acid sulfate soils: Partitioning of iron. Geoderma 155: 244-230.

Claff S.R., L.A. Sullivan, E.D. Burton, R.T. Bush, and S.C. Johnston. 2011b. Partitioning of metals in a degraded acid sulfate soil landscape: Influence of tidal re-inundation. Chemosph. 85: 1220-1226.

Cline I.D. 1969. Spectrophotometric determination of hydrogen sulfide in natural waters. Limn. Oceanog. 14: 454-458.

DENR. 2010. Acid sulfate soils research program summary report. Prepared by the Lower Lakes Acid Sulfate Soils Research Committee for the SA Department of Environment and Natural Resources, Adelaide.

Dent D.L. 1986. Acid sulfate soils: A baseline for research and development. ILRI Publ. 39. International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

Du Laing G., J. Rinklebe, B. Vandecasteele, E. Meers, and F.M.G. Tack. 2009. Trace metal behaviour in estuarine and riverine floodplain soils and sediments: A review. Sci. Total Env. 407: 3972–3985.

Fitzpatrick R.W., P. Shand, S. Marvanek, R.H. Merry, M. Thomas, M.D. Raven, S.L. Simpson, and S. McClure. 2008. Acid sulfate soils in subaqueous, waterlogged and drained soil environments in Lake Albert, Lake Alexandrina and River Murray below Blanchetown (Lock 1): properties, distribution, genesis, risks and management. Report prepared for Department of Environment and Heritage SA. CSIRO Land and Water Report Number 46/08. CSIRO Land and Water, Glen Osmond, SA.

Gambell R.P. 1994. Trace and toxic metals in wetlands – A review. J. Environ. Qual. 23: 883-891.

Goldstone J.V., M.J. Pullin, S. Bertilsson, and B.M. Voelker. 2002. Reactions of hydroxyl radical with humic substances: bleaching, mineralization and production of bioavailable carbon substrates. Env. Sci. Technol. 36: 364-372.

Hicks W.S., N. Creeper, J. Hutson, R.W. Fitzpatrick, S. Grocke, and P. Shand. 2009. The potential for contaminant mobilisation following acid sulfate soil rewetting: field experiment. Prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water for the SA Department of Environment and Natural Resources, Adelaide.

Hudson N., A. Baker, D. Ward, D.M. Reynolds, C. Brunsdon, C. Carliell-Marquet, and S. Browning. 2008. Can fluorescence spectrometry be used as a surrogate for the Biochemical Oxygen Demand (BOD) test in water quality assessment? An example from South West England . Sci. Total Env. 391: 159–158.

Jarvis S.C. and D.C. Whitehead. 1981. The influence of some soil and plant factors on the concentration of copper in perennial ryegrass. Plant and Soil 60: 275-286.

McGuire M.M. and R.J. Hamers. 2000. Extraction and quantitative analysis of elemental sulfur from sulfide mineral surfaces by high-performance liquid chromatography. Env. Sci. Tech. 34: 4651-4655.

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.

NAS. 1975. Nickel. Washington, DC, National Academy of Sciences, pp. 277.

Regenspurg S., A. Brand, and S. Peiffer. 2004. Formation and stability of schwertmannite in acidic mining lakes. Geochim. Cosmochim. Acta 68: 1185-1197.

Rohan D., V. Deepa, G. Rohan, and B. Satish. 2013. Bioelectricity production from microbial fuel using *Escherichia Coli* (Glucose and Brewery Waste). Int. Res. J. Bio. Sci. 2(7): 50-54.

Sarazin G., G. Michard, and F. Prevot. 1999. A rapid and accurate spectroscopic method for alkalinity measurements in sea water samples. Water Res. 33: 290-294.

Shand P., S. Grocke, J. Kirby, and A.K. Baker. 2012. The characterisation of metal and metalloid contaminants in re-flooded acid sulfate soils of Lake Alexandrina, South Australia. CSIRO Water for a Healthy Country Flagship, Australia.

Shirshova L.T., E.A. Ghabbour, and G. Davies. 2006. Spectroscopic characterization of humic acid fractions isolated from soil using different extraction procedures. Geoderma 133(3-4): 204–216.

Silveira M.L., N.B. Comerford, K.R. Reddy, W.T. Cooper and H. El-Rifai. 2008. Characterization of soil organic carbon pools by acid hydrolysis. Geoderma 144: 405–414.

Simpson S., R. Fitzpatrick, P. Shand, B. Angel, D. Spadaro, R. Merry, and M. Thomas. 2008. The acid, metal and nutrient mobilisation following rewetting of acid sulfate soils in the Lower Murray. Prepared for the South Australian Environmental Protection Agency. CSIRO Land and Water Bangor, NSW.

Simpson S.L., R.W. Fitzpatrick, P. Shand, B.M. Angel, D.A. Spadaro, and L. Mosley. 2010. Climate-driven mobilisation of acid and metals from acid sulfate soils. Marine Freshwater Res. 61: 129-138.

Simpson S., R. Jung, C. Jarolimek, and I. Hamilton. 2009. The potential for contaminant mobilisation following acid sulfate soil rewetting: lab experiment. Prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water for the SA Department of Environment and Natural Resources, Adelaide.

Stumm W. and J.J. Morgan. 1996. Aquatic chemistry. 3rd Ed., John Wiley & Sons, New York.

Sullivan L., E. Burton, R. Bush, K. Watling, and M. Bush. 2008. 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. Final Report. A report for "The acid, metal and nutrient mobilisation following rewetting of acid sulfate soils in the Lower Murray Project". Prepared for the South Australian Environmental Protection Agency. Centre for Acid Sulfate Soil Research, Southern Cross GeoScience, Southern Cross University, Lismore, NSW.

Sullivan L.A., E.D. Burton, N.J. Ward, R.T. Bush, J. Coughran, M.D. Cheetham, D.M. Fyfe, P.J. Cheeseman, and T. McIntyre. 2011. Lower Lakes sulfate reduction study. Prepared for South Australian Department of Environment and Natural Resources. Southern Cross GeoScience Technical Report No. 711, Southern Cross University, Lismore, NSW. 312 pp.

Sullivan L.A., R.T. Bush, and D.M. McConchie, 2000. A modified chromium-reducible sulfur method for reduced inorganic sulfur: optimum reaction time for acid sulfate soil. Aust. J. Soil Res. 38: 729–734.

Sullivan L.A., R.T. Bush, N.J. Ward, D.M. Fyfe, M. Johnston, E.D. Burton, P. Cheeseman, M. Bush, C. Maher, M. Cheetham, K.M. Watling, V.N.L Wong, R. Maher, and E. Weber. 2010. Lower Lakes laboratory study of contaminant mobilisation under seawater and freshwater inundation. Prepared by Southern Cross GeoScience for the SA Department of Environment and Natural Resources, Adelaide.

Sullivan L.A., J.F. Parr, N.J. Ward, R.T. Bush, D.M. Fyfe, M. Bush, and R. Hagan. 2012a. Lower Lakes carbon project. Prepared by Southern Cross GeoScience for the SA Department of Environment and Natural Resources, Adelaide.

Sullivan L.A., N.J. Ward, R.T. Bush, M.D. Cheetham, P.J. Cheeseman, D.M. Fyfe, T. McIntyre, M. Bush and R. Hagan. 2012b. Lower Lakes Phase 1 sulfate reduction monitoring project. Prepared by Southern Cross GeoScience for the SA Department of Environment, Water and Natural Resources, Adelaide.

Sullivan L.A., N.J. Ward, M.A. Rosicky, S. Li, R.T. Bush, D.M. Fyfe, M. Bush, and N. Toppler. 2013. Recovery of acid sulfate sediments in the Lower Lakes. Southern Cross GeoScience Technical Report No. 213. Prepared for the SA Department of Environment, Water and Natural Resources, Adelaide.

Vithana C., L.A. Sullivan, R.T. Bush, and E.D. Burton. 2013. Acidity fractions in acid sulfate soils and sediments: contributions of schwertmannite and jarosite. Soil Res. 51: 203-241.

Ward N.J., R.T. Bush, L.A. Sullivan, J. Coughran, and D.M. Fyfe. 2011. Assessment of Acid Sulfate Soil Materials (Phase 2): Edward-Wakool channel system. Prepared for Murray-Darling Basin Authority. Southern Cross GeoScience Technical Report 611, Southern Cross University, Lismore, NSW. 90 pp.

Ward N.J., L.A. Sullivan and R.T. Bush. 2013. Lower Lakes acid sulfate soil detailed conceptual models. Southern Cross GeoScience Technical Report No. 113. Prepared for the SA Department of Environment, Water and Natural Resources, Adelaide.

WHO. 2001. Zinc. Environmental Health Criteria: 221. World Health Organisation, Geneva.

8.0 Appendices

APPENDIX 1. Site and sample descriptions

Table 8-1. Tolderol site and profile descriptions.

Location	Treatment	Date	Profile	GPS Co-ordinates Zone East, North.	Depth (cm)	pH	Eh* (mV)	Location and Profile Remarks
Tolderol	Scald (no bioremediation)	31/10/13	TS 1	54H 0331071, 6083418	0-2.5	7.31	335	Scald (no bioremediation) site down to 10 cm. 0-1 cm: beige sand. 2-10 cm: grey sand with organic matter staining often visible.
					2.5-5	6.90	128	
					5-7.5	6.65	133	
					7.5-10	6.45	121	
					0-2.5	7.33	183	
					2.5-5	6.90	134	
					5-7.5	6.56	124	
					7.5-10	6.23	132	
		31/10/13	TS 2	54H 0331052, 6083437	0-2.5	7.05	177	Scald (no bioremediation) site down to 10 cm. 0-1 cm: beige sand. 1-10 cm: grey sand with organic matter staining often visible.
					2.5-5	6.57	162	
					5-7.5	5.92	217	
					7.5-10	4.10	324	
					0-2.5	7.42	251	
					2.5-5	7.21	160	
					5-7.5	4.90	255	
					7.5-10	4.23	342	
		31/10/13	TS 3	54H 0331043, 6083418	0-2.5	7.00	194	Scald (no bioremediation) site down to 10 cm. 0-1 cm: beige sand. 1-10 cm: grey sand with organic matter staining often visible. Jarosite occasionally visible at depth.
					2.5-5	6.82	147	
					5-7.5	6.65	148	
					7.5-10	6.63	141	
					0-2.5	7.30	135	
					2.5-5	7.03	149	
					5-7.5	6.63	128	
					7.5-10	6.60	131	

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-2. Waltowa site and profile descriptions.

Location	Treatment	Date	Profile	GPS Co-ordinates Zone East, North.	Depth (cm)	pH	Eh* (mV)	Location and Profile Remarks
Waltowa	*Cotula* bioremediation	31/10/13	WC 1	54H 0352233, 6059193	0-2.5	6.92	137	*Cotula* site down to 10 cm. 0-2 cm: beige sand. 2-10 cm: grey sand with organic matter staining often visible.
					2.5-5	6.64	95	
					5-7.5	6.71	77	
					7.5-10	6.40	68	
					0-2.5	7.15	115	
					2.5-5	7.28	67	
					5-7.5	6.59	57	
					7.5-10	6.35	77	
		31/10/13	WC 2	54H 0352217, 6059203	0-2.5	7.18	87	*Cotula* site down to 10 cm. 0-2 cm: beige sand. 2-10 cm: grey sand with organic matter staining often visible.
					2.5-5	7.15	64	
					5-7.5	6.96	47	
					7.5-10	6.70	56	
					0-2.5	6.86	86	
					2.5-5	6.88	70	
					5-7.5	6.91	61	
					7.5-10	6.59	51	
		31/10/13	WC 3	54H 0352241, 6059168	0-2.5	6.97	189	*Cotula* site down to 10 cm. 0-2 cm: beige sand. 2-10 cm: grey sand with organic matter staining often visible.
					2.5-5	6.82	99	
					5-7.5	6.76	88	
					7.5-10	6.57	72	
					0-2.5	6.99	114	
					2.5-5	6.94	76	
					5-7.5	6.77	84	
					7.5-10	6.59	70	

* Eh measurements are presented versus the standard hydrogen electrode

APPENDIX 2. Surface water characteristics (mesocosm experiment)

Table 8-3. Surface water properties (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Acidity[#] (mg/L $CaCO_3$) To pH 5.5	Acidity[#] (mg/L $CaCO_3$) To pH 6.5	Acidity[#] (mg/L $CaCO_3$) To pH 8.3	Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	DIC (mg/L)	Cl (mg/L)	Total S (mg/L)	Redox Potential Ep 1 (V)	Redox Potential Ep 2 (V)
TS	0-2.5	None	0	6.08	234	n.a.	0.1	18	23	40	<0.1	<10	4.81	0.22	9.69	4.18	-	-
		None	0	6.18	237	193	0.1	17	19	34	<0.1	<10	3.41	0.13	12.47	4.41	0.08	-
		Phragmites	0	5.88	248	947	-	3	37	118	<0.1	<10	412.40	0.58	96.16	27.55	0.30	-
		Phragmites	0	5.89	250	950	-	0	0	0	<0.1	<10	419.79	0.50	108.02	29.49	0.30	-
		Schoenoplectus	0	6.07	243	1248	-	24	40	86	<0.1	<10	409.30	0.44	226.80	43.09	0.29	0.60
		Schoenoplectus	0	6.06	245	1223	-	26	26	66	<0.1	<10	428.75	0.30	213.39	41.95	0.29	0.60
	2.5-10	None	0	4.35	325	145	0.1	7	7	22	0.23	<10	4.30	0.12	16.64	9.13	0.28	-
		None	0	4.34	330	150	0.1	6	6	20	0.25	<10	3.50	0.13	15.76	9.81	-	-
		Phragmites	0	5.42	263	961	-	3	40	106	0.50	<10	397.59	0.27	108.20	34.39	0.31	-
		Phragmites	0	5.37	252	951	-	2	43	118	0.54	<10	407.61	0.45	114.21	33.54	0.31	-
		Schoenoplectus	0	5.30	266	1263	-	5	29	63	0.92	<10	416.46	0.24	233.94	48.94	0.30	0.60
		Schoenoplectus	0	5.34	272	1266	-	0	23	55	0.82	<10	430.03	0.22	232.65	48.54	0.30	0.60
WC	0-2.5	None	0	8.29	183	175	0.4	5	16	35	<0.1	<10	6.82	0.20	39.07	6.24	-	-
		None	0	8.35	184	181	0.3	3	13	25	<0.1	<10	5.73	0.19	35.66	6.43	0.09	-
		Phragmites	0	6.15	241	1001	-	0	2	74	<0.1	<10	>460	n.a.	131.14	29.68	0.30	-
		Phragmites	0	6.13	243	1010	-	0	0	0	<0.1	<10	427.29	0.44	114.88	29.82	0.30	-
		Schoenoplectus	0	6.47	239	1337	-	0	7	45	<0.1	<10	425.04	0.29	248.75	45.58	0.29	0.60
		Schoenoplectus	0	6.49	242	1324	-	6	30	63	<0.1	<10	422.05	0.40	244.32	43.97	0.29	0.60
	2.5-10	None	0	5.42	255	271	0.2	5	8	20	<0.1	<10	3.72	0.09	43.74	14.49	-	-
		None	0	5.43	277	266	0.2	4	4	17	<0.1	<10	3.26	0.09	40.89	14.53	-	-
		Phragmites	0	5.73	236	1038	-	0	0	11	0.24	<10	420.23	0.42	128.88	38.36	0.31	-
		Phragmites	0	5.73	242	1040	-	0	0	51	0.26	<10	415.99	0.35	134.10	36.08	0.31	-
		Schoenoplectus	0	5.88	264	1343	-	0	16	49	0.20	<10	421.27	0.47	263.71	52.38	0.30	0.61
		Schoenoplectus	0	5.83	268	1355	-	18	40	71	0.20	<10	420.72	0.29	262.14	52.43	0.30	0.61
TS	0-2.5	None	4	7.76	-217	278	0.6	n.a.	n.a.	33	1.09	<10	12.57	2.20	3.41	2.10	-	-
		None	4	7.86	-216	262	0.5	n.a.	n.a.	25	1.12	<10	11.96	2.04	2.81	2.47	-	-
		Phragmites	4	5.54	-75	1581	-	n.a.	n.a.	319	64.13	n.a.	n.a.	n.a.	84.21	4.91	0.21	0.72
		Phragmites	4	5.52	-67	1552	-	n.a.	n.a.	300	65.04	n.a.	n.a.	n.a.	94.38	5.38	0.23	0.72
		Schoenoplectus	4	5.18	-62	1551	-	n.a.	n.a.	453	62.92	n.a.	n.a.	n.a.	219.94	6.76	0.28	0.72
		Schoenoplectus	4	5.25	-66	1530	-	n.a.	n.a.	435	61.40	n.a.	478.68	1.55	223.92	6.53	0.23	0.73
	2.5-10	None	4	4.86	12	259	0.2	n.a.	n.a.	52	2.74	79	n.a.	n.a.	22.88	13.77	0.10	-
		None	4	5.00	7	238	0.2	n.a.	n.a.	50	2.86	157	n.a.	n.a.	19.42	13.34	0.10	-
		Phragmites	4	5.10	-23	1398	-	n.a.	n.a.	405	42.86	n.a.	n.a.	n.a.	95.83	5.21	0.26	0.56
		Phragmites	4	5.32	-40	1372	-	n.a.	n.a.	293	43.16	n.a.	n.a.	n.a.	105.15	5.04	0.23	0.74
		Schoenoplectus	4	5.19	47	1411	-	n.a.	n.a.	406	37.99	n.a.	n.a.	n.a.	230.41	5.06	0.25	-
		Schoenoplectus	4	5.23	25	1407	-	n.a.	n.a.	410	39.21	n.a.	n.a.	n.a.	217.14	6.00	0.26	-

* Eh measurements are presented versus the standard hydrogen electrode

[#] Acidity method followed uses an end point of pH 8.3 (see APHA 2310 B; APHA 2005)

Table 8-3 (continued). Surface water properties (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Acidity[#] (mg/L CaCO$_3$)			Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	DIC (mg/L)	Cl (mg/L)	Total S (mg/L)	Redox Potential Ep 1 (V)	Redox Potential Ep 2 (V)
								To pH 5.5	To pH 6.5	To pH 8.3								
WC	0-2.5	None	4	8.11	-74	253	1.6	n.a.	n.a.	0	0.30	<10	n.a.	n.a.	32.21	1.97	-	-
		None	4	8.12	-71	259	1.7	n.a.	n.a.	0	<0.1	<10	n.a.	n.a.	31.80	1.86	-	-
		Phragmites	4	5.27	23	1736	-	n.a.	n.a.	375	60.79	n.a.	n.a.	n.a.	125.03	6.57	0.24	-
		Phragmites	4	5.38	34	1699	-	n.a.	n.a.	320	61.70	n.a.	n.a.	n.a.	129.60	5.53	0.23	0.72
		Schoenoplectus	4	5.16	27	1692	-	n.a.	n.a.	434	58.36	n.a.	425.07	1.20	237.07	7.27	0.27	0.74
		Schoenoplectus	4	5.15	37	1676	-	n.a.	n.a.	448	55.32	n.a.	422.89	1.26	246.47	5.97	0.26	0.74
	2.5-10	None	4	7.62	-40	265	0.6	n.a.	n.a.	25	1.55	<10	10.77	1.23	44.01	11.87	-	-
		None	4	7.58	-33	285	0.7	n.a.	n.a.	29	2.16	43	n.a.	n.a.	41.14	12.64	-	-
		Phragmites	4	5.17	93	1688	-	n.a.	n.a.	375	42.25	n.a.	463.72	0.25	126.90	4.77	0.23	0.74
		Phragmites	4	5.23	90	1642	-	n.a.	n.a.	359	42.86	n.a.	455.39	0.59	124.85	5.17	0.23	0.73
		Schoenoplectus	4	5.07	66	1508	-	n.a.	n.a.	393	39.21	n.a.	392.73	0.31	246.18	8.52	0.27	0.75
		Schoenoplectus	4	5.25	86	1497	-	n.a.	n.a.	335	37.08	n.a.	390.88	0.36	256.54	5.59	0.26	0.75
TS	0-2.5	None	8	7.68	-175	n.a.	0.8	0	0	14	1.84	<10	14.64	0.08	14.57	1.77	-	-
		None	8	7.99	-183	168	0.7	0	0	17	0.84	<10	11.45	0.05	8.52	1.70	-	-
		Phragmites	8	7.11	-115	1350	-	0	0	0	28.46	<10	480.86	0.01	91.62	3.72	0.64	-
		Phragmites	8	6.99	-97	1438	-	0	0	0	29.77	<10	390.16	0.05	90.37	3.23	-	-
		Schoenoplectus	8	7.05	-116	1416	-	0	0	22	42.46	<10	234.32	0.01	220.82	3.38	0.67	-
		Schoenoplectus	8	7.22	-111	1418	-	0	0	28	39.90	<10	244.04	0.02	216.26	3.31	0.67	-
	2.5-10	None	8	7.02	-130	187	0.5	13	17	35	6.03	42	12.04	0.03	17.64	12.24	0.10	-
		None	8	7.05	-132	220	0.4	16	21	38	6.14	53	10.55	0.03	12.23	10.24	0.10	-
		Phragmites	8	5.04	52	1361	-	n.a.	n.a.	n.a.	50.02	<10	725.09	0.02	96.26	4.63	0.24	0.76
		Phragmites	8	4.98	49	1377	-	256	374	455	52.44	<10	668.35	0.01	99.05	4.37	0.25	0.75
		Schoenoplectus	8	5.10	19	1407	-	294	374	425	47.45	<10	448.21	0.04	227.98	4.70	0.25	0.75
		Schoenoplectus	8	5.09	5	1433	-	219	317	373	48.36	<10	334.04	0.03	225.01	4.79	0.27	0.67
WC	0-2.5	None	8	8.10	-121	276	1.5	0	0	0	0.11	<10	23.39	0.05	27.71	0.79	-	-
		None	8	8.13	-120	276	1.6	0	0	0	0.21	20	21.29	0.03	20.48	0.76	-	-
		Phragmites	8	7.05	-82	1598	-	0	0	0	20.25	<10	580.98	0.03	127.92	4.00	0.64	-
		Phragmites	8	7.03	-58	1489	-	0	0	5	27.96	<10	629.28	0.03	115.08	3.53	-	-
		Schoenoplectus	8	7.09	-89	1503	-	0	6	62	35.36	<10	385.21	0.03	255.69	3.48	0.66	-
		Schoenoplectus	8	7.03	-78	1456	-	0	0	0	25.39	<10	277.43	0.02	230.22	3.40	0.63	-
	2.5-10	None	8	7.98	-127	243	0.9	0	0	0	0.22	212	9.64	0.04	33.87	3.03	-	-
		None	8	7.89	-119	240	1.0	0	0	12	0.23	156	9.08	0.04	36.80	1.66	-	-
		Phragmites	8	5.05	83	1608	-	221	362	435	49.27	<10	807.99	0.04	122.19	4.72	0.24	0.74
		Phragmites	8	5.09	66	1670	-	199	349	433	45.94	<10	774.75	0.02	123.95	4.65	0.25	0.72
		Schoenoplectus	8	5.13	50	1560	-	173	270	324	45.03	<10	493.91	0.03	249.74	4.16	0.24	0.75
		Schoenoplectus	8	5.09	54	1524	-	190	301	354	43.82	<10	513.84	0.02	252.35	4.96	0.25	0.75

* Eh measurements are presented versus the standard hydrogen electrode

[#] Acidity method followed uses an end point of pH 8.3 (see APHA 2310 B; APHA 2005)

Table 8-3 (continued). Surface water properties (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Acidity# (mg/L $CaCO_3$)			Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	DIC (mg/L)	Cl (mg/L)	Total S (mg/L)	Redox Potential Ep 1 (V)	Redox Potential Ep 2 (V)
								To pH 5.5	To pH 6.5	To pH 8.3								
TS	0-2.5	None	16	7.58	33	n.a.	0.3	0	0	15	0.79	<20	17.34	1.14	13.46	2.68	-	-
		None	16	7.66	22	133	0.3	0	0	12	0.61	<20	19.17	0.40	41.62	4.56	-	-
		Phragmites	16	7.42	-28	1451	-	0	0	0	19.30	<20	343.41	4.45	92.17	5.27	0.62	-
		Phragmites	16	7.42	-29	1271	-	0	0	0	17.67	<20	276.54	8.53	68.46	3.99	0.31	0.65
		Schoenoplectus	16	7.20	-9	1852	-	0	0	0	24.47	<20	184.35	6.68	234.91	5.05	0.65	-
		Schoenoplectus	16	6.86	3	1718	-	0	0	0	36.51	<20	274.60	1.51	232.10	6.36	0.16	0.66
	2.5-10	None	16	7.40	-18	222	0.3	0	0	0	1.55	<20	21.04	3.85	5.46	0.96	-	-
		None	16	7.47	-28	130	0.3	0	0	0	1.66	<20	20.58	3.63	6.37	1.54	-	-
		Phragmites	16	4.98	192	1683	-	306	430	518	63.49	<20	687.28	0.53	89.70	5.71	0.24	0.77
		Phragmites	16	4.99	184	1707	-	263	397	490	62.45	<20	734.91	0.53	109.96	5.67	0.28	-
		Schoenoplectus	16	5.03	211	1687	-	244	356	446	62.61	<20	488.07	0.39	227.30	4.20	0.24	0.76
		Schoenoplectus	16	5.04	204	1663	-	261	402	492	57.66	<20	452.98	0.35	229.28	4.11	0.28	0.56
WC	0-2.5	None	16	8.40	-27	365	1.1	0	0	0	0.10	42	20.81	1.50	8.53	0.84	-	-
		None	16	8.48	-22	293	1.2	0	0	0	0.14	60	21.35	4.27	0.04	1.15	-	-
		Phragmites	16	7.22	7	1548	-	0	0	0	11.21	<20	220.58	9.89	89.76	3.47	0.15	0.64
		Phragmites	16	7.37	-11	1622	-	0	0	0	9.16	<20	257.45	12.96	137.62	3.26	0.64	-
		Schoenoplectus	16	7.02	9	1971	-	0	0	0	22.04	<20	210.08	8.25	255.82	1.67	0.16	0.65
		Schoenoplectus	16	7.10	1	1729	-	0	0	0	19.73	<20	207.77	0.98	268.94	4.14	0.16	0.66
	2.5-10	None	16	8.09	-36	375	0.2	0	0	0	0.12	52	22.27	4.06	48.51	0.40	-	-
		None	16	8.30	-45	283	0.6	0	0	0	<0.1	<20	21.93	3.23	78.44	0.00	-	-
		Phragmites	16	5.02	196	1862	-	681	814	896	59.42	<20	784.89	0.20	128.17	8.47	0.25	0.74
		Phragmites	16	7.16	29	1810	-	0	0	0	8.27	<20	431.48	0.80	115.83	5.88	0.66	-
		Schoenoplectus	16	7.11	1	1845	-	0	0	0	19.81	<20	251.43	0.54	252.47	5.88	0.18	0.72
		Schoenoplectus	16	5.23	179	1798	-	162	262	336	51.91	<20	435.80	0.32	264.82	5.08	0.25	0.75

* Eh measurements are presented versus the standard hydrogen electrode

Acidity method followed uses an end point pH of 8.3 (see APHA 2310 B; APHA 2005)

Table 8-4. Surface water soluble cation and nutrient analyses (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Soluble cations				Nutrients		
				Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Nitrate (mg/L N)	Nitrite (mg/L N)	Ammonia (mg/L N)
TS	0-2.5	None	0	1.10	0.68	1.90	6.89	0.025	0.004	0.343
		None	0	1.09	0.74	1.97	6.43	0.015	0.003	0.368
		Phragmites	0	22.19	15.09	152.27	30.28	0.010	0.016	3.656
		Phragmites	0	23.14	15.60	155.60	32.49	0.017	0.017	3.679
		Schoenoplectus	0	32.72	24.90	77.76	116.23	0.011	0.019	1.402
		Schoenoplectus	0	34.84	26.29	73.30	114.58	0.015	0.018	1.480
	2.5-10	None	0	2.12	1.77	3.51	9.88	0.013	0.004	0.395
		None	0	2.20	1.90	3.57	9.87	0.006	0.005	0.407
		Phragmites	0	20.76	15.81	149.81	34.31	<0.001	0.021	14.810
		Phragmites	0	20.89	15.60	147.27	33.67	0.007	0.013	3.717
		Schoenoplectus	0	32.91	26.42	75.45	119.20	0.006	0.016	1.380
		Schoenoplectus	0	33.40	26.41	73.90	117.45	0.008	0.016	1.364
WC	0-2.5	None	0	3.00	1.71	2.40	19.33	0.138	0.005	0.381
		None	0	3.02	1.73	2.32	19.11	0.144	0.006	0.347
		Phragmites	0	25.87	17.48	151.59	42.45	0.121	0.017	3.739
		Phragmites	0	26.34	17.84	156.34	43.77	0.115	0.018	3.928
		Schoenoplectus	0	36.71	27.62	79.91	131.33	0.104	0.021	1.322
		Schoenoplectus	0	35.48	26.78	81.36	126.83	0.106	0.021	1.439
	2.5-10	None	0	4.97	4.74	3.67	25.24	0.015	0.003	0.366
		None	0	4.83	4.76	3.76	24.85	0.012	0.004	0.391
		Phragmites	0	24.23	20.57	154.91	50.26	0.016	0.015	3.434
		Phragmites	0	23.35	19.54	150.80	49.20	0.017	0.016	3.406
		Schoenoplectus	0	36.34	31.19	78.58	135.66	0.012	0.017	1.121
		Schoenoplectus	0	36.99	30.91	77.95	132.64	0.013	0.018	1.116
TS	0-2.5	None	4	2.65	1.79	1.93	6.89	0.024	0.003	1.227
		None	4	2.70	1.79	1.88	7.59	0.033	0.002	1.014
		Phragmites	4	36.10	20.04	150.15	31.68	0.013	0.014	64.700
		Phragmites	4	37.46	20.07	152.53	32.47	0.015	0.008	62.900
		Schoenoplectus	4	50.65	31.39	78.24	123.34	0.008	0.017	0.262
		Schoenoplectus	4	49.74	32.28	74.28	118.48	0.002	0.015	0.464
	2.5-10	None	4	3.51	3.04	4.49	12.48	0.019	0.002	0.867
		None	4	3.29	2.88	4.37	12.00	0.021	0.001	0.555
		Phragmites	4	31.14	20.43	145.69	35.24	0.018	0.011	39.600
		Phragmites	4	29.39	19.97	144.91	35.88	0.021	0.014	39.400
		Schoenoplectus	4	41.59	29.02	75.72	125.58	0.013	0.065	0.484
		Schoenoplectus	4	40.84	28.66	71.73	120.07	0.017	0.088	0.775

Table 8-4 (continued). Surface water soluble cation and nutrient analyses (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Soluble cations				Nutrients		
				Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Nitrate (mg/L N)	Nitrite (mg/L N)	Ammonia (mg/L N)
WC	0-2.5	None	4	9.06	5.36	3.23	20.53	0.056	0.001	2.645
		None	4	9.37	5.56	3.21	21.52	0.039	0.002	2.919
		Phragmites	4	54.17	27.48	160.53	46.57	0.017	0.011	66.000
		Phragmites	4	53.93	28.39	163.63	47.00	0.010	0.010	64.600
		Schoenoplectus	4	69.98	37.62	82.19	129.44	0.002	0.014	0.707
		Schoenoplectus	4	66.03	37.56	83.27	130.49	0.004	0.014	0.446
	2.5-10	None	4	6.63	6.03	3.72	26.87	0.024	0.003	1.710
		None	4	6.40	5.76	3.64	26.90	0.024	0.002	1.148
		Phragmites	4	42.27	28.16	150.17	52.63	0.023	0.008	69.500
		Phragmites	4	42.19	27.80	154.81	52.92	0.017	0.009	56.800
		Schoenoplectus	4	52.11	37.05	78.03	135.77	0.012	0.014	0.248
		Schoenoplectus	4	53.17	36.99	75.68	139.10	0.012	0.014	0.561
TS	0-2.5	None	8	3.14	2.09	2.08	7.91	0.018	<0.001	1.724
		None	8	2.78	1.85	2.26	8.15	0.009	0.001	1.502
		Phragmites	8	32.67	20.94	164.89	35.44	0.023	0.012	32.465
		Phragmites	8	34.87	21.03	166.49	35.74	0.011	0.013	64.092
		Schoenoplectus	8	48.42	34.06	81.87	132.73	0.004	0.009	0.101
		Schoenoplectus	8	50.01	33.46	81.46	131.04	0.003	0.006	0.057
	2.5-10	None	8	3.39	2.83	3.67	13.08	0.016	0.002	0.631
		None	8	2.98	2.76	3.83	11.59	0.001	<0.001	0.648
		Phragmites	8	37.31	24.48	173.31	42.19	0.004	0.009	36.573
		Phragmites	8	38.47	24.94	174.96	40.85	0.001	0.013	39.796
		Schoenoplectus	8	47.85	33.52	83.48	137.36	<0.001	0.010	0.654
		Schoenoplectus	8	46.06	32.13	81.85	137.02	<0.001	0.014	0.343
WC	0-2.5	None	8	9.30	5.64	3.33	23.33	0.002	<0.001	4.760
		None	8	9.82	5.58	3.29	23.47	0.005	0.001	4.870
		Phragmites	8	45.34	27.10	166.47	50.93	0.012	0.010	79.849
		Phragmites	8	50.09	28.64	179.82	52.25	<0.001	0.011	52.586
		Schoenoplectus	8	62.89	40.03	82.89	145.17	0.012	0.005	0.115
		Schoenoplectus	8	65.35	40.83	87.50	149.85	0.001	0.007	0.065
	2.5-10	None	8	4.22	4.17	3.13	31.20	0.012	0.001	1.051
		None	8	4.27	3.93	3.17	32.15	0.007	<0.001	1.290
		Phragmites	8	50.53	33.79	178.03	61.22	0.024	0.014	51.499
		Phragmites	8	49.74	32.02	179.87	60.14	0.024	0.017	46.165
		Schoenoplectus	8	62.63	43.93	90.36	160.26	0.011	0.016	1.199
		Schoenoplectus	8	62.19	45.26	87.33	160.29	0.005	0.010	0.839

Table 8-4 (continued). Surface water soluble cation and nutrient analyses (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Soluble cations				Nutrients		
				Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Nitrate (mg/L N)	Nitrite (mg/L N)	Ammonia (mg/L N)
TS	0-2.5	None	16	2.10	1.41	2.41	8.62	0.011	0.005	0.991
		None	16	2.10	1.54	2.29	8.40	0.005	0.003	0.970
		Phragmites	16	29.68	21.06	162.73	36.67	n.a.	0.030	17.375
		Phragmites	16	29.47	20.58	162.11	37.50	0.013	0.019	12.670
		Schoenoplectus	16	48.61	34.65	79.24	138.94	n.a.	0.012	0.250
		Schoenoplectus	16	48.84	35.19	80.90	140.90	0.035	0.011	0.015
	2.5-10	None	16	1.35	1.11	3.61	12.73	0.015	0.003	0.293
		None	16	1.32	1.29	3.72	12.97	0.001	0.004	0.309
		Phragmites	16	39.60	27.42	178.28	41.26	0.016	0.026	58.010
		Phragmites	16	39.18	26.73	174.15	40.17	<0.001	0.015	43.840
		Schoenoplectus	16	51.20	38.53	83.34	142.68	0.001	0.016	0.589
		Schoenoplectus	16	51.49	36.99	84.95	144.43	0.002	0.019	0.402
WC	0-2.5	None	16	8.51	4.58	3.68	24.09	0.003	0.002	3.062
		None	16	8.18	4.37	3.30	22.60	<0.001	0.002	3.535
		Phragmites	16	47.85	28.19	165.64	51.66	<0.001	0.025	9.950
		Phragmites	16	48.39	27.73	170.57	52.65	<0.001	0.026	19.080
		Schoenoplectus	16	64.02	42.23	83.85	154.29	<0.001	0.013	0.047
		Schoenoplectus	16	61.37	41.58	81.46	151.24	<0.001	0.011	0.055
	2.5-10	None	16	3.34	3.17	3.24	28.75	0.017	0.002	0.796
		None	16	3.80	3.30	3.23	29.84	0.010	0.001	0.810
		Phragmites	16	52.03	36.45	178.31	58.09	0.118	0.012	31.520
		Phragmites	16	36.60	30.07	166.80	59.66	<0.001	0.031	62.130
		Schoenoplectus	16	52.52	42.81	79.18	160.08	<0.001	0.010	0.010
		Schoenoplectus	16	63.24	46.27	88.55	161.46	<0.001	0.015	1.165

Table 8-5. Surface water metal(loid) concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	
TS	0-2.5	None	0	0.01	0.04	0.4	<0.01	0.4	0.2	1.5	0.06	0.02	1.8	1.1	<0.1	31.5	<0.1
TS	0-2.5	None	0	0.01	0.35	0.4	<0.01	0.6	0.2	0.9	0.23	0.02	1.0	1.8	<0.1	11.3	<0.1
TS	0-2.5	Phragmites	0	0.02	0.08	1.6	0.03	0.4	2.2	12.9	0.21	0.95	8.2	5.0	0.1	290.4	<0.1
TS	0-2.5	Phragmites	0	0.01	0.09	1.8	0.04	0.3	2.1	13.6	0.23	0.98	8.0	5.1	<0.1	371.5	<0.1
TS	0-2.5	Schoenoplectus	0	<0.01	0.21	0.6	0.02	0.4	1.9	10.4	0.20	0.72	8.4	1.9	0.2	105.3	<0.1
TS	0-2.5	Schoenoplectus	0	<0.01	0.20	5.8	0.02	0.4	2.3	11.5	0.21	0.82	9.9	2.1	0.1	146.3	<0.1
TS	2.5-10	None	0	<0.01	0.01	0.8	0.01	0.2	1.8	2.7	0.11	0.08	3.3	1.5	<0.1	31.2	<0.1
TS	2.5-10	None	0	<0.01	0.02	1.1	0.01	0.3	1.9	1.3	0.12	0.08	3.1	1.1	<0.1	38.7	<0.1
TS	2.5-10	Phragmites	0	<0.01	0.44	2.2	0.03	0.6	8.4	18.2	0.49	1.04	13.6	2.9	0.1	256.7	<0.1
TS	2.5-10	Phragmites	0	<0.01	0.42	2.7	0.03	0.8	8.8	19.3	0.50	1.02	13.5	3.1	<0.1	283.9	<0.1
TS	2.5-10	Schoenoplectus	0	0.01	0.80	1.9	0.04	0.8	8.7	16.6	0.82	0.97	17.7	2.1	0.2	99.0	<0.1
TS	2.5-10	Schoenoplectus	0	<0.01	0.66	1.6	0.04	0.5	8.3	15.3	0.62	0.95	16.3	2.1	0.4	102.8	<0.1
WC	0-2.5	None	0	<0.01	0.03	0.7	<0.01	0.3	0.1	2.4	0.04	<0.01	1.6	<0.1	0.2	1.3	<0.1
WC	0-2.5	None	0	<0.01	0.02	0.8	<0.01	0.2	0.2	2.3	0.03	<0.01	1.0	<0.1	0.2	5.7	<0.1
WC	0-2.5	Phragmites	0	<0.01	0.08	2.3	0.03	0.8	2.1	22.2	0.17	0.80	7.8	0.3	0.5	277.8	<0.1
WC	0-2.5	Phragmites	0	0.04	0.12	2.2	0.04	0.4	1.8	19.6	0.18	0.90	7.0	0.2	0.2	274.2	<0.1
WC	0-2.5	Schoenoplectus	0	0.03	0.10	1.2	0.02	0.7	1.3	14.3	0.10	0.60	6.5	0.1	0.4	72.5	<0.1
WC	0-2.5	Schoenoplectus	0	0.03	0.12	1.0	0.01	0.4	1.3	14.7	0.11	0.56	6.4	0.2	0.7	73.4	<0.1
WC	2.5-10	None	0	0.01	<0.01	<0.1	0.03	0.2	3.3	0.8	0.01	0.06	3.3	<0.1	0.2	41.6	<0.1
WC	2.5-10	None	0	0.01	<0.01	<0.1	0.02	0.1	3.4	0.7	0.02	0.06	3.3	<0.1	0.3	13.1	<0.1
WC	2.5-10	Phragmites	0	0.02	0.07	1.6	0.05	0.5	12.8	17.2	0.26	0.90	13.2	0.8	0.3	318.2	<0.1
WC	2.5-10	Phragmites	0	0.01	0.07	1.4	0.05	0.8	11.1	15.8	0.26	0.89	10.7	0.8	<0.1	367.4	<0.1
WC	2.5-10	Schoenoplectus	0	0.01	0.13	0.6	0.04	0.5	10.9	12.5	0.20	0.71	12.9	0.4	0.4	51.7	<0.1
WC	2.5-10	Schoenoplectus	0	<0.01	0.14	0.7	0.03	0.4	11.5	13.9	0.22	0.73	14.0	0.4	0.2	81.7	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-5 (continued). Surface water metal(loid) concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	
TS	0-2.5	None	4	0.11	0.05	10.3	<0.01	95.8*	0.8	1.8	1.59	0.11	4.4	3.1	0.2	40.2	<0.1
TS	0-2.5	None	4	0.08	0.04	12.2	<0.01	0.6	0.4	1.5	1.13	0.10	2.4	2.6	0.2	29.6	<0.1
TS	0-2.5	Phragmites	4	0.09	0.07	10.3	<0.01	1.2	11.9	0.9	65.75	1.79	56.1	0.3	0.7	182.5	<0.1
TS	0-2.5	Phragmites	4	0.05	0.05	12.0	<0.01	1.1	12.1	0.8	66.25	1.82	53.8	0.3	0.5	183.0	<0.1
TS	0-2.5	Schoenoplectus	4	0.05	0.12	9.8	<0.01	2.1	10.2	1.0	63.89	1.59	43.7	0.3	0.3	168.9	<0.1
TS	0-2.5	Schoenoplectus	4	0.04	0.09	9.0	<0.01	1.8	9.5	0.9	61.65	1.67	29.1	0.3	0.4	115.4	<0.1
TS	2.5-10	None	4	0.02	0.02	5.8	<0.01	0.3	3.1	1.3	2.67	0.14	5.5	0.2	<0.1	89.7	<0.1
TS	2.5-10	None	4	0.02	0.02	6.1	<0.01	0.4	2.9	0.4	2.87	0.13	5.6	0.1	0.1	72.7	<0.1
TS	2.5-10	Phragmites	4	0.03	0.20	6.3	<0.01	2.8	8.3	0.6	42.22	1.39	26.6	0.2	0.4	186.4	<0.1
TS	2.5-10	Phragmites	4	0.02	0.16	6.5	<0.01	3.1	8.2	0.9	36.38	1.33	26.4	0.3	0.5	182.1	<0.1
TS	2.5-10	Schoenoplectus	4	0.02	0.16	8.1	<0.01	3.5	5.4	1.2	38.22	1.07	15.3	0.3	0.5	235.2	<0.1
TS	2.5-10	Schoenoplectus	4	0.02	0.19	10.5	<0.01	3.9	5.3	0.9	37.71	1.04	14.3	0.4	0.4	219.0	<0.1
WC	0-2.5	None	4	<0.01	0.04	19.1	<0.01	0.3	0.2	1.2	0.28	0.23	2.4	0.2	0.4	29.3	<0.1
WC	0-2.5	None	4	<0.01	0.05	19.8	0.01	1.1	0.2	1.1	0.10	0.24	4.4	0.1	0.3	32.2	<0.1
WC	0-2.5	Phragmites	4	0.01	0.10	20.9	<0.01	0.7	23.0	1.0	64.88	2.68	134.1	<0.1	0.5	158.0	<0.1
WC	0-2.5	Phragmites	4	0.01	0.10	23.5	<0.01	0.7	23.3	1.0	63.76	2.78	109.4	0.1	0.7	138.8	<0.1
WC	0-2.5	Schoenoplectus	4	0.02	0.07	16.9	<0.01	0.9	16.0	1.0	55.94	2.28	46.6	<0.1	0.8	165.2	<0.1
WC	0-2.5	Schoenoplectus	4	0.01	0.07	15.0	<0.01	0.9	15.6	0.8	56.03	2.27	49.5	0.1	0.6	135.9	<0.1
WC	2.5-10	None	4	<0.01	0.02	25.2	<0.01	5.0	0.5	0.3	1.60	0.09	1.7	0.2	0.2	43.5	<0.1
WC	2.5-10	None	4	<0.01	0.02	23.5	<0.01	0.2	0.4	0.5	2.10	0.08	1.7	0.1	0.3	35.5	<0.1
WC	2.5-10	Phragmites	4	0.06	0.09	6.9	<0.01	216.7*	27.0	1.3	42.44	1.34	113.5	0.6	0.6	197.7	<0.1
WC	2.5-10	Phragmites	4	0.05	0.08	7.1	<0.01	1.2	24.8	0.8	41.46	1.42	137.4	0.4	0.8	216.2	<0.1
WC	2.5-10	Schoenoplectus	4	0.04	0.12	6.6	<0.01	1.6	16.9	1.0	38.38	1.06	43.4	0.2	0.3	209.6	<0.1
WC	2.5-10	Schoenoplectus	4	0.03	0.11	6.7	0.04	7.4	17.3	1.3	36.95	1.12	80.2	0.4	0.4	318.4	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

* Outliers not included in plots.

Table 8-5 (continued). Surface water metal(loid) concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	
TS	0-2.5	None	8	0.15	0.08	26.7	0.02	0.5	0.2	1.9	1.89	0.12	1.8	7.8	0.2	38.8	<0.1
TS	0-2.5	None	8	0.06	0.10	22.7	0.01	0.4	0.2	1.2	0.93	0.10	1.7	3.9	0.3	34.0	<0.1
TS	0-2.5	Phragmites	8	0.08	0.03	16.8	<0.01	1.0	8.0	1.2	34.81	0.91	47.4	0.6	0.3	145.3	<0.1
TS	0-2.5	Phragmites	8	0.05	0.04	22.1	<0.01	1.0	8.2	0.9	31.98	0.82	48.0	0.5	0.5	98.4	<0.1
TS	0-2.5	Schoenoplectus	8	0.06	0.03	17.3	<0.01	1.1	4.7	0.9	46.82	1.45	21.1	0.2	0.4	112.8	<0.1
TS	0-2.5	Schoenoplectus	8	0.04	0.04	18.0	<0.01	0.8	4.7	1.2	44.09	1.46	29.3	0.3	0.5	141.4	<0.1
TS	2.5-10	None	8	0.04	0.04	27.8	<0.01	0.7	1.3	1.2	6.36	0.11	3.6	0.9	0.4	78.8	<0.1
TS	2.5-10	None	8	0.04	0.05	31.0	<0.01	0.7	1.3	0.7	6.54	0.11	3.6	0.8	<0.1	36.9	<0.1
TS	2.5-10	Phragmites	8	0.03	0.27	10.4	<0.01	8.5	8.1	1.0	54.87	1.53	27.3	0.6	0.6	245.6	<0.1
TS	2.5-10	Phragmites	8	0.02	0.19	9.3	<0.01	3.2	8.5	1.0	57.31	1.67	34.4	0.7	0.7	235.4	<0.1
TS	2.5-10	Schoenoplectus	8	0.02	0.11	6.7	0.02	3.5	5.5	1.2	49.85	1.26	11.8	0.7	0.7	239.3	<0.1
TS	2.5-10	Schoenoplectus	8	0.03	0.18	6.6	<0.01	4.1	5.7	1.2	49.61	1.21	12.0	0.5	0.6	242.2	<0.1
WC	0-2.5	None	8	0.01	0.07	18.7	<0.01	0.4	0.2	0.9	0.13	0.17	2.4	0.2	0.3	18.6	<0.1
WC	0-2.5	None	8	0.01	0.09	19.8	<0.01	0.6	0.2	0.8	0.25	0.20	2.1	0.1	0.4	12.5	<0.1
WC	0-2.5	Phragmites	8	0.02	0.06	35.2	<0.01	0.9	12.8	1.4	19.63	1.08	121.4	0.2	0.4	163.8	<0.1
WC	0-2.5	Phragmites	8	0.02	0.08	34.0	<0.01	0.8	13.3	1.3	30.22	1.40	99.3	0.5	0.5	147.5	<0.1
WC	0-2.5	Schoenoplectus	8	0.02	0.05	30.0	<0.01	0.8	7.5	1.2	35.61	1.96	40.7	0.1	0.5	154.8	<0.1
WC	0-2.5	Schoenoplectus	8	0.07	0.02	28.7	<0.01	0.5	5.1	1.0	26.62	1.81	35.0	0.1	0.6	150.1	<0.1
WC	2.5-10	None	8	0.03	0.13	25.8	<0.01	0.4	0.2	0.5	0.29	0.04	1.9	0.2	0.4	11.1	<0.1
WC	2.5-10	None	8	0.02	0.09	22.6	<0.01	0.4	0.2	0.5	0.27	0.03	2.1	0.1	0.2	9.6	<0.1
WC	2.5-10	Phragmites	8	0.03	0.10	8.6	<0.01	1.1	21.9	1.2	53.00	1.58	94.0	0.8	0.8	253.3	<0.1
WC	2.5-10	Phragmites	8	0.02	0.09	8.6	<0.01	1.1	23.4	1.0	49.68	1.56	70.3	0.6	1.2	232.6	<0.1
WC	2.5-10	Schoenoplectus	8	0.01	0.09	8.3	<0.01	1.8	16.0	1.0	46.85	1.31	32.5	0.5	0.8	159.5	<0.1
WC	2.5-10	Schoenoplectus	8	0.02	0.12	7.8	<0.01	5.0	15.3	1.0	47.71	1.30	38.4	0.4	0.7	230.2	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-5 (continued). Surface water metal(loid) concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	
TS	0-2.5	None	16	0.10	0.16	32.3	0.04	<0.1	0.1	1.7	0.58	0.07	2.0	5.1	0.4	18.8	<0.1
TS	0-2.5	None	16	0.09	0.14	30.0	<0.01	<0.1	<0.1	1.3	0.45	0.07	2.1	3.0	<0.1	20.3	<0.1
TS	0-2.5	Phragmites	16	0.10	0.27	26.2	<0.01	1.1	7.7	1.9	18.89	0.25	46.8	1.2	0.2	149.4	<0.1
TS	0-2.5	Phragmites	16	0.13	0.28	20.7	0.26	1.4	7.0	1.7	16.65	0.39	80.6	1.1	0.4	134.0	<0.1
TS	0-2.5	Schoenoplectus	16	0.06	0.05	24.4	0.17	0.3	2.2	1.3	22.55	1.04	15.7	0.7	0.4	141.5	<0.1
TS	0-2.5	Schoenoplectus	16	0.06	0.09	25.1	<0.01	0.7	2.7	1.9	34.32	1.27	18.8	0.4	0.2	223.1	<0.1
TS	2.5-10	None	16	0.05	0.11	26.9	<0.01	0.5	0.3	0.4	1.43	0.04	2.6	0.3	<0.1	43.1	<0.1
TS	2.5-10	None	16	0.10	0.11	29.7	0.18	0.8	0.6	0.5	1.45	0.04	3.3	0.2	<0.1	12.1	<0.1
TS	2.5-10	Phragmites	16	0.06	0.23	13.4	0.10	3.9	9.0	0.9	63.40	1.60	27.9	0.4	1.0	92.5	<0.1
TS	2.5-10	Phragmites	16	0.07	0.17	12.3	0.09	3.2	8.8	0.9	61.06	1.57	32.8	0.2	0.4	142.4	<0.1
TS	2.5-10	Schoenoplectus	16	0.06	0.15	10.3	<0.01	3.6	6.2	1.5	58.61	1.38	13.9	0.6	<0.1	172.1	<0.1
TS	2.5-10	Schoenoplectus	16	0.09	0.17	11.1	<0.01	3.6	6.2	1.1	57.96	1.31	13.8	0.5	0.2	149.0	<0.1
WC	0-2.5	None	16	0.07	0.14	24.0	0.15	<0.1	0.4	1.3	0.17	0.06	3.7	0.3	0.2	8.7	<0.1
WC	0-2.5	None	16	0.02	0.13	22.6	<0.01	<0.1	0.2	0.9	0.21	0.06	1.9	<0.1	0.2	10.2	<0.1
WC	0-2.5	Phragmites	16	0.07	0.45	32.0	<0.01	0.9	9.3	2.4	10.86	0.23	138.4	0.4	0.2	227.0	<0.1
WC	0-2.5	Phragmites	16	0.06	0.10	37.5	0.13	0.6	11.0	1.8	8.63	0.41	128.1	0.3	0.6	197.0	<0.1
WC	0-2.5	Schoenoplectus	16	0.05	0.08	32.1	0.09	<0.1	2.6	1.7	21.65	1.40	32.3	0.2	<0.1	166.5	<0.1
WC	0-2.5	Schoenoplectus	16	0.02	0.06	38.1	<0.01	<0.1	2.7	1.5	18.85	1.25	33.1	0.1	0.2	185.7	<0.1
WC	2.5-10	None	16	0.03	0.25	25.9	<0.01	<0.1	0.2	0.6	0.12	0.02	1.9	<0.1	<0.1	14.0	<0.1
WC	2.5-10	None	16	0.06	0.19	23.4	0.15	<0.1	0.3	0.9	0.21	0.02	2.4	<0.1	<0.1	14.3	<0.1
WC	2.5-10	Phragmites	16	0.19	0.13	9.7	0.03	0.5	26.0	0.8	57.23	1.48	73.0	0.2	0.8	165.1	<0.1
WC	2.5-10	Phragmites	16	0.16	0.05	15.6	0.01	0.4	14.6	1.3	7.50	0.21	73.4	0.1	0.6	175.4	<0.1
WC	2.5-10	Schoenoplectus	16	0.09	0.04	16.6	0.14	<0.1	5.8	1.6	18.51	0.79	24.0	0.3	0.4	159.6	<0.1
WC	2.5-10	Schoenoplectus	16	0.10	0.11	13.2	0.10	1.1	15.9	0.8	51.29	1.29	33.8	0.3	<0.1	151.2	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-6. Surface water fluorescence intensities (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
TS	0-2.5	None	0	258	136	242	1048	0.02	0.01	0.02	0.07
		None	0	300	160	286	1115	0.02	0.01	0.02	0.06
		Phragmites	0	12226	16506	59128	102	0.00	0.00	0.01	0.00
		Phragmites	0	7659	16413	58621	0	0.00	0.00	0.01	0.00
		Schoenoplectus	0	3991	5970	20007	0	0.00	0.00	0.00	0.00
		Schoenoplectus	0	4674	5923	20500	0	0.00	0.00	0.01	0.00
	2.5-10	None	0	231	118	356	1318	0.01	0.01	0.02	0.06
		None	0	219	116	247	955	0.01	0.01	0.02	0.06
		Phragmites	0	8708	14394	53772	258	0.00	0.00	0.02	0.00
		Phragmites	0	6287	14654	56753	0	0.00	0.00	0.01	0.00
		Schoenoplectus	0	4022	5783	23240	9570	0.00	0.00	0.00	0.00
		Schoenoplectus	0	5023	5823	23463	0	0.00	0.00	0.00	0.00
WC	0-2.5	None	0	467	251	409	1345	0.03	0.02	0.02	0.08
		None	0	466	246	389	1275	0.03	0.02	0.03	0.10
		Phragmites	0	5737	16387	58709	0	0.00	0.00	0.00	0.00
		Phragmites	0	6396	16819	59659	0	0.00	0.00	0.01	0.00
		Schoenoplectus	0	1869	6445	21357	0	0.00	0.00	0.00	0.00
		Schoenoplectus	0	2954	6355	20584	0	0.00	0.00	0.00	0.00
	2.5-10	None	0	173	89	309	1153	0.01	0.01	0.02	0.07
		None	0	155	82	259	1253	0.01	0.01	0.02	0.08
		Phragmites	0	8606	16370	62703	4741	0.00	0.00	0.01	0.00
		Phragmites	0	7224	15968	59178	0	0.00	0.01	0.02	0.00
		Schoenoplectus	0	4443	6162	23315	0	0.00	0.00	0.01	0.00
		Schoenoplectus	0	4378	6645	26580	0	0.00	0.00	0.00	0.00
TS	0-2.5	None	4	2442	1130	1055	2385	0.30	0.14	0.13	0.29
		None	4	2567	1152	1270	3028	0.18	0.08	0.09	0.21
		Phragmites	4	23433	15654	70995	61116	0.05	0.03	0.15	0.13
		Phragmites	4	26475	16065	64992	78618	0.05	0.03	0.11	0.13
		Schoenoplectus	4	12147	5399	18605	26771	0.03	0.01	0.05	0.07
		Schoenoplectus	4	11736	5396	18484	26110	0.03	0.01	0.04	0.06
	2.5-10	None	4	339	190	272	1228	0.02	0.01	0.02	0.09
		None	4	395	213	307	1255	0.03	0.02	0.02	0.09
		Phragmites	4	23315	17146	77782	51423	0.04	0.03	0.14	0.10
		Phragmites	4	22670	16803	68915	51035	0.04	0.03	0.13	0.09
		Schoenoplectus	4	10534	6334	33138	21770	0.02	0.01	0.06	0.04
		Schoenoplectus	4	11254	6832	38959	24607	0.02	0.01	0.06	0.04

Table 8-6 (continued). Surface water fluorescence intensities (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	0-2.5	None	4	3060	925	4266	8641	0.12	0.04	0.16	0.33
		None	4	3678	1016	5268	10424	0.12	0.03	0.17	0.33
		Phragmites	4	27784	16497	74470	78577	0.03	0.02	0.09	0.09
		Phragmites	4	27333	17681	79055	69324	0.06	0.04	0.16	0.14
		Schoenoplectus	4	11179	5133	20274	26750	0.03	0.02	0.06	0.08
		Schoenoplectus	4	11886	5283	20585	26599	0.04	0.02	0.06	0.08
	2.5-10	None	4	173	89	309	1153	0.09	0.05	0.04	0.13
		None	4	155	82	259	1253	0.07	0.04	0.03	0.12
		Phragmites	4	8606	16370	62703	4741	0.06	0.04	0.17	0.16
		Phragmites	4	7224	15968	59178	0	0.05	0.03	0.14	0.14
		Schoenoplectus	4	4443	6162	23315	0	0.03	0.01	0.05	0.07
		Schoenoplectus	4	4378	6645	26580	0	0.01	0.00	0.01	0.02
TS	0-2.5	None	8	3293	1484	1865	3958	0.17	0.07	0.09	0.20
		None	8	3427	1630	1480	3182	0.23	0.11	0.10	0.22
		Phragmites	8	20214	17294	69101	29369	0.01	0.00	0.02	0.01
		Phragmites	8	25416	14136	57853	59684	0.01	0.01	0.02	0.02
		Schoenoplectus	8	7942	4742	16323	10912	0.00	0.00	0.01	0.01
		Schoenoplectus	8	9657	4887	18288	18806	0.02	0.01	0.04	0.04
	2.5-10	None	8	2305	1236	647	1763	0.14	0.08	0.04	0.11
		None	8	2465	1286	627	1551	0.22	0.11	0.06	0.14
		Phragmites	8	15915	14869	56001	24221	0.02	0.02	0.07	0.03
		Phragmites	8	16242	15688	62678	30533	0.02	0.02	0.08	0.04
		Schoenoplectus	8	8577	6196	28841	15251	0.01	0.00	0.02	0.01
		Schoenoplectus	8	9069	5934	25667	13363	0.01	0.01	0.04	0.02
WC	0-2.5	None	8	3010	1057	4604	8487	0.08	0.03	0.13	0.24
		None	8	3300	1000	5493	10173	0.10	0.03	0.17	0.32
		Phragmites	8	23775	16642	80668	40193	0.03	0.02	0.10	0.05
		Phragmites	8	19241	15336	74485	32425	0.01	0.00	0.02	0.01
		Schoenoplectus	8	9497	4971	20011	16958	0.02	0.01	0.04	0.04
		Schoenoplectus	8	10669	4840	18122	19840	0.03	0.01	0.05	0.05
	2.5-10	None	8	1877	1027	602	1581	0.16	0.09	0.05	0.13
		None	8	2150	1173	714	1868	0.18	0.10	0.06	0.16
		Phragmites	8	20502	15779	71385	49033	0.04	0.03	0.14	0.10
		Phragmites	8	19825	16019	66677	45386	0.04	0.03	0.14	0.10
		Schoenoplectus	8	10764	5033	19140	20810	0.02	0.01	0.03	0.04
		Schoenoplectus	8	5219	5137	21050	17097	0.00	0.00	0.01	0.01

Table 8-6 (continued). Surface water fluorescence intensities (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
TS	0-2.5	None	16	4119	2073	1059	2564	0.21	0.11	0.05	0.13
		None	16	4186	2042	1637	3566	0.21	0.10	0.08	0.18
		Phragmites	16	7420	17334	68679	0	0.00	0.00	0.01	0.00
		Phragmites	16	10454	13384	71449	11907	0.00	0.00	0.01	0.00
		Schoenoplectus	16	4439	5801	22287	0	0.00	0.00	0.00	0.00
		Schoenoplectus	16	8144	5628	18756	0	0.00	0.00	0.01	0.00
	2.5-10	None	16	3955	2140	1005	2375	0.21	0.11	0.05	0.12
		None	16	4176	2248	1130	2893	0.14	0.08	0.04	0.10
		Phragmites	16	19808	15989	70528	30172	0.02	0.01	0.06	0.03
		Phragmites	16	16352	16568	70994	17893	0.01	0.01	0.06	0.01
		Schoenoplectus	16	9655	6073	24231	9803	0.01	0.00	0.02	0.01
		Schoenoplectus	16	8204	6169	27234	10680	0.01	0.01	0.04	0.02
WC	0-2.5	None	16	3636	1332	5155	9777	0.09	0.03	0.12	0.23
		None	16	3045	1335	3246	6241	0.09	0.04	0.10	0.19
		Phragmites	16	15279	13432	39687	0	0.00	0.00	0.01	0.00
		Phragmites	16	16810	17275	59870	0	0.00	0.00	0.01	0.00
		Schoenoplectus	16	3037	5445	21348	0	0.00	0.00	0.00	0.00
		Schoenoplectus	16	5348	5169	19470	0	0.00	0.00	0.01	0.00
	2.5-10	None	16	2457	1345	844	2541	0.13	0.07	0.05	0.14
		None	16	2603	1388	956	2768	0.14	0.07	0.05	0.15
		Phragmites	16	18916	16343	70505	34911	0.04	0.03	0.14	0.07
		Phragmites	16	18384	17522	62171	15594	0.01	0.01	0.03	0.01
		Schoenoplectus	16	8512	4830	20811	16094	0.01	0.01	0.03	0.02
		Schoenoplectus	16	9418	5282	18963	14277	0.02	0.01	0.05	0.03

Table 8-7. Surface water organic acid concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Acetic Acid* (mg/mL)	Formic Acid* (mg/mL)	Malonic Acid* (mg/mL)	Oxalic Acid* (mg/mL)	Benzoic Acid (mg/mL)	Unknown Phenolic (mg/mL)
TS	0-2.5	None	0	-	-	-	-	-	
		None	0	-	-	-	-	-	
		Phragmites	0	-	-	2.82	-	-	
		Phragmites	0	-	-	2.80	-	-	
		Schoenoplectus	0	-	-	0.03	LOD	-	
		Schoenoplectus	0	-	-	0.02	LOD	-	
	2.5-10	None	0	-	-	-	-	-	
		None	0	-	-	-	-	-	
		Phragmites	0	-	-	2.81	-	-	
		Phragmites	0	-	-	2.80	-	-	
		Schoenoplectus	0	-	-	-	LOD	-	
		Schoenoplectus	0	-	-	-	LOD	-	
WC	0-2.5	None	0	-	-	-	-	-	
		None	0	-	-	-	-	-	
		Phragmites	0	-	-	2.75	-	-	
		Phragmites	0	-	-	2.70	-	-	
		Schoenoplectus	0	-	-	0.02	-	-	
		Schoenoplectus	0	-	-	0.02	-	-	
	2.5-10	None	0	-	-	-	-	-	
		None	0	-	-	-	-	-	
		Phragmites	0	-	-	2.25	-	-	
		Phragmites	0	-	-	3.17	-	-	
		Schoenoplectus	0	-	-	-	-	-	
		Schoenoplectus	0	-	-	-	-	-	
TS	0-2.5	None	4	-	-	-	-	-	
		None	4	-	-	-	-	-	
		Phragmites	4	-	0.53	-	-	-	+
		Phragmites	4	-	0.50	-	-	-	+
		Schoenoplectus	4	-	0.50	-	-	-	+
		Schoenoplectus	4	-	0.53	-	-	-	+
	2.5-10	None	4	-	-	-	-	-	
		None	4	-	-	-	-	-	
		Phragmites	4	-	0.74	-	-	-	
		Phragmites	4	-	0.61	-	-	-	
		Schoenoplectus	4	-	0.52	-	-	-	
		Schoenoplectus	4	-	0.43	-	-	-	
WC	0-2.5	None	4	-	0.02	-	-	-	
		None	4	-	0.04	-	-	-	
		Phragmites	4	-	0.69	-	-	-	+
		Phragmites	4	-	0.68	-	-	-	+
		Schoenoplectus	4	-	0.68	-	-	-	+
		Schoenoplectus	4	-	0.57	-	-	-	+
	2.5-10	None	4	-	-	-	-	-	
		None	4	-	-	-	-	-	
		Phragmites	4	-	0.86	-	-	-	+
		Phragmites	4	-	0.79	-	-	-	+
		Schoenoplectus	4	-	0.55	-	-	-	+
		Schoenoplectus	4	-	0.55	-	-	-	+
TS	0-2.5	None	8	-	-	-	-	-	
		None	8	-	-	-	-	-	
		Phragmites	8	-	-	-	-	-	+
		Phragmites	8	-	-	-	-	-	+
		Schoenoplectus	8	-	-	-	-	-	+
		Schoenoplectus	8	-	-	-	-	-	+
	2.5-10	None	8	-	-	-	-	-	
		None	8	-	-	-	-	-	
		Phragmites	8	-	0.63	-	-	-	
		Phragmites	8	-	0.78	-	-	-	
		Schoenoplectus	8	-	0.45	-	-	-	
		Schoenoplectus	8	-	0.57	-	-	-	+

* Low Molecular Weight (LMW) organic acid
LOD - Concentration at the Limit of Detection
\+ - Unknown phenolic identified in sample

Table 8-7 (continued). Surface water organic acid concentrations (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Acetic Acid* (mg/mL)	Formic Acid* (mg/mL)	Malonic Acid* (mg/mL)	Oxalic Acid* (mg/mL)	Benzoic Acid (mg/mL)	Unknown Phenolic (mg/mL)
WC	0-2.5	None	8	-	0.03	-	-	-	
		None	8	-	0.03	-	-	-	
		Phragmites	8	-	-	-	-	-	+
		Phragmites	8	-	-	-	-	-	+
		Schoenoplectus	8	-	-	-	-	-	+
		Schoenoplectus	8	-	0.05	-	-	-	+
	2.5-10	None	8	-	-	-	-	-	
		None	8	-	-	-	-	-	
		Phragmites	8	-	0.67	-	-	-	+
		Phragmites	8	-	0.82	-	-	-	+
		Schoenoplectus	8	-	0.54	-	-	-	+
		Schoenoplectus	8	-	0.59	-	-	-	+
TS	0-2.5	None	16	-	-	-	-	-	
		None	16	-	-	-	-	-	
		Phragmites	16	-	-	-	-	0.15	+
		Phragmites	16	-	-	-	-	0.15	+
		Schoenoplectus	16	-	-	-	-	0.07	+
		Schoenoplectus	16	-	-	-	-	0.02	+
	2.5-10	None	16	-	-	-	-	-	
		None	16	-	-	-	-	-	
		Phragmites	16	-	0.76	-	-	-	
		Phragmites	16	-	0.83	-	-	-	
		Schoenoplectus	16	-	0.57	-	-	-	+
		Schoenoplectus	16	-	0.68	-	-	-	+
WC	0-2.5	None	16	-	-	-	-	-	
		None	16	-	-	-	-	-	
		Phragmites	16	-	-	-	-	-	
		Phragmites	16	-	-	-	-	0.09	+
		Schoenoplectus	16	-	-	-	-	0.11	+
		Schoenoplectus	16	-	-	-	-	0.15	
	2.5-10	None	16	-	-	-	-	-	
		None	16	-	-	-	-	-	
		Phragmites	16	-	0.80	-	-	-	+
		Phragmites	16	-	-	-	-	-	+
		Schoenoplectus	16	-	-	-	-	0.01	+
		Schoenoplectus	16	-	0.67	-	-	-	+

* Low Molecular Weight (LMW) organic acid
LOD - Concentration at the Limit of Detection
\+ - Unknown phenolic identified in sample

APPENDIX 3. Surface water characteristics (batch experiment)

Table 8-8. Surface water properties (batch experiment – day 0).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	DIC (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	0	5.42	276	n.a.	0.1	<0.1	<10	3.70	0.60	5.55	5.13	3.60	24.46	48.42	15.54
		None	0	5.40	288	396	0.1	<0.1	<10	4.06	0.60	5.26	5.03	3.65	25.12	50.13	15.13
		None	0	5.24	266	392	0.2	<0.1	<10	3.30	0.61	5.36	4.83	3.72	25.73	54.49	15.00
		None/Jarosite	0	5.05	274	352	0.2	<0.1	<10	1.03	0.58	7.56	8.04	11.92	10.03	38.39	17.40
		None/Jarosite	0	5.37	258	291	0.1	<0.1	<10	1.08	0.56	5.09	5.19	7.54	26.45	37.74	18.08
		None/Jarosite	0	5.30	261	311	0.2	<0.1	<10	1.18	0.54	5.19	5.05	6.68	24.67	39.93	17.15
		None/Schwert.	0	6.04	330	922	0.2	<0.1	<10	0.84	0.52	6.25	5.81	4.03	134.22	46.33	87.42
		None/Schwert.	0	6.07	323	910	0.2	<0.1	<10	0.83	0.50	6.65	5.96	4.21	142.87	48.52	94.74
		None/Schwert.	0	6.06	323	874	0.2	<0.1	<10	0.98	0.51	6.41	5.69	4.14	138.53	39.35	93.17
		Glucose	0	5.50	333	225	-	<0.1	<10	218.79	0.55	4.62	4.56	3.69	26.19	39.85	14.42
		Glucose	0	5.47	279	291	-	<0.1	<10	239.29	0.53	5.24	4.61	3.46	25.30	39.53	14.84
		Glucose	0	6.16	236	333	-	<0.1	<10	213.28	0.54	5.19	4.52	3.49	24.87	41.72	13.86
		Glucose/Jarosite	0	5.22	295	321	-	<0.1	<10	234.29	0.52	5.40	5.54	8.10	26.35	171.05	35.99
		Glucose/Jarosite	0	5.43	291	284	-	<0.1	<10	237.25	0.52	4.88	5.31	8.26	24.61	83.11	31.58
		Glucose/Jarosite	0	5.43	291	269	-	<0.1	<10	236.44	0.52	5.57	5.27	7.22	25.26	82.18	33.21
		Glucose/Schwert.	0	6.10	270	931	-	<0.1	<10	234.50	0.46	7.18	6.62	4.40	149.48	85.25	111.09
		Glucose/Schwert.	0	6.14	265	853	-	<0.1	<10	234.19	0.46	7.09	7.36	4.49	146.42	97.70	108.76
		Glucose/Schwert.	0	6.14	265	817	-	<0.1	<10	235.62	0.47	6.57	5.97	4.24	145.88	100.52	119.14
		Acetate	0	5.84	302	1112	-	<0.1	<10	221.54	0.59	6.18	5.88	3.96	219.37	55.82	14.55
		Acetate	0	5.81	280	998	-	<0.1	<10	223.89	0.56	6.70	6.05	4.08	222.92	59.24	14.93
		Acetate	0	5.81	281	974	-	<0.1	<10	227.77	0.57	6.46	6.20	4.22	227.93	60.83	15.07
		Acetate/Jarosite	0	5.83	282	1090	-	<0.1	<10	224.50	0.56	7.83	7.42	8.05	237.30	153.34	32.03
		Acetate/Jarosite	0	5.80	287	1034	-	<0.1	<10	225.42	0.53	6.36	6.63	9.13	217.78	51.72	18.80
		Acetate/Jarosite	0	5.76	292	1033	-	<0.1	<10	226.03	0.57	6.99	7.25	12.92	235.15	143.52	37.65
		Acetate/Schwert.	0	5.76	302	1619	-	<0.1	<10	201.04	0.43	7.59	7.71	4.65	347.92	117.59	127.93
		Acetate/Schwert.	0	5.74	297	1542	-	<0.1	<10	200.43	0.51	7.40	8.04	4.67	353.16	157.66	125.50
		Acetate/Schwert.	0	5.76	299	1528	-	<0.1	<10	196.66	0.51	7.61	7.78	4.65	351.14	114.54	130.35
		Humic	0	5.13	313	566	n.a.	n.a.	n.a.	199.41	0.48	8.46	5.29	4.66	74.00	76.69	17.57
		Humic	0	5.15	286	440	n.a.	n.a.	n.a.	228.38	0.50	8.91	5.37	4.84	75.63	91.12	18.57
		Humic	0	5.12	286	417	n.a.	n.a.	n.a.	195.84	0.49	8.52	5.13	4.52	73.41	86.51	17.64
		Humic/Jarosite	0	5.28	306	542	n.a.	n.a.	n.a.	194.82	0.49	7.91	5.18	6.27	69.85	76.00	17.62
		Humic/Jarosite	0	5.09	301	488	n.a.	n.a.	n.a.	183.50	0.48	8.21	5.49	9.49	73.80	90.57	21.98
		Humic/Jarosite	0	5.12	293	453	n.a.	n.a.	n.a.	205.33	0.46	7.74	5.34	8.58	71.95	91.98	21.38
		Humic/Schwert.	0	5.72	276	1094	n.a.	n.a.	n.a.	137.90	0.46	8.28	5.82	4.45	178.56	86.78	91.36
		Humic/Schwert.	0	5.48	255	1013	n.a.	n.a.	n.a.	168.61	0.47	9.76	6.90	5.24	179.16	93.28	95.02
		Humic/Schwert.	0	5.60	250	997	n.a.	n.a.	n.a.	177.17	0.48	8.58	6.53	4.81	180.26	83.21	92.64

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-8 (continued). Surface water properties (batch experiment- day 0).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	DIC (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	0	5.78	241	1239	-	0.24	<10	460.84	0.41	23.74	20.01	146.41	46.70	138.72	37.61
		Phragmites	0	5.79	251	1095	-	0.26	<10	456.04	0.41	24.35	20.30	152.15	48.05	132.43	37.88
		Phragmites	0	5.78	255	1051	-	0.30	<10	475.93	0.40	23.68	19.93	148.98	48.31	145.90	36.49
		Phragmites/Jarosite	0	5.78	263	1107	-	0.33	<10	467.87	0.41	26.21	23.35	155.97	52.70	333.05	63.00
		Phragmites/Jarosite	0	5.77	264	1141	-	0.34	<10	459.10	0.42	26.59	22.82	156.05	50.56	281.74	62.11
		Phragmites/Jarosite	0	5.64	263	1094	-	0.40	<10	465.94	0.41	25.33	21.95	155.36	48.97	216.83	58.09
		Phragmites/Schwert.	0	6.00	329	1638	-	0.68	<10	464.51	0.42	26.94	21.58	144.56	171.45	254.27	141.34
		Phragmites/Schwert.	0	5.95	331	1629	-	0.74	<10	435.64	0.41	29.41	22.54	148.53	179.21	263.06	152.31
		Phragmites/Schwert.	0	5.86	331	1617	-	0.67	<10	437.48	0.41	26.96	22.04	142.33	170.26	230.74	147.68
		Schoenoplectus	0	5.78	239	1476	-	n.a.	<10	452.88	0.43	37.50	32.32	72.72	143.66	321.73	71.09
		Schoenoplectus	0	5.89	236	1435	-	0.20	<10	452.98	0.44	36.33	32.34	76.94	151.69	400.24	72.70
		Schoenoplectus	0	5.87	237	1423	-	0.20	<10	461.96	0.43	33.93	29.66	78.03	142.52	271.49	53.67
		Schoenoplectus/Jarosite	0	5.75	270	1349	-	0.30	<10	468.38	0.42	39.73	34.13	78.79	158.27	483.99	79.46
		Schoenoplectus/Jarosite	0	5.69	275	1518	-	0.35	<10	467.57	0.44	37.11	32.44	76.49	147.55	418.94	76.47
		Schoenoplectus/Jarosite	0	5.81	275	1397	-	0.27	<10	468.69	0.43	37.93	33.93	77.47	150.88	376.10	75.25
		Schoenoplectus/Schwert.	0	5.86	329	1892	-	1.19	<10	462.16	0.42	37.97	30.91	74.51	247.22	247.90	139.31
		Schoenoplectus/Schwert.	0	5.95	332	1913	-	1.28	<10	464.00	0.44	35.88	29.34	70.90	236.77	256.95	130.50
		Schoenoplectus/Schwert.	0	5.94	220	1902	-	0.71	<10	462.77	0.44	36.76	29.57	75.97	249.60	271.52	133.13

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-9. Surface water properties (batch experiment – day 2).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	2	5.04	336	n.a.	0.0	0.17	<10	7.84	6.75	4.67	26.10	23.98	20.42
		None	2	4.77	312	377	0.0	<0.1	<10	8.17	6.94	4.78	26.36	26.94	20.79
		None	2	4.95	310	357	0.0	0.12	<10	8.36	7.10	4.82	27.37	30.18	22.54
		None/Jarosite	2	4.35	393	520	0.0	0.61	<10	11.22	8.66	10.42	20.22	26.79	25.47
		None/Jarosite	2	4.23	396	411	0.0	0.89	<10	11.63	9.34	12.71	18.32	26.11	26.48
		None/Jarosite	2	4.18	396	391	0.0	0.95	<10	11.42	9.08	12.49	18.74	25.47	27.11
		None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Glucose	2	5.00	-27	n.a.	-	1.56	580	8.65	7.66	4.86	26.93	48.69	24.96
		Glucose	2	5.06	-30	383	-	1.74	642	9.01	7.90	4.87	29.25	46.43	26.77
		Glucose	2	4.94	-22	365	-	1.52	617	8.95	7.62	4.69	29.20	41.03	25.51
		Glucose/Jarosite	2	4.39	27	503	-	2.05	<100	10.60	8.76	10.97	22.65	38.91	27.74
		Glucose/Jarosite	2	4.45	38	452	-	2.06	<100	11.76	9.84	13.03	27.50	45.22	31.69
		Glucose/Jarosite	2	4.29	42	437	-	2.67	<100	11.64	9.64	15.04	24.30	38.76	32.61
		Glucose/Schwert.	2	4.18	93	1124	-	1.60	<10	15.40	11.33	6.04	145.01	42.79	119.07
		Glucose/Schwert.	2	4.17	103	1099	-	1.67	<10	15.60	11.77	6.34	145.52	42.00	119.79
		Glucose/Schwert.	2	4.15	106	1097	-	1.69	<10	17.28	11.79	6.14	145.73	46.47	120.80
		Acetate	2	5.84	50	1271	-	0.16	<10	9.14	7.79	5.18	227.51	54.18	21.53
		Acetate	2	5.87	39	1246	-	0.22	<100	9.29	8.17	5.20	229.52	55.89	22.28
		Acetate	2	5.85	39	1224	-	0.20	<100	9.83	8.51	5.42	238.92	56.45	24.00
		Acetate/Jarosite	2	5.40	70	1202	-	<0.1	<10	10.51	8.98	23.64	217.66	58.63	30.45
		Acetate/Jarosite	2	5.36	75	1194	-	<0.1	<10	10.05	8.90	24.29	205.85	56.69	28.44
		Acetate/Jarosite	2	5.36	86	1176	-	<0.1	<10	10.40	8.75	24.24	210.82	58.32	29.24
		Acetate/Schwert.	2	4.99	143	2032	-	0.28	<10	14.20	10.65	5.93	347.08	58.98	172.57
		Acetate/Schwert.	2	4.97	125	1925	-	0.27	<10	13.92	10.56	5.72	345.22	53.61	169.79
		Acetate/Schwert.	2	4.97	126	1901	-	0.27	<10	13.22	10.59	5.90	349.24	56.68	169.39
		Humic	2	5.02	155	643	n.a.	n.a.	n.a.	10.82	6.47	5.96	76.12	88.59	27.21
		Humic	2	5.02	166	534	n.a.	n.a.	n.a.	11.05	6.74	5.94	74.42	91.73	27.97
		Humic	2	4.94	177	527	n.a.	n.a.	n.a.	11.26	6.85	5.88	75.21	109.78	27.72
		Humic/Jarosite	2	4.48	168	705	n.a.	n.a.	n.a.	12.49	8.31	17.13	72.14	101.46	38.54
		Humic/Jarosite	2	4.35	161	607	n.a.	n.a.	n.a.	12.13	8.32	17.75	66.31	105.41	41.03
		Humic/Jarosite	2	4.36	163	591	n.a.	n.a.	n.a.	12.11	8.07	17.69	62.98	112.30	39.62
		Humic/Schwert.	2	4.33	225	1135	n.a.	n.a.	n.a.	16.94	11.81	7.93	198.59	104.86	141.84
		Humic/Schwert.	2	4.30	212	1316	n.a.	n.a.	n.a.	15.36	10.88	7.28	192.09	110.93	136.98
		Humic/Schwert.	2	4.28	211	1307	n.a.	n.a.	n.a.	15.64	11.45	7.63	193.89	143.87	137.69

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-9 (continued). Surface water properties (batch experiment- day 2).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	2	5.43	185	1387	-	6.54	396	32.78	22.60	154.53	51.33	106.65	45.89
		Phragmites	2	5.36	181	1255	-	6.89	409	31.93	22.29	154.36	49.45	104.11	44.26
		Phragmites	2	5.32	173	1187	-	6.20	392	32.27	22.26	154.28	50.18	104.99	45.83
		Phragmites/Jarosite	2	5.02	207	1267	-	5.78	294	32.56	23.22	144.79	44.51	106.58	51.83
		Phragmites/Jarosite	2	5.03	204	1168	-	5.43	272	32.60	22.89	138.85	44.35	106.16	50.79
		Phragmites/Jarosite	2	5.00	195	1134	-	5.18	341	32.58	23.22	144.07	44.66	105.43	50.76
		Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Schoenoplectus	2	4.71	184	1775	-	8.93	537	45.84	32.61	79.28	147.54	227.14	64.44
		Schoenoplectus	2	4.68	181	1568	-	9.12	398	45.12	32.01	78.46	142.61	229.18	61.40
		Schoenoplectus	2	4.73	173	1549	-	6.67	507	52.11	33.76	76.37	144.17	219.50	64.33
		Schoenoplectus/Jarosite	2	4.60	196	1578	-	9.25	300	47.17	33.16	79.97	126.51	225.41	71.43
		Schoenoplectus/Jarosite	2	4.63	189	1535	-	9.66	356	42.38	30.56	77.68	126.36	227.82	67.19
		Schoenoplectus/Jarosite	2	4.53	195	1493	-	9.88	208	45.97	33.69	79.43	123.53	233.93	72.05
		Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-10. Surface water properties (batch experiment – week 1).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	4	7.42	-157	n.a.	0.5	2.07	<100	6.53	6.02	3.71	27.65	42.19	12.11
		None	4	7.72	-138	365	0.4	3.46	<100	7.05	6.12	3.42	27.03	48.75	14.34
		None	4	7.78	-120	346	0.5	2.71	<100	6.82	5.89	3.49	26.51	38.86	13.54
		None/Jarosite	4	4.85	46	548	0.1	44.83	<100	15.77	12.57	22.09	16.41	39.61	54.16
		None/Jarosite	4	4.88	54	525	0.5	41.94	<100	15.07	11.91	20.89	16.11	32.18	50.83
		None/Jarosite	4	4.83	55	537	0.2	41.64	<100	14.90	12.41	21.32	17.25	37.31	52.28
		None/Schwert.	4	3.86	142	1112	0.1	41.79	<10	18.24	13.02	6.39	136.54	29.11	132.82
		None/Schwert.	4	3.88	125	1137	0.1	44.98	<10	21.85	13.08	6.29	134.84	28.78	136.65
		None/Schwert.	4	3.87	158	1107	0.0	44.07	<10	18.61	13.51	6.43	141.19	28.56	136.87
		Glucose	4	5.13	40	417	-	31.76	249	14.07	11.08	4.81	27.24	31.56	6.90
		Glucose	4	5.38	62	415	-	31.91	<100	14.82	11.64	4.96	28.04	36.52	1.85
		Glucose	4	5.28	45	414	-	32.83	248	14.39	11.22	4.80	26.99	34.73	2.52
		Glucose/Jarosite	4	5.89	6	2710	-	604.08	37	19.64	14.78	286.96	23.36	13.51	385.97
		Glucose/Jarosite	4	6.18	12	1883	-	237.83	172	20.24	14.67	186.15	25.87	26.38	185.38
		Glucose/Jarosite	4	6.16	15	2570	-	550.13	26	20.52	15.49	298.16	26.11	23.01	389.57
		Glucose/Schwert.	4	3.54	398	2026	-	399.68	<50	23.74	16.82	7.00	141.06	24.44	308.27
		Glucose/Schwert.	4	3.54	385	1939	-	378.41	<50	22.33	16.28	7.23	142.30	25.84	298.56
		Glucose/Schwert.	4	3.58	361	2100	-	404.24	<50	24.76	15.58	6.92	138.63	22.84	309.03
		Acetate	4	7.89	-57	1062	-	1.69	<100	7.05	6.27	3.82	223.02	46.24	1.61
		Acetate	4	7.95	-62	1019	-	1.85	<100	6.99	6.11	3.50	220.82	45.19	1.44
		Acetate	4	7.93	-57	1020	-	1.72	<100	6.84	5.99	3.61	223.90	45.17	1.20
		Acetate/Jarosite	4	4.78	252	1860	-	164.13	126	20.93	16.10	119.47	193.64	52.75	196.63
		Acetate/Jarosite	4	4.69	280	1551	-	75.23	<50	17.90	13.93	82.67	191.62	45.75	136.01
		Acetate/Jarosite	4	4.78	250	1831	-	172.49	138	21.33	15.49	120.04	189.32	43.71	192.97
		Acetate/Schwert.	4	4.24	295	2390	-	252.27	<50	20.98	14.59	6.49	329.18	36.25	322.91
		Acetate/Schwert.	4	4.26	298	2410	-	244.67	<50	21.85	14.82	6.58	331.70	40.67	322.08
		Acetate/Schwert.	4	4.15	308	2400	-	268.23	<50	22.05	15.05	6.58	334.15	39.78	335.59
		Humic	4	7.62	-5	373	n.a.	n.a.	n.a.	9.16	4.56	3.50	62.41	57.14	4.95
		Humic	4	7.63	-15	352	n.a.	n.a.	n.a.	9.11	4.46	3.45	63.09	67.69	2.62
		Humic	4	7.74	-25	372	n.a.	n.a.	n.a.	9.55	4.63	3.46	63.61	68.49	5.86
		Humic/Jarosite	4	5.87	112	759	n.a.	n.a.	n.a.	14.13	11.96	36.59	48.93	63.69	69.89
		Humic/Jarosite	4	5.79	118	731	n.a.	n.a.	n.a.	13.99	11.74	35.65	46.22	63.29	67.39
		Humic/Jarosite	4	5.82	105	727	n.a.	n.a.	n.a.	13.79	11.72	35.99	43.37	61.44	66.16
		Humic/Schwert.	4	5.21	177	1384	n.a.	n.a.	n.a.	18.25	13.78	7.76	180.10	61.76	170.34
		Humic/Schwert.	4	5.04	192	1380	n.a.	n.a.	n.a.	17.61	13.59	7.82	180.94	60.71	170.47
		Humic/Schwert.	4	5.27	183	1364	n.a.	n.a.	n.a.	16.73	12.73	7.23	171.79	47.41	162.87

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-10 (continued). Surface water properties (batch experiment- week 1).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	4	5.22	143	1689	-	40.12	n.a.	43.14	27.95	161.01	52.32	119.89	3.74
		Phragmites	4	5.11	145	1631	-	41.64	n.a.	43.33	27.99	161.99	53.12	131.20	4.24
		Phragmites	4	5.13	140	1491	-	41.64	n.a.	46.35	29.56	163.70	55.17	138.75	4.84
		Phragmites/Jarosite	4	6.87	-50	2370	-	174.77	<10	31.89	26.51	416.30	51.30	130.01	27.86
		Phragmites/Jarosite	4	6.83	-30	2190	-	128.41	<10	32.12	26.34	363.04	50.87	132.00	30.77
		Phragmites/Jarosite	4	6.82	-43	2540	-	339.65	<10	35.98	28.26	416.95	49.95	126.74	95.69
		Phragmites/Schwert.	4	7.11	-69	2390	-	373.85	<10	38.82	27.29	145.70	160.92	122.11	2.63
		Phragmites/Schwert.	4	7.04	-71	2400	-	429.32	<10	40.77	28.33	154.49	168.26	123.57	3.09
		Phragmites/Schwert.	4	7.20	-76	2200	-	348.77	<10	40.20	28.00	151.31	167.50	124.41	2.56
		Schoenoplectus	4	5.09	174	1551	-	38.30	n.a.	52.84	38.43	85.47	153.77	284.67	4.98
		Schoenoplectus	4	5.13	145	1508	-	35.86	n.a.	54.24	38.07	84.89	156.39	290.49	5.27
		Schoenoplectus	4	5.25	139	1500	-	36.78	n.a.	53.60	38.98	81.91	149.63	275.87	4.45
		Schoenoplectus/Jarosite	4	6.77	-28	2910	-	461.99	<10	61.04	43.22	278.76	130.20	260.05	272.88
		Schoenoplectus/Jarosite	4	6.72	-13	2760	-	431.59	<10	58.12	40.81	245.79	130.81	243.84	225.03
		Schoenoplectus/Jarosite	4	6.79	-23	2890	-	452.87	<10	57.82	40.98	282.59	134.50	262.53	249.54
		Schoenoplectus/Schwert.	4	7.10	-14	2160	-	109.42	<10	47.69	34.31	77.93	249.55	240.05	71.39
		Schoenoplectus/Schwert.	4	7.10	-39	2170	-	159.57	<10	50.51	35.72	78.70	248.84	245.07	101.87
		Schoenoplectus/Schwert.	4	7.19	-40	1990	-	97.26	<10	46.31	34.08	75.37	248.70	254.09	58.08

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-11. Surface water properties (batch experiment – week 2).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	14	6.99	-8	n.a.	0.0	3.77	<50	7.52	6.24	3.62	26.88	19.63	16.09
		None	14	6.95	-5	389	0.0	3.91	<10	7.79	6.48	3.51	26.99	21.42	17.08
		None	14	6.99	9	395	0.0	4.24	<50	8.16	6.76	3.68	27.55	27.96	18.94
		None/Jarosite	14	4.88	72	715	0.0	24.13	<50	14.87	11.73	18.22	18.58	22.21	45.93
		None/Jarosite	14	5.02	75	612	0.2	27.82	<50	15.56	11.97	20.21	18.38	22.60	49.10
		None/Jarosite	14	4.89	74	543	0.2	21.79	<50	13.85	11.08	15.52	18.96	23.19	42.72
		None/Schwert.	14	4.00	184	1451	0.1	40.11	<10	18.37	12.59	6.26	142.01	19.57	142.10
		None/Schwert.	14	4.06	171	1358	0.0	41.02	<10	20.49	13.37	6.36	141.61	21.59	141.44
		None/Schwert.	14	4.01	172	1326	0.0	43.51	<10	18.44	12.63	6.06	136.08	17.39	140.77
		Glucose	15	4.91	126	n.a.	-	30.01	510	14.53	11.28	5.05	27.64	29.10	16.07
		Glucose	15	4.99	109	556	-	31.38	682	15.18	11.70	5.28	27.90	34.29	16.04
		Glucose	15	4.87	137	527	-	30.08	288	14.25	11.05	5.14	27.03	28.50	16.24
		Glucose/Jarosite	15	4.37	252	775	-	56.85	<50	16.37	12.20	20.25	16.94	21.17	49.66
		Glucose/Jarosite	15	4.37	247	656	-	56.69	<50	16.43	12.56	19.69	17.41	23.05	49.73
		Glucose/Jarosite	15	4.32	258	635	-	47.32	<50	16.40	12.26	19.73	18.71	24.06	46.74
		Glucose/Schwert.	15	3.93	320	1888	-	262.02	<100	22.63	15.33	6.45	137.81	26.92	228.08
		Glucose/Schwert.	15	3.92	328	1740	-	249.32	<50	22.31	14.64	6.36	137.12	27.15	225.58
		Glucose/Schwert.	15	4.01	343	1735	-	243.76	<50	21.82	14.60	6.34	138.59	23.01	225.60
		Acetate	15	7.02	83	1343	-	8.58	<50	10.66	8.30	4.63	220.37	44.70	15.54
		Acetate	15	6.99	73	1265	-	8.58	<50	10.08	8.43	4.55	220.38	49.52	15.28
		Acetate	15	6.95	55	1262	-	9.69	<100	10.44	8.47	4.46	221.26	47.07	17.65
		Acetate/Jarosite	15	4.90	262	1720	-	58.20	<50	16.91	12.73	66.69	184.73	44.69	115.10
		Acetate/Jarosite	15	4.86	259	1483	-	29.78	<50	16.15	11.73	59.19	190.48	42.63	98.54
		Acetate/Jarosite	15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Acetate/Schwert.	15	4.70	292	1968	-	7.15	<50	14.96	10.68	5.70	325.71	40.27	193.00
		Acetate/Schwert.	15	4.70	297	1919	-	3.97	<50	14.20	10.06	5.64	321.84	36.36	188.07
		Acetate/Schwert.	15	4.70	293	1911	-	3.97	<50	14.15	10.01	5.82	324.90	42.51	189.73
		Humic	15	6.76	55	615	n.a.	n.a.	n.a.	12.00	7.04	5.55	74.86	46.58	26.07
		Humic	15	6.97	39	533	n.a.	n.a.	n.a.	11.52	6.22	4.59	66.85	65.78	20.10
		Humic	15	6.93	25	537	n.a.	n.a.	n.a.	11.08	6.44	4.85	66.78	46.29	18.27
		Humic/Jarosite	15	4.82	204	860	n.a.	n.a.	n.a.	15.55	11.36	27.38	54.23	66.55	56.67
		Humic/Jarosite	15	4.53	224	743	n.a.	n.a.	n.a.	15.31	10.78	26.88	54.41	69.26	56.74
		Humic/Jarosite	15	4.80	210	762	n.a.	n.a.	n.a.	15.19	11.53	27.87	56.33	52.05	58.11
		Humic/Schwert.	15	4.48	312	1524	n.a.	n.a.	n.a.	19.32	13.92	8.03	197.26	63.19	175.33
		Humic/Schwert.	15	4.49	310	1445	n.a.	n.a.	n.a.	19.84	13.73	8.25	201.76	73.51	172.06
		Humic/Schwert.	15	4.34	331	1427	n.a.	n.a.	n.a.	19.34	13.58	8.19	197.48	40.67	167.83

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-11 (continued). Surface water properties (batch experiment- week 2).

Site	Depth (cm)	Treatment	Day	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	14	5.27	72	2047	-	39.96	55	42.85	26.80	158.78	52.49	100.13	3.54
		Phragmites	14	5.32	27	1933	-	40.41	651	43.70	27.60	161.05	52.84	113.78	3.96
		Phragmites	14	5.35	-28	1942	-	38.30	1192	41.75	26.13	156.28	50.56	111.60	5.49
		Phragmites/Jarosite	14	6.72	3	3090	-	255.61	<10	37.38	26.66	285.44	45.88	86.82	127.86
		Phragmites/Jarosite	14	6.55	1	3010	-	294.06	<10	41.83	29.42	295.88	48.87	105.98	161.20
		Phragmites/Jarosite	14	6.46	7	3260	-	385.29	<10	40.90	28.05	323.52	47.23	92.92	166.70
		Phragmites/Schwert.	14	7.02	-20	3000	-	330.25	<10	42.47	27.55	153.21	168.07	105.28	3.44
		Phragmites/Schwert.	14	7.29	-59	2770	-	240.53	<10	39.36	26.91	154.67	167.74	104.32	28.82
		Phragmites/Schwert.	14	7.01	-46	2890	-	406.41	<10	45.73	27.98	155.62	168.94	103.38	2.88
		Schoenoplectus	14	5.17	43	1927	-	40.72	1159	53.33	36.53	78.70	147.68	226.75	10.58
		Schoenoplectus	14	5.19	72	1824	-	39.13	409	54.66	37.52	82.24	143.78	235.24	8.28
		Schoenoplectus	14	5.13	58	1796	-	38.38	1351	51.93	35.57	82.97	144.41	229.04	14.77
		Schoenoplectus/Jarosite	14	6.14	57	3420	-	438.07	<10	59.28	39.26	209.39	125.48	222.25	231.81
		Schoenoplectus/Jarosite	14	5.55	50	3010	-	345.33	265	62.84	40.19	178.80	120.38	212.81	203.49
		Schoenoplectus/Jarosite	14	6.26	43	3180	-	378.51	<10	63.18	39.59	202.53	118.56	210.68	202.71
		Schoenoplectus/Schwert.	14	7.04	-7	3230	-	289.54	<10	53.37	34.47	73.12	236.60	206.05	171.82
		Schoenoplectus/Schwert.	14	7.04	-15	2830	-	174.17	<10	51.05	34.07	74.66	240.96	205.20	83.28
		Schoenoplectus/Schwert.	14	6.96	-12	3030	-	285.01	<10	54.54	36.48	76.32	242.49	204.30	152.84

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-12. Surface water properties (batch experiment – week 4).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	4	7.42	-157	n.a.	0.5	2.07	<100	6.53	6.02	3.71	27.65	42.19	12.11
		None	4	7.72	-138	365	0.4	3.46	<100	7.05	6.12	3.42	27.03	48.75	14.34
		None	4	7.78	-120	346	0.5	2.71	<100	6.82	5.89	3.49	26.51	38.86	13.54
		None/Jarosite	4	4.85	46	548	0.1	44.83	<100	15.77	12.57	22.09	16.41	39.61	54.16
		None/Jarosite	4	4.88	54	525	0.5	41.94	<100	15.07	11.91	20.89	16.11	32.18	50.83
		None/Jarosite	4	4.83	55	537	0.2	41.64	<100	14.90	12.41	21.32	17.25	37.31	52.28
		None/Schwert.	4	3.86	142	1112	0.1	41.79	<10	18.24	13.02	6.39	136.54	29.11	132.82
		None/Schwert.	4	3.88	125	1137	0.1	44.98	<10	21.85	13.08	6.29	134.84	28.78	136.65
		None/Schwert.	4	3.87	158	1107	0.0	44.07	<10	18.61	13.51	6.43	141.19	28.56	136.87
		Glucose	4	5.13	40	417	-	31.76	249	14.07	11.08	4.81	27.24	31.56	6.90
		Glucose	4	5.38	62	415	-	31.91	<100	14.82	11.64	4.96	28.04	36.52	1.85
		Glucose	4	5.28	45	414	-	32.83	248	14.39	11.22	4.80	26.99	34.73	2.52
		Glucose/Jarosite	4	5.89	6	2710	-	604.08	37	19.64	14.78	286.96	23.36	13.51	385.97
		Glucose/Jarosite	4	6.18	12	1883	-	237.83	172	20.24	14.67	186.15	25.87	26.38	185.38
		Glucose/Jarosite	4	6.16	15	2570	-	550.13	26	20.52	15.49	298.16	26.11	23.01	389.57
		Glucose/Schwert.	4	3.54	398	2026	-	399.68	<50	23.74	16.82	7.00	141.06	24.44	308.27
		Glucose/Schwert.	4	3.54	385	1939	-	378.41	<50	22.33	16.28	7.23	142.30	25.84	298.56
		Glucose/Schwert.	4	3.58	361	2100	-	404.24	<50	24.76	15.58	6.92	138.63	22.84	309.03
		Acetate	4	7.89	-57	1062	-	1.69	<100	7.05	6.27	3.82	223.02	46.24	1.61
		Acetate	4	7.95	-62	1019	-	1.85	<100	6.99	6.11	3.50	220.82	45.19	1.44
		Acetate	4	7.93	-57	1020	-	1.72	<100	6.84	5.99	3.61	223.90	45.17	1.20
		Acetate/Jarosite	4	4.78	252	1860	-	164.13	126	20.93	16.10	119.47	193.64	52.75	196.63
		Acetate/Jarosite	4	4.69	280	1551	-	75.23	<50	17.90	13.93	82.67	191.62	45.75	136.01
		Acetate/Jarosite	4	4.78	250	1831	-	172.49	138	21.33	15.49	120.04	189.32	43.71	192.97
		Acetate/Schwert.	4	4.24	295	2390	-	252.27	<50	20.98	14.59	6.49	329.18	36.25	322.91
		Acetate/Schwert.	4	4.26	298	2410	-	244.67	<50	21.85	14.82	6.58	331.70	40.67	322.08
		Acetate/Schwert.	4	4.15	308	2400	-	268.23	<50	22.05	15.05	6.58	334.15	39.78	335.59
		Humic	4	7.62	-5	373	n.a.	n.a.	n.a.	9.16	4.56	3.50	62.41	57.14	4.95
		Humic	4	7.63	-15	352	n.a.	n.a.	n.a.	9.11	4.46	3.45	63.09	67.69	2.62
		Humic	4	7.74	-25	372	n.a.	n.a.	n.a.	9.55	4.63	3.46	63.61	68.49	5.86
		Humic/Jarosite	4	5.87	112	759	n.a.	n.a.	n.a.	14.13	11.96	36.59	48.93	63.69	69.89
		Humic/Jarosite	4	5.79	118	731	n.a.	n.a.	n.a.	13.99	11.74	35.65	46.22	63.29	67.39
		Humic/Jarosite	4	5.82	105	727	n.a.	n.a.	n.a.	13.79	11.72	35.99	43.37	61.44	66.16
		Humic/Schwert.	4	5.21	177	1384	n.a.	n.a.	n.a.	18.25	13.78	7.76	180.10	61.76	170.34
		Humic/Schwert.	4	5.04	192	1380	n.a.	n.a.	n.a.	17.61	13.59	7.82	180.94	60.71	170.47
		Humic/Schwert.	4	5.27	183	1364	n.a.	n.a.	n.a.	16.73	12.73	7.23	171.79	47.41	162.87

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-12 (continued). Surface water properties (batch experiment- week 4).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	4	5.22	143	1689	-	40.12	n.a.	43.14	27.95	161.01	52.32	119.89	3.74
		Phragmites	4	5.11	145	1631	-	41.64	n.a.	43.33	27.99	161.99	53.12	131.20	4.24
		Phragmites	4	5.13	140	1491	-	41.64	n.a.	46.35	29.56	163.70	55.17	138.75	4.84
		Phragmites/Jarosite	4	6.87	-50	2370	-	174.77	<10	31.89	26.51	416.30	51.30	130.01	27.86
		Phragmites/Jarosite	4	6.83	-30	2190	-	128.41	<10	32.12	26.34	363.04	50.87	132.00	30.77
		Phragmites/Jarosite	4	6.82	-43	2540	-	339.65	<10	35.98	28.26	416.95	49.95	126.74	95.69
		Phragmites/Schwert.	4	7.11	-69	2390	-	373.85	<10	38.82	27.29	145.70	160.92	122.11	2.63
		Phragmites/Schwert.	4	7.04	-71	2400	-	429.32	<10	40.77	28.33	154.49	168.26	123.57	3.09
		Phragmites/Schwert.	4	7.20	-76	2200	-	348.77	<10	40.20	28.00	151.31	167.50	124.41	2.56
		Schoenoplectus	4	5.09	174	1551	-	38.30	n.a.	52.84	38.43	85.47	153.77	284.67	4.98
		Schoenoplectus	4	5.13	145	1508	-	35.86	n.a.	54.24	38.07	84.89	156.39	290.49	5.27
		Schoenoplectus	4	5.25	139	1500	-	36.78	n.a.	53.60	38.98	81.91	149.63	275.87	4.45
		Schoenoplectus/Jarosite	4	6.77	-28	2910	-	461.99	<10	61.04	43.22	278.76	130.20	260.05	272.88
		Schoenoplectus/Jarosite	4	6.72	-13	2760	-	431.59	<10	58.12	40.81	245.79	130.81	243.84	225.03
		Schoenoplectus/Jarosite	4	6.79	-23	2890	-	452.87	<10	57.82	40.98	282.59	134.50	262.53	249.54
		Schoenoplectus/Schwert.	4	7.10	-14	2160	-	109.42	<10	47.69	34.31	77.93	249.55	240.05	71.39
		Schoenoplectus/Schwert.	4	7.10	-39	2170	-	159.57	<10	50.51	35.72	78.70	248.84	245.07	101.87
		Schoenoplectus/Schwert.	4	7.19	-40	1990	-	97.26	<10	46.31	34.08	75.37	248.70	254.09	58.08

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-13. Surface water properties (batch experiment – week 6).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	6	7.75	-48	n.a.	0.4	0.44	35	4.79	4.76	3.23	28.39	31.44	7.02
		None	6	7.68	-62	322	0.5	0.38	50	3.98	3.91	3.10	28.00	26.85	3.65
		None	6	7.99	-112	337	0.5	0.22	n.a.	3.93	4.01	2.97	28.69	30.42	2.76
		None/Jarosite	6	5.05	52	1027	0.0	104.45	<25	17.67	15.34	46.65	20.02	25.20	103.12
		None/Jarosite	6	5.21	87	987	0.0	114.54	<25	19.05	15.64	46.89	16.87	21.25	107.62
		None/Jarosite	6	5.04	98	985	0.0	119.03	<25	18.64	15.25	48.68	16.73	23.84	111.66
		None/Schwert.	6	3.60	257	1718	0.0	138.25	<25	22.64	16.48	6.99	154.80	25.91	209.12
		None/Schwert.	6	3.68	247	1670	0.0	138.41	<25	24.80	16.83	7.17	154.43	23.13	211.78
		None/Schwert.	6	3.64	248	1645	0.0	134.89	<25	21.84	16.52	6.99	153.51	21.86	204.78
		Glucose	6	5.54	197	n.a.	-	38.49	32	16.22	13.76	5.70	31.27	29.31	0.64
		Glucose	6	5.40	199	532	-	38.81	27	15.64	13.49	5.62	30.65	30.08	0.71
		Glucose	6	5.90	175	499	-	34.67	15	14.53	12.47	5.33	29.87	33.99	0.27
		Glucose/Jarosite	6	4.46	307	866	-	71.89	<10	18.26	15.04	24.27	19.01	23.78	61.58
		Glucose/Jarosite	6	4.42	301	742	-	80.32	<10	18.45	15.26	26.13	18.55	30.13	66.67
		Glucose/Jarosite	6	4.57	297	753	-	88.43	<10	20.14	15.76	26.48	18.29	29.26	69.60
		Glucose/Schwert.	6	3.02	510	2264	-	314.10	<10	23.15	18.45	7.39	154.91	22.55	308.60
		Glucose/Schwert.	6	3.09	509	2221	-	330.80	<10	23.06	17.36	7.20	153.64	21.09	313.50
		Glucose/Schwert.	6	3.06	516	2249	-	330.01	<10	24.18	18.11	7.48	157.93	23.74	324.72
		Acetate	6	7.70	182	1241	-	0.18	17	7.10	6.38	3.53	246.72	45.79	0.41
		Acetate	6	7.43	156	1170	-	0.47	17	7.53	6.54	3.43	251.32	49.42	0.85
		Acetate	6	7.64	142	1167	-	0.26	11	6.48	6.14	3.37	239.67	45.46	0.65
		Acetate/Jarosite	6	4.57	323	2063	-	171.76	<10	21.32	16.67	128.52	221.39	41.45	242.90
		Acetate/Jarosite	6	4.64	318	1827	-	119.28	<10	20.36	16.01	106.25	215.94	44.51	198.19
		Acetate/Jarosite	6	4.59	322	1910	-	155.86	<10	20.35	15.81	121.19	218.87	42.26	227.99
		Acetate/Schwert.	6	3.88	370	2820	-	348.30	<10	23.36	18.41	7.49	386.64	45.62	440.08
		Acetate/Schwert.	6	3.86	369	2790	-	374.54	<30	24.72	17.65	7.13	379.05	43.23	456.02
		Acetate/Schwert.	6	3.99	361	2720	-	337.16	<30	24.87	17.87	7.21	384.57	44.93	424.95
		Humic	6	7.61	49	550	n.a.	n.a.	n.a.	10.78	5.17	3.29	76.98	18.17	0.00
		Humic	6	7.54	61	433	n.a.	n.a.	n.a.	8.38	4.15	3.03	71.84	26.39	0.47
		Humic	6	7.50	47	462	n.a.	n.a.	n.a.	9.57	5.17	3.58	72.31	31.32	4.42
		Humic/Jarosite	6	5.87	184	1076	-	95.58	58	15.11	14.30	49.17	51.61	52.14	103.08
		Humic/Jarosite	6	5.71	176	1080	-	103.69	75	16.59	14.86	56.69	56.11	54.97	116.94
		Humic/Jarosite	6	5.78	170	1130	-	114.83	88	16.70	15.10	59.59	55.41	56.63	126.32
		Humic/Schwert.	6	4.91	228	1783	-	178.92	11	18.96	15.11	7.87	194.85	45.40	229.93
		Humic/Schwert.	6	4.96	219	1775	-	186.08	45	20.66	16.29	8.42	209.32	54.14	242.10
		Humic/Schwert.	6	5.00	216	1686	-	145.36	37	19.91	15.84	8.16	204.76	56.40	224.69

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-13 (continued). Surface water properties (batch experiment- week 6).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	6	5.50	129	1976	-	45.82	26	46.53	33.10	165.49	59.01	103.74	3.26
		Phragmites	6	5.14	134	1936	-	49.34	93	47.21	32.45	161.57	57.37	46.02	3.97
		Phragmites	6	4.92	144	1898	-	50.78	113	47.81	32.73	160.65	55.62	58.58	2.17
		Phragmites/Jarosite	6	7.25	-32	4120	-	407.71	<25	43.96	34.61	706.29	60.93	77.60	361.58
		Phragmites/Jarosite	6	7.16	-43	3100	-	213.87	<25	38.88	31.39	588.17	55.40	62.97	47.67
		Phragmites/Jarosite	6	7.12	-46	4330	-	589.54	<25	46.41	33.31	728.38	55.58	52.88	414.80
		Phragmites/Schwert.	6	7.30	-49	2680	-	352.44	<25	44.65	31.10	146.81	179.43	108.44	2.34
		Phragmites/Schwert.	6	7.12	-46	2820	-	474.99	<25	44.28	30.69	152.23	184.10	114.66	2.23
		Phragmites/Schwert.	6	6.99	-37	3120	-	602.35	<25	45.39	31.46	154.76	183.15	113.22	2.93
		Schoenoplectus	6	5.07	150	1806	-	46.38	63	57.11	41.64	87.50	156.04	245.97	6.77
		Schoenoplectus	6	5.35	129	1751	-	40.77	84	56.19	40.12	82.55	153.55	251.32	3.59
		Schoenoplectus	6	5.04	147	1754	-	45.50	32	56.79	40.66	84.34	151.86	255.62	6.48
		Schoenoplectus/Jarosite	6	7.07	21	3430	-	300.38	<25	57.98	43.01	407.16	142.42	245.74	290.29
		Schoenoplectus/Jarosite	6	6.98	6	3250	-	214.67	<25	60.84	45.99	406.62	146.78	247.46	242.98
		Schoenoplectus/Jarosite	6	7.06	-2	3120	-	220.28	<25	53.84	42.69	388.86	145.78	240.95	215.60
		Schoenoplectus/Schwert.	6	7.43	-33	2551	-	137.77	<25	51.87	39.20	76.88	276.10	238.19	100.21
		Schoenoplectus/Schwert.	6	7.25	-10	2730	-	203.45	<25	61.25	41.63	77.06	275.22	232.69	61.45
		Schoenoplectus/Schwert.	6	7.39	-37	2465	-	142.58	<25	50.35	38.28	76.68	274.54	235.27	82.46

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-14. Surface water properties (batch experiment – week 9).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	9	7.87	-14	n.a.	0.7	0.18	<25	3.41	3.60	4.41	28.25	190.44	9.78
		None	9	7.88	-31	276	0.7	0.24	95	4.05	3.62	4.01	26.54	140.70	6.88
		None	9	7.83	-51	305	1.0	0.14	152	6.80	4.72	4.09	27.85	191.29	4.44
		None/Jarosite	9	5.05	171	1234	0.1	180.59	<25	20.41	16.70	73.96	17.03	56.61	159.55
		None/Jarosite	9	5.18	178	1182	0.1	185.06	<25	21.10	17.20	74.19	16.91	85.74	170.05
		None/Jarosite	9	5.00	184	1321	0.1	216.06	<25	22.32	19.02	93.09	23.01	133.58	201.01
		None/Schwert.	9	3.28	423	1923	0.0	233.64	<25	26.35	19.11	9.09	163.02	89.58	287.43
		None/Schwert.	9	3.20	442	2024	0.0	242.27	<25	24.45	18.00	8.53	156.08	59.77	282.20
		None/Schwert.	9	3.24	447	1958	0.0	217.98	<25	26.24	18.62	8.73	166.59	99.91	279.32
		Glucose	9	5.38	230	n.a.	-	40.02	64	15.82	12.76	6.60	28.16	116.89	0.63
		Glucose	9	5.45	222	596	-	39.69	52	17.07	13.44	6.66	27.52	141.03	3.19
		Glucose	9	5.47	218	565	-	39.05	53	15.85	13.26	6.72	28.67	134.49	<0.01
		Glucose/Jarosite	9	5.85	203	3170	-	623.19	<25	27.34	20.45	447.65	30.67	35.81	577.81
		Glucose/Jarosite	9	4.44	291	957	-	72.46	<25	19.78	15.28	29.28	16.73	63.68	63.07
		Glucose/Jarosite	9	5.77	145	3600	-	929.95	<25	25.83	18.87	489.41	28.48	59.18	729.50
		Glucose/Schwert.	9	2.84	560	2612	-	322.06	<25	28.18	19.87	9.91	165.05	65.63	377.71
		Glucose/Schwert.	9	2.84	568	2645	-	297.91	<25	25.96	19.71	9.43	162.57	94.05	374.70
		Glucose/Schwert.	9	2.82	572	2760	-	325.28	<25	27.04	19.83	9.33	161.73	74.34	374.43
		Acetate	9	7.93	140	1751	-	0.34	83	5.69	5.59	4.22	245.72	80.72	<0.01
		Acetate	9	7.82	133	1314	-	0.25	82	5.60	5.29	4.25	250.34	114.36	0.35
		Acetate	9	8.21	114	1303	-	0.15	174	5.56	5.38	4.47	254.93	148.79	6.58
		Acetate/Jarosite	9	4.57	312	2237	-	209.34	<25	23.75	17.39	149.28	228.89	121.61	294.36
		Acetate/Jarosite	9	4.55	311	2418	-	263.28	<25	23.64	18.19	170.82	227.30	122.51	327.33
		Acetate/Jarosite	9	4.54	308	2296	-	218.20	<25	22.75	17.41	152.20	225.21	70.58	296.38
		Acetate/Schwert.	9	3.85	363	2940	-	400.16	<25	25.35	18.39	8.61	370.41	59.94	484.21
		Acetate/Schwert.	9	3.51	421	3010	-	360.71	<25	25.78	18.59	8.76	383.25	108.92	483.89
		Acetate/Schwert.	9	3.44	431	3030	-	317.23	<25	37.99	21.34	8.94	368.92	94.68	456.49
		Humic	9	7.66	142	518	n.a.	n.a.	<25	11.06	5.08	4.31	72.58	107.16	0.25
		Humic	9	7.56	107	493	n.a.	n.a.	<25	8.87	3.94	3.94	70.81	194.37	<0.01
		Humic	9	7.66	98	485	n.a.	n.a.	<25	9.75	4.67	3.98	70.85	114.25	<0.01
		Humic/Jarosite	9	5.96	189	1442	-	157.81	64	20.25	17.27	85.33	58.34	160.92	174.12
		Humic/Jarosite	9	5.83	184	1303	-	128.82	74	18.48	15.80	69.87	53.82	134.27	140.72
		Humic/Jarosite	9	5.85	181	1412	-	161.03	74	17.97	15.88	80.79	54.45	110.21	172.96
		Humic/Schwert.	9	4.30	278	2038	-	260.06	<25	22.49	17.53	9.98	209.03	126.01	302.66
		Humic/Schwert.	9	4.39	274	2075	-	268.11	<25	23.51	18.88	10.23	211.26	92.25	301.06
		Humic/Schwert.	9	4.27	288	2038	-	257.65	<25	22.53	17.40	9.84	213.70	74.21	307.04

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-14 (continued). Surface water properties (batch experiment- week 9).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	9	5.10	213	1987	-	53.38	<25	47.15	33.23	164.06	55.75	173.92	2.10
		Phragmites	9	7.30	56	1863	-	12.94	<25	36.93	27.09	158.69	53.22	193.32	2.90
		Phragmites	9	5.14	210	1965	-	52.26	<25	47.13	31.43	163.99	52.63	182.88	0.93
		Phragmites/Jarosite	9	7.18	14	4300	-	389.14	<25	44.94	32.41	869.01	55.73	184.45	483.95
		Phragmites/Jarosite	9	7.08	2	4190	-	349.98	<25	44.36	31.76	852.96	56.61	181.99	388.02
		Phragmites/Jarosite	9	7.11	-9	4370	-	466.65	<25	45.85	33.52	839.18	56.93	179.71	385.10
		Phragmites/Schwert.	9	7.36	-15	2660	-	372.36	<25	43.82	31.67	157.19	192.53	212.15	13.23
		Phragmites/Schwert.	9	7.31	-33	2770	-	371.56	<25	42.41	30.79	157.06	185.25	175.30	11.82
		Phragmites/Schwert.	9	7.39	-53	2720	-	261.29	<25	45.28	32.81	158.55	194.29	219.60	10.21
		Schoenoplectus	9	5.09	171	1788	-	49.54	<25	62.90	45.23	88.44	178.63	375.22	11.26
		Schoenoplectus	9	5.03	193	1706	-	47.62	<25	58.05	42.16	87.14	158.71	331.07	7.22
		Schoenoplectus	9	5.15	196	1765	-	48.90	<25	59.73	45.21	88.27	172.84	350.25	12.01
		Schoenoplectus/Jarosite	9	7.06	38	3640	-	346.79	<25	61.21	45.05	551.85	152.14	342.54	444.57
		Schoenoplectus/Jarosite	9	6.98	26	4060	-	433.09	<25	62.96	48.62	594.10	164.07	325.02	526.62
		Schoenoplectus/Jarosite	9	7.03	17	3860	-	338.80	<25	65.18	49.12	570.40	163.75	341.63	466.29
		Schoenoplectus/Schwert.	9	7.21	-5	2700	-	215.74	<25	56.71	44.26	78.71	292.23	318.77	7.34
		Schoenoplectus/Schwert.	9	7.25	-18	2539	-	173.39	<25	55.75	42.96	76.59	295.02	332.25	8.34
		Schoenoplectus/Schwert.	9	7.19	-20	2720	-	265.28	<25	64.25	44.64	79.66	289.32	267.08	13.61

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-15. Surface water properties (batch experiment – week 12).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	None	12	7.73	70	n.a.	0.7	0.69	<10	23.58	4.02	3.41	2.59	28.76	26.51	1.97
		None	12	7.66	41	355	0.7	0.58	<100	22.40	4.06	3.58	2.77	28.84	32.86	1.85
		None	12	7.86	35	310	0.6	0.48	<100	18.96	3.40	3.06	2.55	26.86	23.84	1.27
		None/Jarosite	12	5.83	88	1889	0.0	215.29	153	3.76	22.54	16.02	107.08	22.70	21.72	186.38
		None/Jarosite	12	5.96	85	1642	0.0	218.35	175	4.39	21.54	16.34	105.13	17.53	23.07	189.43
		None/Jarosite	12	5.81	89	1220	0.0	143.53	175	3.74	18.03	14.17	65.29	15.85	18.21	125.54
		None/Schwert.	12	3.32	459	2330	0.0	299.27	<20	4.11	22.11	15.58	7.19	136.31	14.75	279.00
		None/Schwert.	12	3.29	461	2217	0.0	<0.1	<20	4.43	24.08	15.79	7.13	137.77	18.34	280.13
		None/Schwert.	12	3.27	464	2263	0.0	295.46	<20	3.81	26.44	16.84	7.72	143.09	18.23	284.85
		Glucose	12	5.38	233	n.a.	-	37.41	<20	157.13	15.52	11.81	5.47	29.09	25.65	1.04
		Glucose	12	6.11	189	535	-	31.30	<20	141.37	14.75	11.55	4.88	29.65	34.02	1.07
		Glucose	12	5.49	240	546	-	38.94	<20	145.96	14.95	12.05	5.01	28.78	26.35	0.88
		Glucose/Jarosite	12	5.32	227	4940	-	1213.89	<20	5.10	23.29	16.63	611.46	29.11	15.70	836.78
		Glucose/Jarosite	12	5.40	225	3810	-	797.04	<20	4.52	24.27	17.03	495.16	29.48	17.94	626.99
		Glucose/Jarosite	12	5.25	230	4780	-	1236.79	<20	4.61	25.59	16.87	649.70	29.57	21.45	895.39
		Glucose/Schwert.	12	2.73	544	3350	-	413.79	<20	131.27	25.65	17.48	9.25	148.80	22.45	406.64
		Glucose/Schwert.	12	2.82	545	3140	-	404.63	<20	124.75	36.77	18.12	8.71	147.50	23.39	390.76
		Glucose/Schwert.	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
		Acetate	12	8.85	-51	1341	-	<0.1	124	102.01	4.73	3.44	3.24	228.99	47.64	2.24
		Acetate	12	8.66	-48	1259	-	<0.1	<20	122.91	4.84	3.64	2.98	230.18	43.89	1.31
		Acetate	12	8.82	-49	1240	-	<0.1	<100	136.48	4.43	3.44	2.70	227.43	46.48	1.19
		Acetate/Jarosite	12	4.55	330	2960	-	276.37	<20	204.41	26.48	17.72	188.92	216.02	46.47	338.59
		Acetate/Jarosite	12	6.13	127	6100	-	1516.21	<20	105.26	29.44	17.19	706.29	239.46	0.00	1323.49
		Acetate/Jarosite	12	6.54	80	5710	-	1168.08	<20	5.88	25.21	16.94	699.72	232.62	0.00	1140.91
		Acetate/Schwert.	12	3.20	490	3230	-	294.69	<20	197.68	24.73	16.67	7.70	338.37	34.40	434.10
		Acetate/Schwert.	12	3.71	438	3110	-	343.55	<20	196.76	26.04	17.34	8.15	340.81	35.71	456.58
		Acetate/Schwert.	12	3.65	444	3050	-	374.09	<20	192.68	24.03	16.82	7.73	346.54	37.57	457.02
		Humic	12	7.86	34	476	n.a.	n.a.	n.a	67.83	11.18	4.98	3.71	68.45	41.78	6.58
		Humic	12	7.78	41	428	n.a.	n.a.	n.a	65.25	8.71	3.78	3.43	60.89	40.09	0.39
		Humic	12	7.89	34	427	n.a.	n.a.	n.a	59.91	11.20	4.65	3.32	63.38	17.51	0.00
		Humic/Jarosite	12	6.04	153	2573	-	381.73	<100	8.81	20.48	15.76	167.18	49.73	47.09	306.04
		Humic/Jarosite	12	6.20	147	2438	-	424.48	<100	7.29	21.37	16.71	189.39	50.52	48.19	330.91
		Humic/Jarosite	12	6.10	148	2432	-	426.01	<20	6.89	19.68	15.59	179.69	49.57	40.27	321.21
		Humic/Schwert.	12	4.55	272	2533	-	403.10	<20	5.59	23.68	16.83	8.48	187.97	49.28	348.86
		Humic/Schwert.	12	4.65	264	2349	-	369.51	<20	6.78	22.63	16.16	8.54	183.41	52.26	333.78
		Humic/Schwert.	12	4.60	258	2285	-	335.92	153	5.56	22.80	16.68	8.63	192.73	57.80	333.34

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-15 (continued). Surface water properties (batch experiment- week 12).

Site	Depth (cm)	Treatment	Week	pH	Eh* (mV)	EC (µS/cm)	Alkalinity (mmol/L)	Fe^{2+} (mg/L)	Sulfide (µg/L)	DOC (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (mg/L)	Total S (mg/L)
WC	2.5-10	Phragmites	12	6.84	58	1814	-	18.02	<20	486.60	41.26	27.34	155.69	55.20	101.72	4.20
		Phragmites	12	5.10	211	2046	-	51.00	<20	818.36	52.57	30.62	165.10	52.65	86.57	1.63
		Phragmites	12	7.38	41	2031	-	9.24	<20	377.30	37.71	26.85	156.59	53.24	81.49	0.52
		Phragmites/Jarosite	12	7.54	-30	3720	-	60.85	<20	63.50	29.15	24.97	775.26	55.32	105.04	172.04
		Phragmites/Jarosite	12	7.53	-41	3760	-	74.59	<20	69.08	29.85	26.99	814.78	57.31	92.54	222.54
		Phragmites/Jarosite	12	7.60	-47	3910	-	76.57	<20	51.85	40.51	29.61	880.56	57.62	117.59	346.78
		Phragmites/Schwert.	12	7.62	-67	2202	-	83.67	<20	297.76	37.15	27.07	145.95	180.52	95.62	4.98
		Phragmites/Schwert.	12	7.79	-82	1833	-	31.07	<20	132.48	25.11	22.53	138.26	178.86	84.72	2.96
		Phragmites/Schwert.	12	7.40	-64	2319	-	194.22	<20	460.23	42.87	29.71	146.17	179.61	93.25	1.74
		Schoenoplectus	12	6.94	3	1778	-	27.56	<20	286.80	54.25	39.10	76.21	162.46	210.00	3.61
		Schoenoplectus	12	7.02	0	1671	-	20.38	<20	261.99	51.67	38.62	78.09	152.92	251.21	0.82
		Schoenoplectus	12	5.20	196	1772	-	48.94	<20	528.49	62.25	42.26	81.95	165.36	285.37	2.51
		Schoenoplectus/Jarosite	12	7.14	-15	4530	-	684.05	<20	36.90	65.04	45.66	662.92	153.48	206.11	655.72
		Schoenoplectus/Jarosite	12	7.21	-14	4670	-	575.64	<20	35.18	69.83	45.98	705.46	155.87	193.67	624.02
		Schoenoplectus/Jarosite	12	7.17	-13	4960	-	713.06	<20	25.82	64.28	41.18	673.30	137.32	209.00	636.01
		Schoenoplectus/Schwert.	12	7.15	-17	3130	-	412.26	<20	617.73	63.59	42.04	81.26	274.15	248.22	2.39
		Schoenoplectus/Schwert.	12	7.03	-16	2840	-	271.79	<20	441.97	55.55	40.56	74.74	258.55	228.89	1.55
		Schoenoplectus/Schwert.	12	7.12	-20	2710	-	250.41	<20	408.82	51.93	40.27	76.38	268.74	250.28	1.54

* Eh measurements are presented versus the standard hydrogen electrode

Table 8-16. Surface water metal(loid) concentrations (batch experiment – day 0).

Site	Depth (cm)	Treatment	Day	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	0	<0.01	<0.01	<0.1	0.02	0.4	4.1	0.7	0.01	0.06	4.0	<0.1	0.2	46.0	<0.1
WC	2.5-10	None	0	<0.01	0.01	<0.1	<0.01	0.3	3.9	0.9	0.01	0.06	3.9	<0.1	0.1	44.6	<0.1
WC	2.5-10	None	0	<0.01	<0.01	<0.1	0.02	0.5	3.9	1.5	<0.01	0.06	4.7	<0.1	0.2	81.4	<0.1
WC	2.5-10	None/Jarosite	0	<0.01	<0.01	<0.1	0.07	0.7	12.6	0.6	0.21	0.13	15.2	<0.1	0.1	60.5	<0.1
WC	2.5-10	None/Jarosite	0	<0.01	<0.01	<0.1	0.02	0.4	3.9	0.4	0.01	0.06	4.5	<0.1	<0.1	50.3	<0.1
WC	2.5-10	None/Jarosite	0	<0.01	<0.01	<0.1	0.03	0.6	4.5	0.5	0.02	0.07	8.2	<0.1	<0.1	48.8	<0.1
WC	2.5-10	None/Schwert.	0	<0.01	<0.01	<0.1	0.01	0.6	1.3	0.4	<0.01	0.04	2.5	<0.1	0.1	12.0	<0.1
WC	2.5-10	None/Schwert.	0	<0.01	<0.01	<0.1	<0.01	0.2	1.2	0.4	<0.01	0.04	2.3	<0.1	0.1	11.0	<0.1
WC	2.5-10	None/Schwert.	0	<0.01	<0.01	<0.1	<0.01	0.3	1.0	0.2	<0.01	0.03	2.0	<0.1	<0.1	11.7	<0.1
WC	2.5-10	Glucose	0	<0.01	<0.01	<0.1	0.01	0.4	3.1	1.0	0.01	0.05	3.1	<0.1	0.1	48.0	<0.1
WC	2.5-10	Glucose	0	0.04	0.01	<0.1	0.01	0.5	3.5	1.2	0.02	0.05	3.6	<0.1	<0.1	59.0	<0.1
WC	2.5-10	Glucose	0	0.02	<0.01	<0.1	0.01	0.5	2.9	0.9	0.01	0.05	2.8	<0.1	0.1	32.8	<0.1
WC	2.5-10	Glucose/Jarosite	0	0.12	<0.01	0.8	0.03	<0.1	4.0	0.5	0.02	0.07	4.9	0.1	0.3	41.7	<0.1
WC	2.5-10	Glucose/Jarosite	0	0.08	<0.01	0.9	0.05	0.8	3.9	0.6	0.04	0.06	5.1	<0.1	0.6	58.3	<0.1
WC	2.5-10	Glucose/Jarosite	0	0.10	<0.01	0.8	0.02	<0.1	3.7	0.9	0.02	0.06	4.7	0.2	1.5	45.6	<0.1
WC	2.5-10	Glucose/Schwert.	0	0.02	<0.01	1.8	<0.01	0.2	1.4	0.4	0.01	0.04	3.4	<0.1	0.3	13.5	<0.1
WC	2.5-10	Glucose/Schwert.	0	0.07	<0.01	0.9	0.02	<0.1	2.0	0.4	0.01	0.05	4.3	0.1	0.3	12.5	<0.1
WC	2.5-10	Glucose/Schwert.	0	0.05	<0.01	1.2	0.03	<0.1	1.1	0.3	<0.01	0.04	2.8	<0.1	0.3	11.5	<0.1
WC	2.5-10	Acetate	0	<0.01	<0.01	<0.1	0.02	0.6	4.0	1.0	<0.01	0.07	4.1	<0.1	0.1	33.7	<0.1
WC	2.5-10	Acetate	0	<0.01	<0.01	<0.1	0.02	0.5	4.3	1.1	<0.01	0.07	4.4	<0.1	0.1	94.7	<0.1
WC	2.5-10	Acetate	0	<0.01	<0.01	<0.1	0.03	1.7	4.1	1.0	<0.01	0.07	4.9	<0.1	<0.1	96.4	<0.1
WC	2.5-10	Acetate/Jarosite	0	<0.01	<0.01	0.5	0.06	<0.1	5.2	0.5	<0.01	0.08	4.9	<0.1	0.3	41.0	<0.1
WC	2.5-10	Acetate/Jarosite	0	<0.01	<0.01	<0.1	0.03	0.5	4.6	0.5	<0.01	0.07	4.5	<0.1	0.1	39.3	<0.1
WC	2.5-10	Acetate/Jarosite	0	<0.01	<0.01	1.4	0.04	<0.1	5.0	0.5	<0.01	0.09	6.6	<0.1	<0.1	43.2	<0.1
WC	2.5-10	Acetate/Schwert.	0	<0.01	<0.01	<0.1	0.01	<0.1	3.3	0.3	<0.01	0.07	5.0	<0.1	1.2	6.7	<0.1
WC	2.5-10	Acetate/Schwert.	0	<0.01	<0.01	1.3	0.03	<0.1	3.3	0.3	<0.01	0.07	5.0	<0.1	0.6	13.2	<0.1
WC	2.5-10	Acetate/Schwert.	0	<0.01	<0.01	1.4	0.06	<0.1	2.8	0.4	<0.01	0.07	4.7	<0.1	1.2	7.3	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-16 (continued). Surface water metal(loid) concentrations (batch experiment – day 0).

Site	Depth (cm)	Treatment	Day	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	0	1.38	0.10	1.3	0.14	1.8	15.6	18.5	1.09	0.11	21.2	8.6	0.2	368.6	<0.1
WC	2.5-10	Humic	0	0.09	0.09	1.3	0.16	1.1	15.0	13.4	0.96	0.11	20.8	7.6	0.2	377.7	<0.1
WC	2.5-10	Humic	0	0.05	0.09	1.2	0.15	1.2	14.6	12.8	0.93	0.11	21.2	7.6	0.2	323.3	<0.1
WC	2.5-10	Humic/Jarosite	0	1.44	0.09	0.8	0.16	1.5	14.2	14.5	1.20	0.11	20.4	6.8	0.3	269.4	<0.1
WC	2.5-10	Humic/Jarosite	0	1.36	0.08	0.7	0.15	1.3	15.1	14.3	1.31	0.11	20.7	6.7	0.3	400.2	<0.1
WC	2.5-10	Humic/Jarosite	0	0.11	0.08	0.6	0.16	1.7	14.5	11.8	1.09	0.11	21.3	6.3	0.2	242.5	<0.1
WC	2.5-10	Humic/Schwert.	0	0.06	0.07	0.2	0.13	0.8	11.8	10.9	1.38	0.09	17.6	4.8	0.4	116.9	<0.1
WC	2.5-10	Humic/Schwert.	0	0.05	0.10	0.3	0.15	1.0	15.2	13.6	1.49	0.12	22.4	6.7	0.1	144.7	<0.1
WC	2.5-10	Humic/Schwert.	0	1.29	0.09	0.2	0.12	1.4	14.0	15.9	1.83	0.11	21.5	6.3	0.2	120.1	<0.1
WC	2.5-10	Phragmites	0	0.11	0.11	1.3	0.07	1.5	12.4	17.0	0.22	0.88	14.2	0.6	0.4	195.7	<0.1
WC	2.5-10	Phragmites	0	0.05	0.12	1.6	0.06	0.5	13.1	18.0	0.26	0.88	12.8	0.8	0.4	265.5	<0.1
WC	2.5-10	Phragmites	0	0.03	0.08	1.4	0.05	0.6	13.4	18.4	0.26	0.85	13.1	0.8	0.4	295.7	<0.1
WC	2.5-10	Phragmites/Jarosite	0	0.08	0.11	1.0	0.05	<0.1	13.1	19.1	0.34	0.92	14.1	0.2	0.6	240.1	<0.1
WC	2.5-10	Phragmites/Jarosite	0	0.04	0.07	2.4	0.05	<0.1	13.2	18.1	0.32	0.91	14.5	0.2	0.3	246.2	<0.1
WC	2.5-10	Phragmites/Jarosite	0	0.04	0.08	1.3	0.06	<0.1	12.2	16.9	0.37	0.92	19.0	0.3	0.3	245.5	<0.1
WC	2.5-10	Phragmites/Schwert.	0	0.04	0.08	1.7	0.05	<0.1	13.6	20.8	0.70	0.66	15.5	0.2	<0.1	179.0	<0.1
WC	2.5-10	Phragmites/Schwert.	0	0.08	0.10	2.1	0.04	<0.1	13.9	22.3	0.80	0.73	16.8	0.1	0.6	248.4	<0.1
WC	2.5-10	Phragmites/Schwert.	0	<0.01	0.11	1.7	0.05	<0.1	14.4	21.3	0.65	0.76	17.7	0.1	0.9	245.3	<0.1
WC	2.5-10	Schoenoplectus	0	0.01	0.09	2.7	0.07	0.3	11.3	14.4	0.19	0.73	14.6	0.4	0.3	129.8	<0.1
WC	2.5-10	Schoenoplectus	0	0.03	0.08	1.0	0.05	<0.1	11.6	12.7	0.14	0.71	14.8	0.4	<0.1	85.5	<0.1
WC	2.5-10	Schoenoplectus	0	0.02	0.09	0.5	0.04	0.3	10.6	11.0	0.14	0.63	12.8	0.3	0.3	86.9	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	0	<0.01	0.18	1.4	0.05	0.1	12.3	14.4	0.36	0.69	17.9	0.3	1.3	161.3	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	0	0.03	0.19	1.7	0.05	0.2	11.8	15.1	0.39	0.68	17.3	0.3	0.6	129.4	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	0	0.25	0.12	1.8	0.08	<0.1	11.9	15.0	0.32	0.70	15.9	0.2	0.3	154.2	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	0	0.03	0.13	<0.1	0.03	0.3	12.3	16.3	1.00	0.56	20.4	0.1	0.4	82.7	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	0	0.03	0.13	<0.1	0.03	0.8	11.9	17.3	1.10	0.51	19.6	0.2	0.2	180.6	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	0	0.03	0.08	<0.1	0.03	2.2	8.4	14.9	0.63	0.53	13.1	0.1	<0.1	135.2	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-17. Surface water metal(loid) concentrations (batch experiment – day 2).

Site	Depth (cm)	Treatment	Day	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	2	0.04	<0.01	1.2	0.03	0.1	7.0	0.4	0.16	0.10	8.7	0.1	0.1	11.2	0.1
WC	2.5-10	None	2	0.02	0.01	0.8	0.03	<0.1	7.4	0.5	0.08	0.10	9.5	0.1	0.2	7.2	<0.1
WC	2.5-10	None	2	0.02	0.01	0.8	0.02	0.1	7.1	0.6	0.12	0.10	8.6	<0.1	0.3	98.9	<0.1
WC	2.5-10	None/Jarosite	2	0.02	0.02	0.9	0.05	0.1	13.7	1.3	0.56	0.15	24.9	<0.1	0.3	108.3	<0.1
WC	2.5-10	None/Jarosite	2	0.02	0.03	1.1	0.07	0.2	15.9	0.8	0.82	0.17	23.4	<0.1	0.3	12.9	<0.1
WC	2.5-10	None/Jarosite	2	0.02	0.03	1.1	0.08	0.2	15.0	0.8	0.88	0.16	24.4	<0.1	0.2	12.2	<0.1
WC	2.5-10	None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Glucose	2	0.03	0.02	3.1	0.03	0.5	8.3	0.2	1.53	0.12	26.0	0.2	0.5	27.1	0.2
WC	2.5-10	Glucose	2	0.02	0.02	3.3	0.01	0.4	8.0	0.3	1.77	0.13	10.9	0.1	0.8	45.1	0.1
WC	2.5-10	Glucose	2	0.02	0.02	3.1	<0.01	0.3	7.7	0.5	1.55	0.12	10.7	<0.1	0.5	34.8	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.04	0.02	0.8	0.05	0.5	13.2	0.6	1.87	0.16	17.8	<0.1	0.2	71.0	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.06	0.02	0.9	0.04	0.3	13.7	0.4	2.09	0.17	20.0	0.1	0.1	71.0	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.03	0.02	1.1	0.03	0.4	14.4	0.5	2.64	0.18	20.1	<0.1	0.2	133.2	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.04	0.02	<0.1	0.12	0.4	21.5	1.5	1.56	0.23	49.3	0.1	0.2	56.3	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.04	0.02	<0.1	0.15	0.4	22.1	1.8	1.61	0.24	36.5	0.1	<0.1	111.5	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.03	0.02	0.1	0.14	0.3	22.1	1.8	1.66	0.25	33.8	0.2	0.1	131.0	<0.1
WC	2.5-10	Acetate	2	0.04	<0.01	1.2	0.02	0.4	5.6	0.6	0.15	0.10	6.2	<0.1	0.3	94.9	<0.1
WC	2.5-10	Acetate	2	0.05	<0.01	1.2	0.02	0.4	5.7	0.5	0.21	0.11	5.3	<0.1	0.3	98.0	<0.1
WC	2.5-10	Acetate	2	0.03	0.01	1.3	0.02	0.4	5.5	0.7	0.20	0.11	5.2	<0.1	0.2	191.2	<0.1
WC	2.5-10	Acetate/Jarosite	2	<0.01	<0.01	0.5	0.04	0.5	8.2	0.9	0.03	0.13	13.7	<0.1	0.2	112.8	<0.1
WC	2.5-10	Acetate/Jarosite	2	<0.01	<0.01	0.4	0.03	0.3	7.9	0.4	0.03	0.12	9.7	<0.1	0.2	18.3	<0.1
WC	2.5-10	Acetate/Jarosite	2	<0.01	<0.01	0.5	0.03	0.4	7.9	0.4	0.03	0.13	10.3	<0.1	0.3	17.7	<0.1
WC	2.5-10	Acetate/Schwert.	2	0.01	<0.01	<0.1	0.08	0.2	14.6	0.2	0.27	0.19	28.8	<0.1	0.1	21.8	<0.1
WC	2.5-10	Acetate/Schwert.	2	0.01	<0.01	0.1	0.07	0.2	14.0	0.3	0.26	0.19	22.2	<0.1	0.1	19.7	<0.1
WC	2.5-10	Acetate/Schwert.	2	0.01	<0.01	0.1	0.06	0.4	14.3	0.3	0.26	0.19	30.2	<0.1	<0.1	20.3	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-17 (continued). Surface water metal(loid) concentrations (batch experiment – day 2).

Site	Depth (cm)	Treatment	Day	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	2	0.06	0.21	3.2	0.17	0.7	19.2	23.4	1.41	0.15	41.0	10.0	<0.1	419.3	<0.1
WC	2.5-10	Humic	2	0.14	0.25	3.9	0.18	0.4	20.1	24.4	1.60	0.15	41.0	10.8	0.3	278.5	<0.1
WC	2.5-10	Humic	2	0.06	0.21	3.8	0.18	0.5	20.2	22.4	1.69	0.15	34.7	10.7	<0.1	169.1	<0.1
WC	2.5-10	Humic/Jarosite	2	0.30	0.29	2.4	0.22	0.7	20.0	23.1	2.74	0.17	35.1	9.9	0.2	586.7	<0.1
WC	2.5-10	Humic/Jarosite	2	0.14	0.31	3.1	0.20	0.3	19.9	23.2	4.17	0.17	38.7	8.5	<0.1	779.1	<0.1
WC	2.5-10	Humic/Jarosite	2	0.21	0.27	2.5	0.26	0.5	19.8	23.1	3.96	0.17	31.5	8.7	0.3	627.9	<0.1
WC	2.5-10	Humic/Schwert.	2	0.86	0.24	1.2	0.22	0.5	23.5	20.7	11.67	0.24	46.3	5.7	<0.1	634.1	0.1
WC	2.5-10	Humic/Schwert.	2	0.89	0.20	0.8	0.21	0.4	22.4	19.3	11.51	0.23	41.6	5.1	0.6	567.2	0.1
WC	2.5-10	Humic/Schwert.	2	0.86	0.22	1.1	0.18	0.4	23.5	19.6	11.74	0.24	46.2	5.6	0.7	344.8	0.1
WC	2.5-10	Phragmites	2	0.01	0.18	16.5	0.01	0.6	24.8	3.2	6.25	1.07	42.6	0.5	0.4	241.3	<0.1
WC	2.5-10	Phragmites	2	<0.01	0.16	16.4	<0.01	0.6	25.4	2.8	6.49	1.09	46.5	0.4	0.4	216.3	<0.1
WC	2.5-10	Phragmites	2	0.01	0.21	15.9	0.01	0.6	24.1	3.6	6.00	1.08	40.3	0.6	0.6	284.8	<0.1
WC	2.5-10	Phragmites/Jarosite	2	<0.01	0.20	14.1	0.04	0.5	24.2	3.8	5.57	1.12	44.6	0.1	0.5	231.2	<0.1
WC	2.5-10	Phragmites/Jarosite	2	<0.01	0.20	14.0	0.03	0.5	24.5	4.3	5.12	1.11	54.6	0.2	0.4	301.2	<0.1
WC	2.5-10	Phragmites/Jarosite	2	<0.01	0.19	13.1	0.03	0.5	24.4	3.7	4.92	1.11	49.0	0.2	0.8	248.6	<0.1
WC	2.5-10	Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Schoenoplectus	2	<0.01	0.74	13.6	0.02	1.0	23.9	5.9	8.31	0.85	42.8	0.8	0.8	280.8	<0.1
WC	2.5-10	Schoenoplectus	2	<0.01	0.63	13.9	0.03	1.0	24.1	4.8	8.42	0.82	46.0	0.8	0.6	205.5	<0.1
WC	2.5-10	Schoenoplectus	2	0.02	0.67	11.6	0.01	0.8	21.4	5.9	6.16	0.81	39.8	0.9	0.8	269.7	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	0.02	0.68	9.6	0.07	0.7	23.5	6.2	8.47	0.88	44.3	0.3	0.6	164.5	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	0.01	0.67	9.6	0.06	0.6	23.1	5.6	8.70	0.79	46.9	0.3	0.5	143.2	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	0.01	0.67	8.6	0.07	0.7	23.9	6.6	9.68	0.88	42.1	0.2	0.5	156.7	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-18. Surface water metal(loid) concentrations (batch experiment – week 1).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	1	0.10	<0.01	3.2	<0.01	0.4	8.0	0.3	2.00	0.11	10.2	0.1	0.4	9.9	0.3
WC	2.5-10	None	1	0.09	0.01	4.4	<0.01	0.3	6.8	0.3	2.30	0.11	8.1	<0.1	0.2	8.1	0.2
WC	2.5-10	None	1	0.04	0.01	3.7	<0.01	0.4	7.8	0.3	2.12	0.11	9.0	<0.1	0.4	15.2	0.1
WC	2.5-10	None/Jarosite	1	0.04	0.03	0.9	0.08	0.3	22.8	0.7	8.01	0.22	62.8	<0.1	<0.1	100.3	<0.1
WC	2.5-10	None/Jarosite	1	0.03	0.03	0.9	0.10	0.5	20.3	0.4	5.79	0.21	33.8	<0.1	0.1	30.6	<0.1
WC	2.5-10	None/Jarosite	1	0.04	0.03	0.8	0.09	0.3	20.9	0.6	7.64	0.22	96.3	<0.1	0.2	72.2	<0.1
WC	2.5-10	None/Schwert.	1	0.05	0.02	<0.1	0.17	0.4	27.9	1.5	15.52	0.25	51.3	0.3	0.1	175.5	<0.1
WC	2.5-10	None/Schwert.	1	0.04	0.03	0.1	0.17	0.5	29.1	1.8	14.84	0.26	71.5	0.3	0.2	179.9	<0.1
WC	2.5-10	None/Schwert.	1	0.05	0.03	<0.1	0.17	0.4	27.7	1.3	12.71	0.25	50.7	0.3	0.1	112.4	<0.1
WC	2.5-10	Glucose	1	0.01	0.06	14.1	<0.01	0.5	13.8	0.2	23.53	0.25	30.1	0.1	0.5	97.4	<0.1
WC	2.5-10	Glucose	1	<0.01	0.08	12.1	<0.01	0.8	11.6	0.2	25.72	0.26	29.6	0.1	0.3	70.9	<0.1
WC	2.5-10	Glucose	1	<0.01	0.06	15.3	<0.01	1.1	12.2	0.2	25.01	0.26	24.7	0.1	0.7	77.7	<0.1
WC	2.5-10	Glucose/Jarosite	1	<0.01	0.05	4.9	0.04	0.4	22.8	0.3	32.49	0.28	48.3	<0.1	0.3	98.3	<0.1
WC	2.5-10	Glucose/Jarosite	1	<0.01	0.04	5.3	0.01	0.6	22.1	0.2	43.96	0.31	40.7	<0.1	0.3	90.9	<0.1
WC	2.5-10	Glucose/Jarosite	1	<0.01	0.05	5.3	0.03	0.5	22.3	0.2	31.15	0.29	39.7	<0.1	0.2	96.1	<0.1
WC	2.5-10	Glucose/Schwert.	1	0.01	<0.01	0.3	0.13	0.4	33.1	0.4	123.30	0.34	83.1	0.2	0.3	105.4	<0.1
WC	2.5-10	Glucose/Schwert.	1	<0.01	<0.01	0.2	0.11	0.4	33.6	0.3	124.42	0.35	60.1	0.2	0.3	94.9	<0.1
WC	2.5-10	Glucose/Schwert.	1	<0.01	<0.01	0.2	0.10	0.5	32.3	0.3	123.02	0.33	88.1	0.1	0.3	94.1	<0.1
WC	2.5-10	Acetate	1	<0.01	<0.01	16.4	<0.01	0.5	5.2	0.5	8.53	0.16	12.2	0.1	0.6	58.6	<0.1
WC	2.5-10	Acetate	1	<0.01	<0.01	15.2	<0.01	0.5	5.5	0.5	8.38	0.16	11.0	0.1	0.4	73.8	<0.1
WC	2.5-10	Acetate	1	0.05	0.01	15.1	<0.01	0.5	4.4	0.4	8.28	0.15	10.1	0.2	0.6	37.4	<0.1
WC	2.5-10	Acetate/Jarosite	1	0.12	<0.01	0.2	0.03	0.4	17.2	0.3	10.09	0.22	32.8	<0.1	0.3	87.7	0.1
WC	2.5-10	Acetate/Jarosite	1	0.06	<0.01	0.2	0.03	0.3	16.5	0.2	9.85	0.22	43.2	<0.1	0.1	82.3	<0.1
WC	2.5-10	Acetate/Jarosite	1	0.06	<0.01	0.2	0.04	0.3	16.8	0.3	9.20	0.21	30.8	<0.1	0.2	91.4	<0.1
WC	2.5-10	Acetate/Schwert.	1	0.04	<0.01	<0.1	0.08	0.3	18.0	0.4	1.43	0.20	35.7	<0.1	0.3	82.0	<0.1
WC	2.5-10	Acetate/Schwert.	1	0.07	<0.01	<0.1	0.09	0.4	18.9	0.3	1.82	0.20	66.7	<0.1	0.1	83.7	<0.1
WC	2.5-10	Acetate/Schwert.	1	0.04	<0.01	<0.1	0.07	0.4	18.0	0.9	2.06	0.19	34.9	0.1	0.2	90.4	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-18 (continued). Surface water metal(loid) concentrations (batch experiment – week 1).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	1	0.10	0.35	19.8	0.08	1.5	16.6	20.9	10.50	0.17	42.1	11.2	0.8	138.1	<0.1
WC	2.5-10	Humic	1	0.09	0.29	20.6	0.10	1.0	15.8	19.0	10.46	0.16	57.5	9.0	0.4	141.5	<0.1
WC	2.5-10	Humic	1	0.07	0.29	19.0	0.07	0.8	15.4	16.7	10.84	0.17	44.7	6.0	0.3	247.7	<0.1
WC	2.5-10	Humic/Jarosite	1	0.08	0.33	2.2	0.16	0.7	22.5	11.5	23.04	0.23	38.9	3.0	0.7	547.9	<0.1
WC	2.5-10	Humic/Jarosite	1	0.07	0.37	2.3	0.19	0.3	21.0	20.0	10.16	0.20	41.6	5.2	0.2	568.8	<0.1
WC	2.5-10	Humic/Jarosite	1	0.06	0.34	3.4	0.18	0.6	20.9	20.3	5.56	0.19	41.3	6.3	0.5	471.6	<0.1
WC	2.5-10	Humic/Schwert.	1	0.36	0.13	0.2	0.19	0.8	28.0	12.9	31.14	0.26	48.7	4.0	0.2	675.7	<0.1
WC	2.5-10	Humic/Schwert.	1	0.29	0.12	0.3	0.17	0.1	27.4	13.0	27.06	0.26	44.1	3.8	<0.1	598.2	<0.1
WC	2.5-10	Humic/Schwert.	1	0.54	0.15	0.9	0.17	0.5	27.0	16.4	21.75	0.25	76.4	4.6	0.2	772.4	<0.1
WC	2.5-10	Phragmites	1	0.19	0.22	11.6	0.02	0.9	28.1	1.7	33.32	1.39	73.0	0.2	0.4	174.1	<0.1
WC	2.5-10	Phragmites	1	0.10	0.16	11.4	<0.01	0.7	27.6	1.5	31.88	1.41	69.9	0.1	0.5	248.6	<0.1
WC	2.5-10	Phragmites	1	0.05	0.18	12.3	<0.01	0.8	28.3	1.7	31.49	1.40	74.3	0.3	1.1	322.4	<0.1
WC	2.5-10	Phragmites/Jarosite	1	0.07	0.17	12.2	0.02	0.9	29.6	2.1	30.29	1.40	63.9	0.1	1.0	202.0	<0.1
WC	2.5-10	Phragmites/Jarosite	1	0.26	0.16	13.7	0.02	0.9	29.3	1.7	31.09	1.41	80.4	0.1	0.3	229.2	<0.1
WC	2.5-10	Phragmites/Jarosite	1	0.19	0.16	12.3	0.03	0.8	29.7	1.9	29.68	1.40	106.6	<0.1	0.8	229.4	<0.1
WC	2.5-10	Phragmites/Schwert.	1	0.16	0.04	<0.1	0.02	0.9	24.9	0.7	436.72	1.57	38.3	<0.1	0.2	40.7	<0.1
WC	2.5-10	Phragmites/Schwert.	1	0.12	0.02	<0.1	0.02	0.2	25.7	0.8	441.44	1.64	87.3	<0.1	<0.1	101.3	<0.1
WC	2.5-10	Phragmites/Schwert.	1	0.09	0.02	<0.1	0.02	0.5	25.8	0.9	430.08	1.65	40.4	<0.1	<0.1	104.3	<0.1
WC	2.5-10	Schoenoplectus	1	0.07	0.49	9.1	0.03	1.7	24.2	4.7	34.48	1.07	115.5	0.5	0.5	279.2	<0.1
WC	2.5-10	Schoenoplectus	1	0.05	0.35	8.2	0.02	1.7	23.4	3.5	33.67	1.09	48.7	0.4	1.4	253.0	<0.1
WC	2.5-10	Schoenoplectus	1	0.03	0.46	8.4	0.02	1.9	22.8	3.5	32.69	1.08	60.8	0.4	0.8	265.3	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	1	0.02	0.29	7.8	0.02	1.3	30.9	2.6	115.11	1.30	56.4	<0.1	0.4	218.6	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	1	<0.01	0.24	8.1	0.04	0.8	29.4	2.5	99.43	1.31	57.3	<0.1	0.7	236.7	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	1	<0.01	0.29	9.4	0.06	1.1	29.6	3.5	81.70	1.30	66.9	0.1	1.0	252.1	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	1	0.02	0.03	0.3	0.01	0.7	24.8	1.4	538.89	1.23	37.4	0.1	0.2	90.8	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	1	0.01	0.04	0.4	<0.01	0.5	24.1	1.7	585.02	1.23	28.0	0.1	0.4	77.9	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	1	0.02	0.02	0.3	<0.01	0.5	24.1	1.3	580.66	1.22	28.7	0.2	0.3	47.0	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-19. Surface water metal(loid) concentrations (batch experiment – week 2).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	2	0.02	0.05	21.9	<0.01	0.3	0.6	0.4	3.71	0.10	1.8	<0.1	0.3	35.3	<0.1
WC	2.5-10	None	2	0.03	0.04	22.8	<0.01	0.4	1.0	0.4	4.01	0.10	2.6	<0.1	0.7	51.1	<0.1
WC	2.5-10	None	2	0.04	0.03	18.5	<0.01	0.2	1.2	0.4	4.46	0.11	2.2	0.1	0.4	18.0	<0.1
WC	2.5-10	None/Jarosite	2	0.02	0.02	1.0	0.05	0.2	26.9	0.3	24.97	0.27	63.9	<0.1	0.3	113.1	<0.1
WC	2.5-10	None/Jarosite	2	0.01	0.02	0.9	0.05	0.1	27.1	0.4	28.57	0.29	40.7	<0.1	0.3	74.0	<0.1
WC	2.5-10	None/Jarosite	2	0.01	0.02	0.7	0.04	0.1	24.7	0.4	22.40	0.25	42.9	<0.1	0.2	76.4	<0.1
WC	2.5-10	None/Schwert.	2	0.25	0.04	0.2	0.15	0.2	32.3	0.9	38.94	0.26	77.5	0.5	0.1	103.2	<0.1
WC	2.5-10	None/Schwert.	2	0.23	0.04	0.2	0.15	0.1	33.3	0.7	41.93	0.30	72.1	0.5	<0.1	87.3	<0.1
WC	2.5-10	None/Schwert.	2	0.21	0.03	0.1	0.14	<0.1	33.0	0.7	44.14	0.27	62.8	0.5	<0.1	21.5	<0.1
WC	2.5-10	Glucose	2	<0.01	0.05	13.2	<0.01	0.5	14.5	0.3	29.11	0.26	62.5	<0.1	0.4	121.2	<0.1
WC	2.5-10	Glucose	2	<0.01	0.04	13.4	<0.01	0.5	14.7	0.2	31.23	0.27	32.1	<0.1	0.5	107.7	<0.1
WC	2.5-10	Glucose	2	<0.01	0.04	15.9	<0.01	0.5	15.8	0.3	30.13	0.27	41.1	0.1	0.4	110.2	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.37	0.06	4.1	0.04	0.2	28.4	0.1	52.86	0.31	48.2	<0.1	0.2	108.2	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.24	0.06	3.6	0.04	0.2	27.1	<0.1	53.93	0.32	40.9	<0.1	0.3	34.1	<0.1
WC	2.5-10	Glucose/Jarosite	2	0.15	0.07	4.9	0.05	0.2	27.8	0.2	44.82	0.32	50.4	<0.1	0.2	103.7	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.02	0.05	0.6	0.13	0.2	37.7	0.6	210.14	0.36	77.7	0.7	0.2	179.3	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.02	0.05	0.5	0.15	0.2	36.7	0.4	203.74	0.36	72.2	0.7	0.2	98.4	<0.1
WC	2.5-10	Glucose/Schwert.	2	0.01	0.03	0.5	0.12	0.2	35.3	0.6	205.33	0.37	63.7	0.5	0.1	118.6	<0.1
WC	2.5-10	Acetate	2	0.02	0.01	22.2	<0.01	0.2	3.0	0.5	7.48	0.15	5.7	0.1	0.4	86.1	<0.1
WC	2.5-10	Acetate	2	0.03	0.01	21.5	<0.01	0.2	3.1	0.2	8.00	0.15	6.2	<0.1	0.2	14.3	<0.1
WC	2.5-10	Acetate	2	0.01	0.01	19.5	<0.01	0.1	3.9	0.4	9.05	0.15	10.7	0.1	0.4	77.6	<0.1
WC	2.5-10	Acetate/Jarosite	2	0.02	<0.01	0.4	0.04	0.2	27.3	0.1	56.70	0.34	49.9	<0.1	0.3	72.8	<0.1
WC	2.5-10	Acetate/Jarosite	2	0.02	<0.01	0.4	0.04	0.1	24.0	0.2	28.72	0.29	44.9	<0.1	0.3	76.8	<0.1
WC	2.5-10	Acetate/Jarosite	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Acetate/Schwert.	2	0.02	<0.01	0.2	0.09	<0.01	19.9	0.1	6.73	0.20	184.1	<0.1	0.2	3.4	<0.1
WC	2.5-10	Acetate/Schwert.	2	0.02	<0.01	0.1	0.08	0.2	18.7	0.2	3.71	0.19	33.2	<0.1	0.1	84.1	<0.1
WC	2.5-10	Acetate/Schwert.	2	0.02	<0.01	0.2	0.07	0.1	18.2	0.1	3.72	0.19	50.6	<0.1	<0.1	3.4	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-19 (continued). Surface water metal(loid) concentrations (batch experiment – week 2).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	2	0.07	0.05	26.9	0.09	<0.01	15.7	23.6	13.29	0.19	56.3	14.1	1.0	159.0	0.1
WC	2.5-10	Humic	2	0.07	0.03	29.7	0.08	0.8	12.2	18.6	13.96	0.18	39.9	11.6	0.4	226.8	<0.1
WC	2.5-10	Humic	2	0.04	0.05	25.3	0.09	<0.01	14.7	23.2	13.69	0.18	58.0	12.3	0.8	201.5	<0.1
WC	2.5-10	Humic/Jarosite	2	0.17	0.03	4.5	0.09	<0.01	24.6	9.8	34.74	0.26	40.1	1.6	<0.1	444.4	<0.1
WC	2.5-10	Humic/Jarosite	2	0.08	0.04	2.8	0.11	1.3	24.6	11.8	27.02	0.26	72.6	2.0	0.6	484.1	<0.1
WC	2.5-10	Humic/Jarosite	2	0.31	0.05	3.2	0.08	0.8	24.8	10.3	33.84	0.28	58.0	2.2	0.2	511.7	0.2
WC	2.5-10	Humic/Schwert.	2	0.36	0.01	1.5	0.16	<0.01	32.1	13.4	58.66	0.30	54.3	4.0	0.2	490.6	0.2
WC	2.5-10	Humic/Schwert.	2	0.42	0.01	1.7	0.20	<0.01	31.4	14.7	54.75	0.29	52.1	4.2	0.8	588.9	<0.1
WC	2.5-10	Humic/Schwert.	2	0.11	<0.01	1.9	0.16	0.1	30.5	9.3	42.14	0.31	72.5	2.8	0.2	348.6	0.3
WC	2.5-10	Phragmites	2	0.03	0.10	6.8	<0.01	1.0	26.4	0.8	41.59	1.34	79.2	0.2	0.5	193.4	<0.1
WC	2.5-10	Phragmites	2	0.02	0.11	7.0	0.01	1.1	26.5	0.8	41.93	1.40	73.6	0.2	0.4	151.6	<0.1
WC	2.5-10	Phragmites	2	0.01	0.09	8.3	<0.01	1.0	24.0	0.5	39.26	1.33	66.7	0.1	0.6	86.4	<0.1
WC	2.5-10	Phragmites/Jarosite	2	0.03	<0.01	18.3	<0.01	1.8	19.7	<0.1	284.35	1.53	54.0	<0.1	0.5	22.1	<0.1
WC	2.5-10	Phragmites/Jarosite	2	0.02	<0.01	15.7	<0.01	0.7	20.8	0.2	313.04	1.71	71.5	<0.1	0.4	43.9	<0.1
WC	2.5-10	Phragmites/Jarosite	2	0.02	<0.01	15.4	0.01	0.7	24.0	<0.1	418.40	1.72	42.4	<0.1	0.4	47.5	<0.1
WC	2.5-10	Phragmites/Schwert.	2	0.01	<0.01	1.5	<0.01	0.3	0.6	0.6	366.06	1.08	4.2	<0.1	0.2	160.1	<0.1
WC	2.5-10	Phragmites/Schwert.	2	0.01	<0.01	0.9	0.01	0.1	0.7	0.3	260.19	0.82	5.1	<0.1	0.2	66.8	<0.1
WC	2.5-10	Phragmites/Schwert.	2	<0.01	<0.01	1.0	0.01	0.3	0.6	0.6	437.52	0.94	4.1	<0.1	0.2	129.3	<0.1
WC	2.5-10	Schoenoplectus	2	0.01	0.26	6.7	<0.01	1.6	21.0	1.4	40.32	1.02	41.3	0.2	0.6	160.1	<0.1
WC	2.5-10	Schoenoplectus	2	0.01	0.12	9.0	<0.01	1.7	21.1	0.6	41.48	1.08	60.8	<0.1	0.6	119.5	<0.1
WC	2.5-10	Schoenoplectus	2	<0.01	0.23	7.6	<0.01	1.7	21.0	1.0	40.00	0.98	51.1	0.2	0.5	131.6	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	0.01	0.02	11.1	<0.01	0.9	24.7	<0.1	442.52	1.41	43.0	<0.1	0.4	38.6	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	<0.01	0.03	11.8	0.01	1.0	34.4	0.2	378.49	1.44	77.1	<0.1	0.5	19.3	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	2	<0.01	0.02	13.5	0.01	1.1	28.2	0.1	411.58	1.43	46.4	<0.1	0.2	42.0	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	2	<0.01	<0.01	0.4	<0.01	<0.1	0.3	<0.1	309.94	0.84	0.7	<0.1	0.2	16.1	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	2	<0.01	<0.01	0.5	<0.01	0.2	0.2	<0.1	186.48	0.77	0.7	<0.1	0.1	19.6	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	2	<0.01	<0.01	0.3	<0.01	0.3	0.3	<0.1	308.13	0.89	0.7	<0.1	0.2	34.6	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-20. Surface water metal(loid) concentrations (batch experiment – week 4).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	4	0.01	0.07	22.8	<0.01	0.4	0.3	0.4	2.03	0.08	3.6	<0.1	0.3	16.7	<0.1
WC	2.5-10	None	4	<0.01	0.05	20.9	<0.01	1.6	0.2	0.5	3.39	0.10	4.6	<0.1	0.3	13.4	<0.1
WC	2.5-10	None	4	<0.01	0.03	22.1	<0.01	0.4	0.2	0.3	2.67	0.09	5.6	<0.1	0.1	5.5	<0.1
WC	2.5-10	None/Jarosite	4	0.02	0.01	0.5	0.04	0.3	27.2	0.2	45.44	0.30	50.8	<0.1	0.6	61.6	<0.1
WC	2.5-10	None/Jarosite	4	<0.01	0.01	0.3	0.03	0.5	27.3	0.2	41.79	0.29	44.9	<0.1	0.4	56.7	<0.1
WC	2.5-10	None/Jarosite	4	0.01	0.01	0.8	0.03	<0.1	28.0	0.2	42.43	0.30	57.2	<0.1	0.2	62.8	<0.1
WC	2.5-10	None/Schwert.	4	0.02	0.05	<0.1	0.14	0.2	33.4	1.9	40.96	0.29	64.0	0.9	<0.1	64.1	<0.1
WC	2.5-10	None/Schwert.	4	0.02	0.05	0.2	0.15	0.2	35.0	0.7	44.42	0.35	61.6	0.8	0.1	14.8	<0.1
WC	2.5-10	None/Schwert.	4	0.02	0.06	<0.1	0.14	0.1	33.6	0.7	43.78	0.29	76.3	0.9	0.1	14.8	<0.1
WC	2.5-10	Glucose	4	0.02	0.03	8.5	<0.01	0.8	7.9	0.6	32.65	0.26	25.5	<0.1	0.2	168.3	<0.1
WC	2.5-10	Glucose	4	<0.01	0.02	10.2	<0.01	0.9	6.1	0.5	32.63	0.26	31.2	0.1	0.2	115.2	<0.1
WC	2.5-10	Glucose	4	<0.01	0.03	6.5	<0.01	4.9	6.5	0.5	33.57	0.26	15.0	<0.1	0.4	115.5	<0.1
WC	2.5-10	Glucose/Jarosite	4	0.03	<0.01	0.6	<0.01	<0.1	0.1	<0.1	648.31	0.70	2.4	0.1	<0.1	12.4	<0.1
WC	2.5-10	Glucose/Jarosite	4	0.01	<0.01	1.0	<0.01	0.6	<0.1	0.2	261.62	0.58	2.3	0.2	0.2	45.3	<0.1
WC	2.5-10	Glucose/Jarosite	4	0.02	<0.01	0.4	<0.01	3.0	<0.1	0.2	591.87	0.73	2.2	<0.1	0.2	47.1	<0.1
WC	2.5-10	Glucose/Schwert.	4	0.05	0.50	0.8	0.16	2.5	39.5	1.4	420.02	0.40	85.3	3.0	0.2	19.0	<0.1
WC	2.5-10	Glucose/Schwert.	4	0.04	0.53	0.7	0.12	0.3	39.1	1.1	403.10	0.40	79.9	3.0	<0.1	17.0	<0.1
WC	2.5-10	Glucose/Schwert.	4	0.03	0.46	0.8	0.14	1.9	39.0	0.6	437.34	0.40	77.0	2.6	0.2	106.4	<0.1
WC	2.5-10	Acetate	4	0.03	0.03	24.1	<0.01	0.3	0.2	0.5	1.54	0.08	2.9	<0.1	0.4	22.8	<0.1
WC	2.5-10	Acetate	4	0.02	0.09	19.6	<0.01	1.2	0.1	0.6	1.85	0.09	2.6	<0.1	0.3	21.6	<0.1
WC	2.5-10	Acetate	4	0.01	0.08	24.8	<0.01	7.4	0.2	0.9	1.79	0.08	3.0	<0.1	0.3	24.8	<0.1
WC	2.5-10	Acetate/Jarosite	4	0.02	<0.01	0.4	0.02	0.4	30.3	0.1	183.07	0.51	74.8	<0.1	0.2	23.1	<0.1
WC	2.5-10	Acetate/Jarosite	4	0.04	0.01	0.3	0.03	0.3	25.7	0.2	74.62	0.40	47.3	<0.1	0.6	107.6	<0.1
WC	2.5-10	Acetate/Jarosite	4	<0.01	<0.01	0.6	<0.01	0.3	29.0	0.2	179.09	0.51	101.6	<0.1	0.3	118.1	<0.1
WC	2.5-10	Acetate/Schwert.	4	0.01	0.03	<0.1	0.10	0.1	25.7	0.1	273.88	0.27	69.7	0.5	<0.1	71.5	<0.1
WC	2.5-10	Acetate/Schwert.	4	0.02	0.02	<0.1	0.10	4.2	25.2	0.2	266.12	0.28	77.7	0.5	<0.1	4.4	<0.1
WC	2.5-10	Acetate/Schwert.	4	<0.01	0.05	<0.1	0.12	1.0	27.4	0.2	278.80	0.30	74.6	0.7	0.2	4.8	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-20 (continued). Surface water metal(loid) concentrations (batch experiment – week 4).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	4	<0.01	0.38	28.4	0.06	1.5	3.3	10.5	12.40	0.16	16.9	7.7	0.5	133.0	<0.1
WC	2.5-10	Humic	4	<0.01	0.36	25.1	0.06	1.2	4.2	8.6	10.95	0.16	12.0	7.0	0.2	140.3	<0.1
WC	2.5-10	Humic	4	0.01	0.38	27.3	0.07	1.2	3.1	9.7	11.52	0.16	10.9	7.7	0.3	189.9	<0.1
WC	2.5-10	Humic/Jarosite	4	0.49	0.22	2.4	0.06	0.7	24.7	9.8	57.15	0.29	32.9	2.0	0.3	194.1	<0.1
WC	2.5-10	Humic/Jarosite	4	0.32	0.17	2.0	0.03	1.7	24.5	5.3	58.20	0.28	31.0	0.5	0.2	139.0	<0.1
WC	2.5-10	Humic/Jarosite	4	0.21	0.14	1.5	0.01	0.4	23.9	3.6	60.65	0.27	29.0	0.3	<0.1	69.1	<0.1
WC	2.5-10	Humic/Schwert.	4	0.16	0.05	0.3	0.05	1.5	33.1	4.8	89.80	0.30	58.4	1.3	0.2	182.7	<0.1
WC	2.5-10	Humic/Schwert.	4	0.14	0.05	<0.1	0.09	1.3	33.5	4.4	91.20	0.29	122.4	1.4	0.2	177.0	<0.1
WC	2.5-10	Humic/Schwert.	4	0.16	0.04	0.2	0.03	1.1	33.4	4.0	89.73	0.29	44.4	1.0	0.1	210.0	<0.1
WC	2.5-10	Phragmites	4	0.07	0.07	7.2	0.01	1.5	23.8	0.8	41.86	1.40	70.9	0.2	0.7	133.5	<0.1
WC	2.5-10	Phragmites	4	0.04	0.07	6.6	0.01	0.9	22.8	0.7	42.46	1.40	93.2	0.2	1.2	110.7	<0.1
WC	2.5-10	Phragmites	4	0.02	0.09	8.2	<0.01	1.1	24.1	0.7	43.85	1.42	68.5	0.3	0.7	114.2	<0.1
WC	2.5-10	Phragmites/Jarosite	4	0.02	<0.01	17.0	0.01	2.6	6.3	0.4	189.01	1.35	56.7	<0.1	0.5	81.5	<0.1
WC	2.5-10	Phragmites/Jarosite	4	0.01	<0.01	17.1	0.01	2.7	9.2	0.4	151.28	1.32	49.8	<0.1	0.4	84.5	<0.1
WC	2.5-10	Phragmites/Jarosite	4	<0.01	<0.01	19.3	0.02	16.5	16.0	0.2	357.69	1.57	46.4	<0.1	0.4	6.0	<0.1
WC	2.5-10	Phragmites/Schwert.	4	<0.01	<0.01	1.5	0.02	0.3	0.6	0.4	414.48	0.80	5.1	<0.1	<0.1	64.1	<0.1
WC	2.5-10	Phragmites/Schwert.	4	<0.01	<0.01	1.9	0.02	0.2	0.5	0.4	467.94	0.88	4.1	<0.1	0.2	67.4	<0.1
WC	2.5-10	Phragmites/Schwert.	4	<0.01	<0.01	1.6	0.01	0.6	0.7	1.2	381.69	0.65	4.3	<0.1	0.2	64.1	<0.1
WC	2.5-10	Schoenoplectus	4	<0.01	0.09	6.1	<0.01	6.8	15.2	0.7	39.12	1.02	41.5	0.2	0.4	182.5	<0.1
WC	2.5-10	Schoenoplectus	4	<0.01	0.08	5.5	<0.01	1.5	15.1	0.6	38.68	1.04	36.2	0.1	0.6	152.4	<0.1
WC	2.5-10	Schoenoplectus	4	<0.01	0.05	7.3	<0.01	2.3	14.4	0.6	37.63	1.05	38.8	0.1	0.8	164.3	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	4	<0.01	<0.01	13.6	0.02	0.7	25.2	2.2	537.32	1.58	21.7	0.1	0.8	31.8	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	4	<0.01	<0.01	12.4	0.01	3.1	24.4	0.2	477.68	1.42	43.3	<0.1	0.5	33.9	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	4	<0.01	<0.01	11.7	0.01	4.0	21.7	0.1	504.03	1.48	23.3	<0.1	0.3	17.4	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	4	<0.01	<0.01	0.8	<0.01	0.8	<0.1	0.2	109.18	0.60	1.0	0.1	0.2	13.8	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	4	<0.01	<0.01	0.7	0.01	1.1	<0.1	0.1	165.24	0.70	1.1	<0.1	0.2	13.2	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	4	<0.01	<0.01	0.7	<0.01	0.2	<0.1	0.6	97.56	0.64	0.9	<0.1	0.5	74.7	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-21. Surface water metal(loid) concentrations (batch experiment – week 6).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	6	<0.01	0.05	25.4	<0.01	0.2	0.3	0.2	0.40	0.05	1.6	<0.1	0.2	7.8	<0.1
WC	2.5-10	None	6	<0.01	0.25	26.7	0.02	0.5	0.2	0.2	0.45	0.04	2.0	0.1	0.1	5.1	<0.1
WC	2.5-10	None	6	<0.01	0.10	26.6	0.01	0.3	0.2	0.2	0.25	0.03	1.6	0.1	0.3	4.2	<0.1
WC	2.5-10	None/Jarosite	6	0.02	0.02	0.9	0.13	0.1	37.4	0.2	94.21	0.43	65.5	<0.1	0.2	31.4	<0.1
WC	2.5-10	None/Jarosite	6	0.02	0.01	0.6	0.09	0.8	36.6	0.1	104.84	0.43	53.0	<0.1	0.1	30.8	<0.1
WC	2.5-10	None/Jarosite	6	0.02	0.01	0.5	0.08	0.2	36.6	0.1	109.51	0.43	67.6	<0.1	0.2	32.3	<0.1
WC	2.5-10	None/Schwert.	6	0.01	0.92	0.4	0.24	0.2	40.2	0.9	124.55	0.36	181.8	2.0	<0.1	12.7	<0.1
WC	2.5-10	None/Schwert.	6	0.02	0.46	0.5	0.24	0.1	39.4	1.2	126.14	0.36	84.4	1.9	<0.1	23.8	<0.1
WC	2.5-10	None/Schwert.	6	0.01	0.57	0.4	0.22	0.2	40.3	0.9	125.45	0.36	76.4	2.1	<0.1	12.7	<0.1
WC	2.5-10	Glucose	6	<0.01	0.02	8.9	<0.01	0.5	7.7	0.1	36.53	0.30	12.3	0.1	0.3	4.7	<0.1
WC	2.5-10	Glucose	6	<0.01	0.02	11.1	0.01	0.4	12.7	0.1	36.45	0.30	20.1	0.1	0.2	5.8	<0.1
WC	2.5-10	Glucose	6	<0.01	0.01	15.1	<0.01	0.5	10.4	<0.1	32.81	0.26	25.0	<0.1	0.4	4.5	<0.1
WC	2.5-10	Glucose/Jarosite	6	0.01	0.08	3.9	0.06	0.1	29.7	0.1	66.85	0.39	52.7	0.2	0.1	38.1	<0.1
WC	2.5-10	Glucose/Jarosite	6	<0.01	0.10	4.1	0.07	0.2	32.6	0.2	75.61	0.43	54.1	<0.1	0.1	41.0	<0.1
WC	2.5-10	Glucose/Jarosite	6	<0.01	0.06	4.3	0.02	0.2	29.7	<0.1	86.13	0.42	49.8	<0.1	<0.1	40.0	<0.1
WC	2.5-10	Glucose/Schwert.	6	0.01	2.12	1.1	0.24	0.4	44.0	6.1	272.48	0.42	92.6	9.0	<0.1	23.1	<0.1
WC	2.5-10	Glucose/Schwert.	6	<0.01	1.82	1.1	0.21	0.3	44.0	3.8	308.19	0.42	75.0	7.4	0.1	21.7	<0.1
WC	2.5-10	Glucose/Schwert.	6	<0.01	1.99	1.3	0.19	0.3	45.3	4.4	315.72	0.43	100.9	8.3	0.2	22.4	<0.1
WC	2.5-10	Acetate	6	0.01	0.01	23.4	0.01	0.3	0.2	0.1	0.21	0.05	2.1	<0.1	0.2	2.0	<0.1
WC	2.5-10	Acetate	6	<0.01	0.03	22.1	0.01	0.2	0.2	0.3	0.43	0.07	2.2	<0.1	0.3	28.0	<0.1
WC	2.5-10	Acetate	6	0.02	0.02	22.6	0.01	0.2	0.3	0.4	0.23	0.07	1.9	<0.1	0.2	24.9	<0.1
WC	2.5-10	Acetate/Jarosite	6	0.07	0.03	0.6	0.08	0.2	38.2	0.2	155.30	0.53	91.8	<0.1	0.4	23.8	<0.1
WC	2.5-10	Acetate/Jarosite	6	0.05	0.03	0.5	0.06	0.2	34.7	0.1	106.48	0.48	71.0	<0.1	0.2	20.6	<0.1
WC	2.5-10	Acetate/Jarosite	6	0.04	0.03	0.7	0.07	0.2	35.8	0.2	141.14	0.51	147.2	<0.1	0.3	35.5	<0.1
WC	2.5-10	Acetate/Schwert.	6	<0.01	0.35	0.4	0.23	0.4	29.1	0.1	338.90	0.34	91.8	2.5	0.3	5.8	<0.1
WC	2.5-10	Acetate/Schwert.	6	0.01	0.35	0.8	0.17	0.1	30.9	0.1	365.00	0.36	112.0	2.7	0.3	7.2	<0.1
WC	2.5-10	Acetate/Schwert.	6	<0.01	0.19	0.5	0.15	0.3	27.5	<0.1	318.86	0.33	71.1	1.6	0.2	4.5	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-21 (continued). Surface water metal(loid) concentrations (batch experiment – week 6).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	6	0.10	0.43	22.4	0.07	0.8	2.7	1.9	9.31	0.18	13.1	2.0	0.5	135.2	<0.1
WC	2.5-10	Humic	6	0.09	0.28	26.3	0.03	0.3	2.2	3.4	8.04	0.15	10.0	3.0	<0.1	250.6	<0.1
WC	2.5-10	Humic	6	0.02	0.39	26.5	0.06	0.8	1.9	3.2	8.99	0.17	9.5	4.8	0.6	152.5	<0.1
WC	2.5-10	Humic/Jarosite	6	0.02	0.02	0.9	<0.01	0.2	27.2	0.7	88.99	0.34	29.1	<0.1	<0.1	44.4	<0.1
WC	2.5-10	Humic/Jarosite	6	0.01	0.02	0.7	<0.01	0.2	23.7	0.6	97.63	0.37	76.5	<0.1	0.1	45.8	<0.1
WC	2.5-10	Humic/Jarosite	6	0.03	0.02	0.7	<0.01	0.2	28.6	0.9	107.31	0.38	27.3	<0.1	0.2	44.3	<0.1
WC	2.5-10	Humic/Schwert.	6	0.04	0.01	0.1	0.08	<0.1	36.2	0.9	150.29	0.33	92.7	<0.1	<0.1	93.1	<0.1
WC	2.5-10	Humic/Schwert.	6	0.02	<0.01	0.2	0.05	0.1	35.0	0.5	161.83	0.36	69.8	<0.1	<0.1	71.6	<0.1
WC	2.5-10	Humic/Schwert.	6	0.02	0.03	0.1	0.06	0.2	35.0	0.5	134.23	0.34	82.4	<0.1	<0.1	81.1	<0.1
WC	2.5-10	Phragmites	6	<0.01	0.09	9.0	0.02	0.9	25.6	0.8	44.87	1.44	76.4	0.1	0.7	183.7	<0.1
WC	2.5-10	Phragmites	6	<0.01	0.25	8.0	0.01	0.8	27.2	1.1	50.16	1.54	104.1	0.4	<0.1	257.6	<0.1
WC	2.5-10	Phragmites	6	0.10	0.22	5.9	0.02	<0.1	29.3	1.2	50.78	1.58	83.6	0.3	1.0	277.2	<0.1
WC	2.5-10	Phragmites/Jarosite	6	0.05	0.49	6.1	0.05	<0.1	3.4	0.6	386.32	1.55	12.3	<0.1	0.2	109.8	<0.1
WC	2.5-10	Phragmites/Jarosite	6	0.29	0.11	13.3	0.03	<0.1	1.8	0.5	193.19	1.40	12.4	<0.1	<0.1	61.7	0.2
WC	2.5-10	Phragmites/Jarosite	6	0.14	0.11	12.4	0.06	<0.1	2.0	0.2	554.05	1.78	15.0	<0.1	<0.1	7.7	0.1
WC	2.5-10	Phragmites/Schwert.	6	0.02	0.01	0.9	0.03	0.2	0.6	1.0	327.37	0.80	3.7	0.2	0.2	182.7	<0.1
WC	2.5-10	Phragmites/Schwert.	6	0.01	<0.01	1.2	0.02	0.2	0.3	0.5	435.68	0.94	3.0	<0.1	<0.1	112.0	<0.1
WC	2.5-10	Phragmites/Schwert.	6	0.01	0.02	1.1	0.03	0.3	0.3	0.7	578.67	0.95	2.9	<0.1	0.1	178.1	<0.1
WC	2.5-10	Schoenoplectus	6	0.01	0.16	7.7	<0.01	1.6	21.7	0.7	48.54	1.18	42.4	0.3	0.3	118.2	<0.1
WC	2.5-10	Schoenoplectus	6	0.02	0.10	6.6	0.01	1.2	16.6	0.7	42.52	1.12	35.3	0.3	0.3	109.4	<0.1
WC	2.5-10	Schoenoplectus	6	0.01	0.10	8.5	0.02	1.4	22.7	0.2	46.76	1.17	62.3	0.3	0.6	6.1	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	6	<0.01	0.06	5.9	0.02	0.3	2.0	0.4	294.12	1.57	2.0	<0.1	0.4	71.0	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	6	<0.01	<0.01	6.5	0.03	0.2	1.0	<0.1	210.29	1.45	4.8	<0.1	0.2	3.2	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	6	<0.01	0.11	7.1	0.01	0.3	1.8	<0.1	207.68	1.42	1.5	<0.1	0.3	3.8	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	6	<0.01	0.25	0.6	0.03	0.1	<0.1	<0.1	134.07	0.60	0.5	<0.1	0.2	19.5	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	6	<0.01	<0.01	0.6	<0.01	0.4	<0.1	0.4	199.20	0.75	0.5	<0.1	0.2	84.2	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	6	<0.01	<0.01	0.7	<0.01	0.1	<0.1	<0.1	138.19	0.58	0.6	<0.1	0.2	15.3	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-22. Surface water metal(loid) concentrations (batch experiment – week 9).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	9	0.03	0.06	24.1	0.01	1.3	<0.1	0.4	0.16	0.03	2.7	0.2	<0.1	8.1	0.1
WC	2.5-10	None	9	0.08	0.07	20.5	0.02	2.1	<0.1	0.2	0.18	0.03	2.3	0.2	0.9	11.9	<0.1
WC	2.5-10	None	9	0.03	0.07	16.3	<0.01	1.0	<0.1	0.4	0.11	0.02	2.2	0.2	0.4	10.8	0.1
WC	2.5-10	None/Jarosite	9	0.07	0.01	0.1	0.04	0.8	42.5	<0.1	169.94	0.53	87.8	<0.1	<0.1	44.7	0.5
WC	2.5-10	None/Jarosite	9	0.10	0.03	<0.1	0.02	0.4	42.3	0.5	175.05	0.54	86.5	<0.1	<0.1	34.3	0.2
WC	2.5-10	None/Jarosite	9	0.03	1.32	2.6	0.08	1.2	46.2	<0.1	208.14	0.63	124.0	<0.1	0.5	56.7	0.1
WC	2.5-10	None/Schwert.	9	0.05	1.34	2.4	0.30	1.0	46.4	1.3	223.62	0.42	85.2	5.0	0.5	21.0	0.1
WC	2.5-10	None/Schwert.	9	0.05	1.54	1.0	0.19	0.4	45.5	1.4	232.67	0.41	85.9	6.8	0.9	17.9	0.1
WC	2.5-10	None/Schwert.	9	<0.01	1.32	0.5	0.23	<0.1	43.0	1.3	202.53	0.41	109.2	5.5	<0.1	21.4	<0.1
WC	2.5-10	Glucose	9	0.01	0.02	10.4	0.02	1.2	13.2	0.1	37.31	0.30	22.1	0.1	0.9	106.1	0.1
WC	2.5-10	Glucose	9	0.03	0.12	14.0	<0.01	0.6	10.5	<0.1	38.24	0.32	20.0	0.2	0.9	6.0	0.1
WC	2.5-10	Glucose	9	0.04	0.02	18.0	0.02	1.5	9.6	0.5	36.63	0.31	16.8	0.3	1.7	90.7	0.2
WC	2.5-10	Glucose/Jarosite	9	0.04	<0.01	1.0	0.01	0.4	<0.1	<0.1	636.84	1.02	0.9	<0.1	1.4	9.9	0.2
WC	2.5-10	Glucose/Jarosite	9	<0.01	0.11	4.7	0.13	0.5	34.7	<0.1	67.34	0.40	54.4	<0.1	0.9	41.5	0.1
WC	2.5-10	Glucose/Jarosite	9	0.05	<0.01	1.5	0.03	1.0	0.3	<0.1	894.30	1.07	1.5	0.1	0.5	11.6	<0.1
WC	2.5-10	Glucose/Schwert.	9	0.02	4.52	1.8	0.21	2.0	51.0	9.0	322.48	0.49	119.5	15.4	0.5	30.4	<0.1
WC	2.5-10	Glucose/Schwert.	9	0.05	4.61	2.0	0.26	1.2	49.3	8.6	294.91	0.46	113.9	15.2	<0.1	29.4	<0.1
WC	2.5-10	Glucose/Schwert.	9	<0.01	4.28	2.0	0.35	2.3	49.4	8.7	322.54	0.46	92.4	15.8	<0.1	28.6	0.2
WC	2.5-10	Acetate	9	<0.01	0.04	26.1	<0.01	0.8	<0.1	<0.1	0.25	0.04	1.9	0.1	1.4	6.5	<0.1
WC	2.5-10	Acetate	9	0.02	0.02	24.6	<0.01	0.6	<0.1	<0.1	0.16	0.04	1.5	<0.1	<0.1	2.9	0.1
WC	2.5-10	Acetate	9	0.17	0.02	26.9	<0.01	0.5	<0.1	<0.1	0.10	0.03	2.2	<0.1	1.4	6.4	0.4
WC	2.5-10	Acetate/Jarosite	9	0.14	0.05	0.2	0.09	0.7	39.9	<0.1	200.52	0.62	78.9	<0.1	0.9	36.9	0.2
WC	2.5-10	Acetate/Jarosite	9	0.06	0.05	0.6	0.06	1.3	43.5	<0.1	253.45	0.67	83.2	<0.1	<0.1	33.2	0.2
WC	2.5-10	Acetate/Jarosite	9	0.06	0.06	0.7	0.07	0.9	40.7	<0.1	212.23	0.62	104.1	<0.1	<0.1	33.4	<0.1
WC	2.5-10	Acetate/Schwert.	9	0.05	0.37	2.1	0.15	1.2	30.9	<0.1	369.30	0.36	100.9	3.3	<0.1	17.4	0.2
WC	2.5-10	Acetate/Schwert.	9	0.03	1.16	0.8	0.20	1.6	35.0	<0.1	346.33	0.38	93.4	6.2	0.5	13.1	<0.1
WC	2.5-10	Acetate/Schwert.	9	0.03	1.73	0.8	0.23	0.8	35.0	0.5	293.44	0.38	101.5	6.9	<0.1	18.0	0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-22 (continued). Surface water metal(loid) concentrations (batch experiment – week 9).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	9	0.05	0.62	27.8	0.03	2.7	2.3	5.6	10.22	0.18	10.5	5.4	1.8	246.5	<0.1
WC	2.5-10	Humic	9	0.01	0.31	22.9	0.05	1.6	2.2	3.9	7.80	0.13	10.3	4.3	<0.1	283.7	<0.1
WC	2.5-10	Humic	9	<0.01	0.69	22.9	0.01	2.2	1.9	3.8	9.92	0.17	9.9	3.8	<0.1	91.4	<0.1
WC	2.5-10	Humic/Jarosite	9	0.01	0.01	0.4	0.01	1.1	33.8	0.2	151.76	0.48	35.4	<0.1	0.9	7.5	<0.1
WC	2.5-10	Humic/Jarosite	9	0.03	0.01	0.3	0.01	1.3	31.5	0.7	121.03	0.43	40.7	<0.1	0.4	10.1	<0.1
WC	2.5-10	Humic/Jarosite	9	<0.01	0.01	0.2	0.02	0.6	30.2	<0.1	147.39	0.44	32.2	<0.1	<0.1	9.0	<0.1
WC	2.5-10	Humic/Schwert.	9	0.01	0.03	0.6	0.14	0.3	40.8	0.3	247.20	0.39	69.7	0.5	0.5	23.5	<0.1
WC	2.5-10	Humic/Schwert.	9	0.02	0.03	<0.1	0.16	0.9	40.5	<0.1	250.12	0.40	76.3	0.4	0.4	15.2	<0.1
WC	2.5-10	Humic/Schwert.	9	<0.01	0.04	0.5	0.17	1.9	42.8	0.2	248.20	0.40	75.0	0.4	<0.1	23.1	0.1
WC	2.5-10	Phragmites	9	<0.01	0.10	10.1	0.02	1.9	27.4	3.9	51.70	1.46	97.0	0.6	0.4	223.3	<0.1
WC	2.5-10	Phragmites	9	0.04	0.03	19.1	0.03	1.4	20.0	0.3	13.13	0.50	81.9	0.2	2.2	97.7	<0.1
WC	2.5-10	Phragmites	9	<0.01	0.10	11.1	0.01	0.8	26.6	0.9	48.99	1.43	70.9	0.5	0.9	178.7	<0.1
WC	2.5-10	Phragmites/Jarosite	9	<0.01	<0.01	9.3	0.04	0.2	1.2	<0.1	358.13	1.24	6.7	<0.1	<0.1	23.4	<0.1
WC	2.5-10	Phragmites/Jarosite	9	0.20	0.03	10.4	0.06	0.9	1.0	0.1	326.75	1.26	16.6	<0.1	<0.1	80.9	0.2
WC	2.5-10	Phragmites/Jarosite	9	0.09	<0.01	13.1	<0.01	1.4	1.2	<0.1	460.28	1.80	18.9	<0.1	<0.1	2.9	0.1
WC	2.5-10	Phragmites/Schwert.	9	0.10	<0.01	0.4	0.02	0.9	0.2	0.2	363.96	0.90	3.3	0.1	0.4	144.2	<0.1
WC	2.5-10	Phragmites/Schwert.	9	0.18	<0.01	<0.1	0.05	1.0	<0.1	<0.1	344.78	0.81	2.1	<0.1	0.4	89.7	<0.1
WC	2.5-10	Phragmites/Schwert.	9	0.06	<0.01	0.9	<0.01	0.8	0.2	0.3	258.59	0.90	2.8	<0.1	0.5	126.1	<0.1
WC	2.5-10	Schoenoplectus	9	0.03	0.08	9.1	<0.01	1.3	22.8	0.5	50.55	1.18	107.2	0.4	2.3	225.0	<0.1
WC	2.5-10	Schoenoplectus	9	<0.01	0.16	9.0	0.02	2.9	23.5	0.4	46.30	1.17	54.6	0.3	<0.1	130.6	<0.1
WC	2.5-10	Schoenoplectus	9	<0.01	0.11	9.5	0.01	3.0	20.5	0.2	48.95	1.25	40.8	0.3	0.5	98.2	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	9	0.02	0.01	4.7	0.03	0.2	1.0	<0.1	335.50	1.62	1.8	0.2	<0.1	4.1	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	9	<0.01	<0.01	4.8	0.03	0.8	0.9	<0.1	416.29	1.81	3.6	<0.1	0.5	4.4	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	9	0.03	0.02	6.2	0.01	1.3	0.4	<0.1	350.57	1.77	2.0	<0.1	<0.1	3.9	0.1
WC	2.5-10	Schoenoplectus/Schwert.	9	<0.01	<0.01	1.7	<0.01	1.5	<0.1	0.3	212.82	0.71	1.0	<0.1	<0.1	95.4	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	9	<0.01	<0.01	0.5	<0.01	0.6	<0.1	<0.1	163.88	0.48	0.7	<0.1	0.5	23.5	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	9	<0.01	<0.01	0.6	<0.01	0.7	<0.1	<0.1	262.29	0.67	1.2	<0.1	0.4	27.7	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-23. Surface water metal(loid) concentrations (batch experiment – week 12).

Site	Depth (cm)	Treatment	Week	Ag (µg/L)	Al (mg/L)	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Co (µg/L)	Cu (µg/L)	Fe (mg/L)	Mn (mg/L)	Ni (µg/L)	Pb (µg/L)	Se (µg/L)	Zn (µg/L)	Hg (µg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	None	12	0.05	0.10	25.6	<0.01	0.5	0.2	0.6	0.63	0.03	1.9	0.2	0.1	17.5	0.1
WC	2.5-10	None	12	0.04	0.08	23.6	<0.01	0.4	0.2	0.5	0.64	0.04	1.6	0.1	0.4	23.9	<0.1
WC	2.5-10	None	12	0.02	0.15	24.8	<0.01	0.3	0.2	0.4	0.47	0.03	1.6	0.1	0.1	9.6	<0.1
WC	2.5-10	None/Jarosite	12	0.03	<0.01	1.0	<0.01	<0.1	0.6	<0.1	210.64	0.65	0.4	<0.1	0.2	5.8	0.1
WC	2.5-10	None/Jarosite	12	0.03	<0.01	0.8	<0.01	0.3	24.3	<0.1	231.26	0.56	22.8	<0.1	0.1	9.3	<0.1
WC	2.5-10	None/Jarosite	12	0.03	<0.01	0.6	<0.01	0.2	34.2	0.1	150.73	0.44	79.9	<0.1	0.2	9.6	<0.1
WC	2.5-10	None/Schwert.	12	0.03	1.63	1.2	0.22	0.2	48.4	1.0	312.40	0.40	98.2	6.3	<0.1	14.8	<0.1
WC	2.5-10	None/Schwert.	12	0.02	1.58	1.4	0.22	0.5	48.9	1.1	309.92	0.40	90.8	6.2	0.1	25.0	<0.1
WC	2.5-10	None/Schwert.	12	0.02	1.79	1.4	0.28	0.3	51.1	1.2	321.57	0.46	106.7	6.1	0.2	13.9	<0.1
WC	2.5-10	Glucose	12	0.02	0.02	14.8	<0.01	0.4	6.8	0.6	35.13	0.29	11.3	0.4	0.3	150.8	<0.1
WC	2.5-10	Glucose	12	0.02	0.01	11.0	<0.01	0.5	2.1	0.6	31.44	0.26	3.4	0.2	0.4	133.2	<0.1
WC	2.5-10	Glucose	12	0.02	0.05	8.3	<0.01	0.5	5.6	0.7	37.73	0.28	9.0	0.3	0.3	153.4	<0.1
WC	2.5-10	Glucose/Jarosite	12	0.02	<0.01	0.6	0.01	0.2	0.4	<0.1	1292.90	1.18	1.7	<0.1	<0.1	66.5	0.1
WC	2.5-10	Glucose/Jarosite	12	0.01	<0.01	0.4	0.02	0.2	0.1	<0.1	842.58	1.06	1.4	<0.1	0.2	38.2	<0.1
WC	2.5-10	Glucose/Jarosite	12	0.01	<0.01	0.7	0.02	0.2	0.6	<0.1	1321.74	1.23	3.1	<0.1	0.1	5.4	<0.1
WC	2.5-10	Glucose/Schwert.	12	0.01	0.61	2.9	0.22	3.0	53.6	11.1	455.45	0.47	101.9	20.9	0.2	142.8	<0.1
WC	2.5-10	Glucose/Schwert.	12	0.01	0.62	2.9	0.23	2.5	50.2	12.3	424.46	0.53	115.2	17.5	0.4	125.5	<0.1
WC	2.5-10	Glucose/Schwert.	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Acetate	12	<0.01	0.10	24.0	<0.01	0.5	0.4	0.8	0.22	<0.01	2.8	0.2	0.6	9.5	<0.1
WC	2.5-10	Acetate	12	<0.01	0.06	23.1	<0.01	0.6	0.4	0.9	0.13	0.01	2.8	0.2	0.4	11.4	<0.1
WC	2.5-10	Acetate	12	0.03	0.06	23.3	<0.01	0.4	0.5	0.7	0.12	<0.01	2.5	0.2	0.3	10.6	<0.1
WC	2.5-10	Acetate/Jarosite	12	0.02	0.06	1.0	0.03	0.2	37.8	0.2	300.43	0.71	67.1	<0.1	0.3	110.3	<0.1
WC	2.5-10	Acetate/Jarosite	12	0.08	<0.01	1.9	0.01	<0.1	8.4	0.1	1561.60	1.38	23.0	0.2	1.3	79.8	<0.1
WC	2.5-10	Acetate/Jarosite	12	0.07	<0.01	1.2	0.12	<0.1	0.1	0.6	1180.33	1.27	0.9	0.1	1.5	53.5	<0.1
WC	2.5-10	Acetate/Schwert.	12	0.01	0.29	2.0	0.20	0.9	36.4	3.8	322.32	0.37	81.0	10.2	0.3	110.9	<0.1
WC	2.5-10	Acetate/Schwert.	12	0.01	0.95	1.1	0.12	0.4	40.0	0.4	404.48	0.42	114.4	3.8	0.2	93.8	<0.1
WC	2.5-10	Acetate/Schwert.	12	0.01	0.98	0.9	0.11	0.3	36.4	0.2	396.26	0.40	93.7	4.6	0.3	12.7	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-23 (continued). Surface water metal(loid) concentrations (batch experiment – week 12).

Site	Depth (cm)	Treatment	Week	Ag (μg/L)	Al (mg/L)	As (μg/L)	Cd (μg/L)	Cr (μg/L)	Co (μg/L)	Cu (μg/L)	Fe (mg/L)	Mn (mg/L)	Ni (μg/L)	Pb (μg/L)	Se (μg/L)	Zn (μg/L)	Hg (μg/L)
ANZECC WQG[#]				0.05	0.055[A]	13[B]	0.2	1.0[C]	1.4	1.4	0.3	1.9	11	3.4	11	8.0	0.6
WC	2.5-10	Humic	12	0.10	0.05	30.4	0.11	1.3	4.1	12.7	13.68	0.19	16.6	8.9	0.5	354.1	0.1
WC	2.5-10	Humic	12	0.30	0.03	25.4	0.10	1.1	2.7	6.8	10.45	0.15	11.5	5.0	0.9	221.4	<0.1
WC	2.5-10	Humic	12	0.54	0.04	32.0	0.10	1.5	3.4	16.7	13.26	0.18	17.5	9.9	0.4	439.9	<0.1
WC	2.5-10	Humic/Jarosite	12	0.02	<0.01	0.4	<0.01	0.2	0.9	0.1	423.29	0.60	1.3	<0.1	0.4	82.4	<0.1
WC	2.5-10	Humic/Jarosite	12	<0.01	<0.01	0.5	<0.01	0.1	0.9	<0.1	451.80	0.66	0.8	<0.1	0.2	4.5	<0.1
WC	2.5-10	Humic/Jarosite	12	<0.01	<0.01	0.6	<0.01	0.2	0.9	<0.1	459.49	0.62	1.3	<0.1	<0.1	47.7	<0.1
WC	2.5-10	Humic/Schwert.	12	0.02	0.03	0.3	0.06	0.2	36.6	0.1	444.87	0.42	49.1	0.3	0.1	12.7	<0.1
WC	2.5-10	Humic/Schwert.	12	0.01	<0.01	0.4	0.03	0.2	41.6	0.1	397.49	0.41	72.0	0.2	0.1	10.8	<0.1
WC	2.5-10	Humic/Schwert.	12	0.02	0.02	0.2	0.02	0.2	37.1	0.1	366.74	0.42	54.9	0.3	0.2	9.7	<0.1
WC	2.5-10	Phragmites	12	0.05	<0.01	10.5	0.03	0.9	17.7	1.7	18.26	0.43	84.7	0.3	1.2	176.5	0.1
WC	2.5-10	Phragmites	12	0.04	0.01	11.2	0.04	1.1	25.2	1.4	54.89	1.53	78.3	0.7	0.7	306.3	0.2
WC	2.5-10	Phragmites	12	0.04	<0.01	16.2	0.05	0.7	17.0	0.7	9.23	0.41	110.6	0.2	2.2	74.9	<0.1
WC	2.5-10	Phragmites/Jarosite	12	0.02	<0.01	7.3	0.04	0.2	1.1	0.6	60.81	0.63	10.8	<0.1	0.2	76.7	0.1
WC	2.5-10	Phragmites/Jarosite	12	0.12	<0.01	14.0	0.10	0.2	1.3	0.5	77.71	0.55	8.8	0.2	0.2	64.4	0.4
WC	2.5-10	Phragmites/Jarosite	12	0.14	<0.01	11.2	<0.01	<0.1	1.3	0.3	80.75	0.63	8.4	<0.1	<0.1	53.7	0.2
WC	2.5-10	Phragmites/Schwert.	12	0.12	<0.01	1.9	<0.01	<0.1	0.2	0.6	86.97	0.42	2.2	<0.1	1.0	111.9	<0.1
WC	2.5-10	Phragmites/Schwert.	12	0.10	<0.01	1.0	0.01	<0.1	<0.1	0.5	30.21	0.06	1.2	<0.1	<0.1	102.5	<0.1
WC	2.5-10	Phragmites/Schwert.	12	0.08	<0.01	0.3	<0.01	<0.1	0.2	0.7	231.69	0.58	2.0	0.1	0.2	139.9	<0.1
WC	2.5-10	Schoenoplectus	12	0.10	<0.01	14.1	0.05	0.8	9.9	0.8	30.16	0.91	26.4	0.2	0.4	145.1	<0.1
WC	2.5-10	Schoenoplectus	12	0.08	<0.01	14.1	0.07	0.4	6.9	1.0	21.37	0.72	28.3	0.3	1.0	144.6	<0.1
WC	2.5-10	Schoenoplectus	12	0.09	<0.01	9.4	<0.01	0.7	15.9	1.1	50.77	1.23	61.4	0.5	0.9	316.6	<0.1
WC	2.5-10	Schoenoplectus/Jarosite	12	0.04	<0.01	7.7	<0.01	0.2	2.1	0.2	563.04	1.89	1.7	<0.1	1.1	52.4	0.2
WC	2.5-10	Schoenoplectus/Jarosite	12	0.07	<0.01	6.7	0.06	<0.1	0.1	<0.1	573.71	1.84	1.4	<0.1	0.2	55.0	0.1
WC	2.5-10	Schoenoplectus/Jarosite	12	0.01	<0.01	3.4	<0.01	0.3	0.2	<0.1	717.30	1.77	0.9	<0.1	0.1	49.6	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	12	0.02	<0.01	1.3	<0.01	0.3	<0.1	0.5	403.04	0.50	0.2	<0.1	<0.1	115.6	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	12	0.02	0.01	1.2	<0.01	0.3	<0.1	0.7	301.84	0.26	0.4	<0.1	0.2	88.1	<0.1
WC	2.5-10	Schoenoplectus/Schwert.	12	0.02	<0.01	1.5	<0.01	0.2	<0.1	0.4	244.39	0.22	0.3	<0.1	0.1	95.1	<0.1

[#] *ANZECC water quality guidelines (WQG) – trigger values (without hardness corrections) for 95% freshwater ecosystem protection (ANZECC/ARMCANZ 2000).*

[A] *Guideline for Al in freshwater where pH > 6.5.*

[B] *Guideline assumes As in solution as AsV.*

[C] *Guideline for Cr is applicable to CrVI only.*

Table 8-24. Surface water fluorescence intensities (batch experiment – Day 0).

Site	Depth (cm)	Treatment	Day	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	0	142.73	76.92	228.58	1039.22	0.01	0.00	0.01	0.06
WC	2.5-10	None/Jarosite	0	97.55	47.94	246.21	1223.68	0.01	0.00	0.01	0.07
WC	2.5-10	None/Schwert.	0	134.55	70.71	259.34	1098.75	0.01	0.00	0.02	0.07
WC	2.5-10	Glucose	0	142.95	78.98	224.58	1118.35	0.01	0.01	0.02	0.08
WC	2.5-10	Glucose/Jarosite	0	106.56	56.28	238.02	1154.57	0.01	0.00	0.02	0.07
WC	2.5-10	Glucose/Schwert.	0	108.10	56.60	244.67	1199.56	0.01	0.00	0.01	0.07
WC	2.5-10	Acetate	0	176.10	92.16	220.28	1105.28	0.01	0.01	0.02	0.09
WC	2.5-10	Acetate/Jarosite	0	139.21	79.72	242.77	887.12	0.01	0.01	0.02	0.07
WC	2.5-10	Acetate/Schwert.	0	139.12	73.14	245.42	1002.68	0.01	0.00	0.02	0.06
WC	2.5-10	Humic	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	0	34439.47	0.00	0.00	0.00	0.01	0.00	0.00	0.00
WC	2.5-10	Humic/Schwert.	0	22618.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Phragmites	0	8122.16	16123.89	59082.32	0.00	0.00	0.00	0.01	0.00
WC	2.5-10	Phragmites/Jarosite	0	8165.38	15714.33	58121.64	0.00	0.00	0.00	0.01	0.00
WC	2.5-10	Phragmites/Schwert.	0	8224.85	16358.93	59038.71	4334.66	0.00	0.01	0.02	0.00
WC	2.5-10	Schoenoplectus	0	4056.05	5764.89	22882.40	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Schoenoplectus/Jarosite	0	4758.77	6472.62	23978.61	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Schoenoplectus/Schwert.	0	4480.48	6448.65	21888.90	0.00	0.00	0.00	0.01	0.00

Table 8-25. Surface water fluorescence intensities (batch experiment – Day 2).

Site	Depth (cm)	Treatment	Day	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	2	185.25	105.46	95.41	432.18	0.08	0.04	0.04	0.18
WC	2.5-10	None/Jarosite	2	117.86	62.00	80.06	434.49	0.05	0.02	0.03	0.17
WC	2.5-10	None/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Glucose	2	336.85	150.54	130.82	585.48	0.08	0.04	0.03	0.14
WC	2.5-10	Glucose/Jarosite	2	119.86	68.04	74.46	325.68	0.05	0.03	0.03	0.12
WC	2.5-10	Glucose/Schwert.	2	93.38	48.79	70.81	370.08	0.03	0.02	0.03	0.13
WC	2.5-10	Acetate	2	303.27	169.91	121.10	503.35	0.09	0.05	0.04	0.15
WC	2.5-10	Acetate/Jarosite	2	179.31	93.85	93.61	440.52	0.04	0.02	0.02	0.10
WC	2.5-10	Acetate/Schwert.	2	111.34	63.99	79.88	424.09	0.03	0.02	0.02	0.12
WC	2.5-10	Humic	2	7728.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	2	5734.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Schwert.	2	328.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Phragmites	2	17133.66	16841.34	68509.01	30768.74	0.02	0.02	0.09	0.04
WC	2.5-10	Phragmites/Jarosite	2	15929.86	15995.33	65255.38	28194.58	0.03	0.03	0.10	0.05
WC	2.5-10	Phragmites/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WC	2.5-10	Schoenoplectus	2	7450.98	6954.58	28427.61	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Schoenoplectus/Jarosite	2	4911.31	6337.58	29443.30	0.00	0.00	0.00	0.01	0.00
WC	2.5-10	Schoenoplectus/Schwert.	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 8-26. Surface water fluorescence intensities (batch experiment – Week 1).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	1	377.92	203.79	146.97	468.82	0.20	0.11	0.08	0.25
WC	2.5-10	None/Jarosite	1	132.62	81.49	284.16	1191.28	0.01	0.00	0.02	0.07
WC	2.5-10	None/Schwert.	1	129.04	63.24	230.30	1022.86	0.01	0.00	0.02	0.08
WC	2.5-10	Glucose	1	1015.44	458.00	659.46	1501.78	0.17	0.08	0.11	0.25
WC	2.5-10	Glucose/Jarosite	1	282.85	133.86	433.80	1425.51	0.02	0.01	0.03	0.10
WC	2.5-10	Glucose/Schwert.	1	160.81	73.00	326.02	1128.43	0.01	0.01	0.02	0.08
WC	2.5-10	Acetate	1	1476.76	510.47	1449.68	3020.19	0.17	0.06	0.17	0.36
WC	2.5-10	Acetate/Jarosite	1	274.53	191.66	281.33	1088.17	0.02	0.01	0.02	0.07
WC	2.5-10	Acetate/Schwert.	1	144.86	81.26	245.90	997.61	0.01	0.01	0.02	0.07
WC	2.5-10	Humic	1	7379.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Schwert.	1	6416.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Phragmites	1	17197.37	15825.83	66698.49	37487.82	0.03	0.03	0.13	0.07
WC	2.5-10	Phragmites/Jarosite	1	18176.53	15487.92	53847.12	43715.16	0.03	0.03	0.09	0.08
WC	2.5-10	Phragmites/Schwert.	1	16588.27	8080.53	44489.10	71943.74	0.08	0.04	0.21	0.34
WC	2.5-10	Schoenoplectus	1	8460.09	5485.19	28937.25	18068.56	0.01	0.01	0.04	0.02
WC	2.5-10	Schoenoplectus/Jarosite	1	6780.96	4482.71	26228.35	18845.08	0.01	0.01	0.04	0.03
WC	2.5-10	Schoenoplectus/Schwert.	1	4625.13	2229.03	13101.62	25786.75	0.02	0.01	0.07	0.14

Table 8-27. Surface water fluorescence intensities (batch experiment – Week 2).

Site	Depth (cm)	Treatment	Day	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	14	1143.27	619.21	389.38	1140.86	0.29	0.16	0.10	0.29
WC	2.5-10	None/Jarosite	14	162.35	90.22	266.21	1033.83	0.01	0.01	0.02	0.07
WC	2.5-10	None/Schwert.	14	119.50	64.06	259.45	1215.56	0.01	0.00	0.02	0.08
WC	2.5-10	Glucose	15	1045.95	509.17	511.03	1116.83	0.28	0.13	0.13	0.29
WC	2.5-10	Glucose/Jarosite	15	242.36	123.88	392.93	1399.23	0.01	0.01	0.02	0.08
WC	2.5-10	Glucose/Schwert.	15	191.84	87.82	401.83	1521.35	0.01	0.01	0.03	0.09
WC	2.5-10	Acetate	15	1286.12	603.07	757.15	1767.66	0.11	0.05	0.07	0.15
WC	2.5-10	Acetate/Jarosite	15	273.91	129.01	500.82	1562.92	0.02	0.01	0.03	0.09
WC	2.5-10	Acetate/Schwert.	15	118.97	63.45	67.97	275.74	0.07	0.04	0.04	0.15
WC	2.5-10	Humic	15	991.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	15	4003.46	644.95	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Schwert.	15	4409.19	120.22	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Phragmites	14	17253.19	15705.33	58868.33	41250.87	0.03	0.03	0.11	0.07
WC	2.5-10	Phragmites/Jarosite	14	8374.70	8284.37	36065.79	19259.98	0.01	0.01	0.06	0.03
WC	2.5-10	Phragmites/Schwert.	14	13440.73	5789.27	46289.90	40546.64	0.05	0.02	0.19	0.17
WC	2.5-10	Schoenoplectus	14	6934.05	4868.94	18276.57	15165.05	0.01	0.01	0.04	0.03
WC	2.5-10	Schoenoplectus/Jarosite	14	4394.69	2680.65	12476.91	20431.73	0.00	0.00	0.01	0.01
WC	2.5-10	Schoenoplectus/Schwert.	14	3910.77	1634.33	7293.45	13829.15	0.02	0.01	0.03	0.05

Table 8-28. Surface water fluorescence intensities (batch experiment – Week 4).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	4	1308.02	692.23	463.12	1582.67	0.08	0.04	0.03	0.10
WC	2.5-10	None/Jarosite	4	144.46	78.50	209.61	1061.44	0.01	0.01	0.01	0.07
WC	2.5-10	None/Schwert.	4	112.46	57.42	220.63	1309.12	0.01	0.00	0.02	0.09
WC	2.5-10	Glucose	4	1045.63	484.53	830.27	2296.46	0.06	0.03	0.04	0.12
WC	2.5-10	Glucose/Jarosite	4	263.92	118.44	367.01	1369.38	0.02	0.01	0.02	0.09
WC	2.5-10	Glucose/Schwert.	4	176.33	73.48	208.98	971.07	0.05	0.02	0.06	0.28
WC	2.5-10	Acetate	4	3328.17	986.99	4615.92	9133.87	0.16	0.05	0.22	0.44
WC	2.5-10	Acetate/Jarosite	4	198.48	103.01	150.64	695.77	0.05	0.03	0.04	0.18
WC	2.5-10	Acetate/Schwert.	4	173.67	88.05	270.16	1442.04	0.01	0.01	0.02	0.10
WC	2.5-10	Humic	4	0.00	0.00	0.00	45688.66	0.00	0.00	0.00	0.01
WC	2.5-10	Humic/Jarosite	4	1739.13	1235.18	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Schwert.	4	518.11	208.49	361.97	1639.24	0.01	0.01	0.01	0.04
WC	2.5-10	Phragmites	4	22946.34	16333.32	72932.58	69888.48	0.00	0.00	0.01	0.08
WC	2.5-10	Phragmites/Jarosite	4	13280.19	6528.85	32828.50	36131.90	0.03	0.01	0.07	0.08
WC	2.5-10	Phragmites/Schwert.	4	29862.11	8541.20	44256.24	64896.63	0.08	0.02	0.12	0.17
WC	2.5-10	Schoenoplectus	4	10991.27	5325.21	22977.94	28760.45	0.03	0.01	0.06	0.08
WC	2.5-10	Schoenoplectus/Jarosite	4	5826.74	2547.70	11229.70	15499.10	0.02	0.01	0.04	0.05
WC	2.5-10	Schoenoplectus/Schwert.	4	4255.14	1779.54	8407.60	17533.81	0.01	0.01	0.03	0.05

Table 8-29. Surface water fluorescence intensities (batch experiment – Week 6).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	6	1762.78	949.81	635.22	1833.23	0.10	0.05	0.04	0.11
WC	2.5-10	None/Jarosite	6	136.14	86.14	89.09	291.86	0.08	0.05	0.05	0.18
WC	2.5-10	None/Schwert.	6	119.30	47.73	87.13	495.55	0.07	0.03	0.05	0.29
WC	2.5-10	Glucose	6	2292.84	573.39	3968.77	7068.97	0.13	0.03	0.23	0.41
WC	2.5-10	Glucose/Jarosite	6	184.19	110.12	143.41	375.73	0.06	0.04	0.05	0.13
WC	2.5-10	Glucose/Schwert.	6	170.01	70.25	174.15	1013.94	0.07	0.03	0.07	0.41
WC	2.5-10	Acetate	6	2443.17	1193.44	1109.52	2359.41	0.33	0.16	0.15	0.32
WC	2.5-10	Acetate/Jarosite	6	173.94	99.99	107.04	373.07	0.09	0.05	0.05	0.18
WC	2.5-10	Acetate/Schwert.	6	130.03	72.60	112.83	538.55	0.07	0.04	0.06	0.27
WC	2.5-10	Humic	6	16998.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	6	1108.86	655.51	301.34	596.34	0.37	0.22	0.10	0.20
WC	2.5-10	Humic/Schwert.	6	281.79	165.61	344.80	1344.59	0.02	0.01	0.02	0.08
WC	2.5-10	Phragmites	6	27012.49	17918.69	82486.38	51928.54	0.07	0.04	0.20	0.13
WC	2.5-10	Phragmites/Jarosite	6	19869.49	7949.52	23363.40	45258.66	0.06	0.02	0.07	0.13
WC	2.5-10	Phragmites/Schwert.	6	25027.56	8697.04	21745.47	22432.30	0.12	0.04	0.11	0.11
WC	2.5-10	Schoenoplectus	6	10990.59	5178.66	21015.12	30018.68	0.02	0.01	0.03	0.04
WC	2.5-10	Schoenoplectus/Jarosite	6	5614.14	2233.38	9367.76	17825.73	0.04	0.01	0.06	0.11
WC	2.5-10	Schoenoplectus/Schwert.	6	5321.68	2126.73	8173.45	16220.26	0.02	0.01	0.03	0.06

Table 8-30. Surface water fluorescence intensities (batch experiment – Week 9).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	9	2336.74	1236.09	904.35	2404.90	0.11	0.06	0.04	0.11
WC	2.5-10	None/Jarosite	9	160.55	88.63	100.35	290.65	0.08	0.04	0.05	0.14
WC	2.5-10	None/Schwert.	9	137.64	52.57	135.19	869.91	0.08	0.03	0.08	0.48
WC	2.5-10	Glucose	9	1870.76	597.86	2581.69	5130.23	0.09	0.03	0.12	0.24
WC	2.5-10	Glucose/Jarosite	9	165.28	93.79	121.79	396.31	0.08	0.04	0.06	0.19
WC	2.5-10	Glucose/Schwert.	9	213.46	74.83	186.35	1183.88	0.06	0.02	0.05	0.31
WC	2.5-10	Acetate	9	2446.75	1217.69	1080.04	2313.11	0.31	0.16	0.14	0.30
WC	2.5-10	Acetate/Jarosite	9	156.52	100.85	126.61	424.66	0.09	0.06	0.07	0.23
WC	2.5-10	Acetate/Schwert.	9	188.16	92.71	144.66	687.85	0.07	0.03	0.05	0.26
WC	2.5-10	Humic	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	9	940.03	538.41	316.89	704.54	0.37	0.21	0.12	0.27
WC	2.5-10	Humic/Schwert.	9	206.57	126.55	118.66	409.28	0.13	0.08	0.08	0.26
WC	2.5-10	Phragmites	9	17084.60	15336.40	60854.11	34357.70	0.03	0.02	0.09	0.05
WC	2.5-10	Phragmites/Jarosite	9	20804.36	8261.29	24408.97	45270.66	0.05	0.02	0.05	0.10
WC	2.5-10	Phragmites/Schwert.	9	22561.21	7971.56	16577.98	23938.46	0.07	0.03	0.05	0.08
WC	2.5-10	Schoenoplectus	9	9062.32	4803.86	20068.67	23023.20	0.01	0.01	0.02	0.03
WC	2.5-10	Schoenoplectus/Jarosite	9	4258.55	2180.05	6541.06	11235.64	0.06	0.03	0.10	0.17
WC	2.5-10	Schoenoplectus/Schwert.	9	5377.49	1995.35	9133.84	19535.11	0.01	0.00	0.02	0.04

Table 8-31. Surface water fluorescence intensities (batch experiment – Week 12).

Site	Depth (cm)	Treatment	Week	Measured Data				Normalised Data			
				Peak A	Peak C	Peak T_1	Peak T_2	Peak A	Peak C	Peak T_1	Peak T_2
WC	2.5-10	None	12	2424.40	1271.20	835.21	2158.78	0.35	0.18	0.12	0.31
WC	2.5-10	None/Jarosite	12	168.06	94.30	106.26	301.96	0.09	0.05	0.06	0.16
WC	2.5-10	None/Schwert.	12	151.58	54.76	154.54	1074.78	0.08	0.03	0.08	0.54
WC	2.5-10	Glucose	12	1465.55	528.87	1865.00	3558.45	0.11	0.04	0.15	0.28
WC	2.5-10	Glucose/Jarosite	12	360.19	137.81	585.35	1743.58	0.02	0.01	0.04	0.11
WC	2.5-10	Glucose/Schwert.	12	287.09	117.69	415.92	2242.61	0.02	0.01	0.03	0.14
WC	2.5-10	Acetate	12	3444.15	1685.91	1616.80	3831.39	0.17	0.08	0.08	0.19
WC	2.5-10	Acetate/Jarosite	12	231.50	119.37	313.64	1201.12	0.02	0.01	0.02	0.08
WC	2.5-10	Acetate/Schwert.	12	249.45	106.71	373.65	1911.40	0.02	0.01	0.02	0.12
WC	2.5-10	Humic	12	30592.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WC	2.5-10	Humic/Jarosite	12	706.78	397.83	450.09	1313.15	0.05	0.03	0.03	0.09
WC	2.5-10	Humic/Schwert.	12	253.25	146.68	137.79	424.68	0.14	0.08	0.08	0.24
WC	2.5-10	Phragmites	12	15203.88	16328.71	68319.22	16159.66	0.02	0.02	0.08	0.02
WC	2.5-10	Phragmites/Jarosite	12	19892.78	7736.68	20354.36	36858.62	0.06	0.02	0.06	0.11
WC	2.5-10	Phragmites/Schwert.	12	27680.11	9264.99	24103.04	45922.91	0.01	0.00	0.01	0.01
WC	2.5-10	Schoenoplectus	12	7600.66	5057.82	15922.02	11962.74	0.01	0.00	0.01	0.01
WC	2.5-10	Schoenoplectus/Jarosite	12	4877.02	2011.81	8634.70	16093.48	0.04	0.02	0.07	0.14
WC	2.5-10	Schoenoplectus/Schwert.	12	4312.82	1763.64	8261.39	14016.37	0.02	0.01	0.03	0.05

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APPENDIX 4. Characteristics of sediments (mesocosm experiment)

Table 8-32. Characteristics of the Tolderol and Waltowa soil materials (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Moisture Content (%)	pH_{KCl}	TAA (mol H^+ t^{-1})	ANC (% $CaCO_3$)	Retained acidity (mol H^+ t^{-1})	Pyritic Sulfur (%S)	Elemental Sulfur (%S)	Acid Volatile Sulfide (%S_{AV})	Net acidity (mol H^+ t^{-1})*	Total N (%N)	Total C (%C)	Total Organic C (%C)	Hydrolysable Organic C (%C)
TS	0-2.5	None	0	20.52	5.74	2.9	0.0	0.0	<0.01	<0.001	<0.01	2.9	0.07	0.22	0.20	0.07
		None	0	20.63	5.68	2.9	0.0	0.0	<0.01	<0.001	<0.01	2.9	0.05	0.21	0.20	0.07
		Phragmites	0	27.72	5.98	2.5	0.0	0.0	<0.01	n.a.	<0.01	2.5	0.08	1.56	1.45	1.01
		Phragmites	0	24.81	5.69	2.9	0.0	0.0	<0.01	<0.001	<0.01	2.9	0.08	1.57	1.26	0.16
		Schoenoplectus	0	27.05	5.66	2.9	0.0	0.0	<0.01	<0.001	<0.01	2.9	0.07	1.44	1.27	0.60
		Schoenoplectus	0	26.88	5.51	3.4	0.0	0.0	<0.01	n.a.	<0.01	3.4	0.07	1.48	1.40	0.93
	2.5-10	None	0	21.16	4.77	5.9	0.0	0.0	<0.01	0.002	<0.01	7.1	0.05	0.21	0.19	0.05
		None	0	20.88	4.79	6.2	0.0	0.0	<0.01	<0.001	<0.01	6.2	0.05	0.19	0.18	0.04
		Phragmites	0	25.09	5.11	4.9	0.0	0.0	<0.01	<0.001	<0.01	4.9	0.08	1.58	1.47	0.83
		Phragmites	0	25.62	5.07	5.3	0.0	0.0	<0.01	<0.001	<0.01	5.3	0.09	1.76	1.60	0.95
		Schoenoplectus	0	26.79	4.96	5.4	0.0	0.0	<0.01	<0.001	<0.01	5.4	0.07	1.55	1.51	1.05
		Schoenoplectus	0	26.49	4.90	5.8	0.0	0.0	<0.01	<0.001	<0.01	5.8	0.07	1.68	1.52	1.01
WC	0-2.5	None	0	18.22	6.44	0.5	0.0	0.0	<0.01	0.001	<0.01	1.2	0.05	0.21	0.12	0.00
		None	0	18.17	6.63	0.0	0.0	0.0	<0.01	0.001	<0.01	0.8	0.05	0.22	0.15	0.02
		Phragmites	0	25.84	6.33	1.5	0.0	0.0	<0.01	0.004	<0.01	4.2	0.09	1.55	1.44	0.88
		Phragmites	0	24.65	6.49	0.5	0.0	0.0	<0.01	<0.001	<0.01	0.5	0.08	1.56	1.33	0.98
		Schoenoplectus	0	24.73	6.48	0.5	0.0	0.0	<0.01	<0.001	<0.01	0.5	0.07	1.43	1.31	0.97
		Schoenoplectus	0	24.48	6.31	1.4	0.0	0.0	<0.01	0.001	<0.01	2.3	0.08	1.63	1.51	0.91
	2.5-10	None	0	18.98	5.61	2.5	0.0	0.0	<0.01	0.002	<0.01	3.7	0.05	0.20	0.20	0.06
		None	0	18.23	5.88	1.9	0.0	0.0	<0.01	0.002	<0.01	2.9	0.07	0.18	0.17	0.03
		Phragmites	0	21.72	5.67	2.5	0.0	0.0	<0.01	0.001	<0.01	3.2	0.08	1.72	1.56	1.09
		Phragmites	0	22.82	5.89	2.9	0.0	0.0	<0.01	0.001	<0.01	3.8	0.08	1.65	1.64	1.07
		Schoenoplectus	0	24.14	5.69	2.5	0.0	0.0	<0.01	0.002	<0.01	3.5	0.06	1.47	1.33	0.80
		Schoenoplectus	0	24.35	5.56	2.9	0.0	0.0	<0.01	0.001	<0.01	3.8	0.06	1.34	1.26	0.69
TS	0-2.5	None	4	-	5.83	2.0	0.0	0.0	-	-	-	2.0	0.05	0.21	0.21	0.07
		None	4	-	5.53	2.9	0.0	0.0	-	-	-	2.9	0.05	0.18	0.18	0.04
		Phragmites	4	-	5.62	2.9	0.0	0.0	-	-	-	2.9	0.08	1.70	1.63	0.86
		Phragmites	4	-	5.50	3.4	0.0	0.0	-	-	-	3.4	0.09	1.70	1.52	0.78
		Schoenoplectus	4	-	5.19	4.9	0.0	0.0	-	-	-	4.9	0.08	1.73	1.61	0.58
		Schoenoplectus	4	-	5.37	4.3	0.0	0.0	-	-	-	4.3	0.08	1.69	1.59	0.83
	2.5-10	None	4	-	4.74	6.4	0.0	0.0	-	-	-	6.4	0.06	0.21	0.21	0.05
		None	4	-	4.94	5.3	0.0	0.0	-	-	-	5.3	0.05	0.19	0.17	0.02
		Phragmites	4	-	5.40	3.9	0.0	0.0	-	-	-	3.9	0.10	1.87	1.75	1.35
		Phragmites	4	-	5.51	3.8	0.0	0.0	-	-	-	3.8	0.09	1.82	1.73	0.54
		Schoenoplectus	4	-	5.18	5.4	0.0	0.0	-	-	-	5.4	0.08	1.77	1.71	0.88
		Schoenoplectus	4	-	5.21	4.8	0.0	0.0	-	-	-	4.8	0.08	1.69	1.64	0.99

** Net acidity in italics assumes RIS content of <0.01% S*

Table 8-32 (continued). Characteristics of the Tolderol and Waltowa soil materials (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Moisture Content (%)	pH_{KCl}	TAA (mol H^+ t^{-1})	ANC (% $CaCO_3$)	Retained acidity (mol H^+ t^{-1})	Pyritic Sulfur (%S)	Elemental Sulfur (%S)	Acid Volatile Sulfide (%S_{AV})	Net acidity (mol H^+ t^{-1})*	Total N (%N)	Total C (%C)	Total Organic C (%C)	Hydrolysable Organic C (%C)
WC	0-2.5	None	4	-	6.27	1.5	0.0	0.0	-	-	-	1.5	0.06	0.22	0.15	0.00
		None	4	-	6.45	0.5	0.0	0.0	-	-	-	0.5	0.05	0.19	0.12	0.00
		Phragmites	4	-	5.81	2.5	0.0	0.0	-	-	-	2.5	0.09	1.66	1.55	0.92
		Phragmites	4	-	5.61	2.9	0.0	0.0	-	-	-	2.9	0.10	1.75	1.53	0.56
		Schoenoplectus	4	-	5.47	3.4	0.0	0.0	-	-	-	3.4	0.09	1.81	1.63	1.20
		Schoenoplectus	4	-	5.50	5.3	0.0	0.0	-	-	-	5.3	0.08	1.69	1.69	1.10
	2.5-10	None	4	-	6.00	2.0	0.0	0.0	-	-	-	2.0	0.05	0.18	0.18	0.05
		None	4	-	5.92	2.9	0.0	0.0	-	-	-	2.9	0.05	0.18	0.17	0.04
		Phragmites	4	-	5.72	2.5	0.0	0.0	-	-	-	2.5	0.09	1.67	1.67	0.93
		Phragmites	4	-	5.54	3.8	0.0	0.0	-	-	-	3.8	0.09	1.78	1.59	0.76
		Schoenoplectus	4	-	5.31	3.9	0.0	0.0	-	-	-	3.9	0.08	1.74	1.65	1.26
		Schoenoplectus	4	-	5.44	0.6	0.0	0.0	-	-	-	0.6	0.08	1.74	1.64	1.00
TS	0-2.5	None	8	-	5.78	2.0	0.0	0.0	-	-	-	2.0	0.05	0.19	0.13	0.00
		None	8	-	5.81	2.9	0.0	0.0	-	-	-	2.9	0.05	0.18	0.12	0.00
		Phragmites	8	-	6.41	1.5	0.0	0.0	-	-	-	1.5	0.10	1.46	1.46	0.82
		Phragmites	8	-	6.27	2.4	0.0	0.0	-	-	-	2.4	0.09	1.68	1.52	0.82
		Schoenoplectus	8	-	5.83	2.9	0.0	0.0	-	-	-	2.9	0.08	1.69	1.57	0.82
		Schoenoplectus	8	-	5.92	3.8	0.0	0.0	-	-	-	3.8	0.08	1.58	1.57	1.15
	2.5-10	None	8	-	4.88	5.4	0.0	0.0	-	-	-	5.4	0.05	0.20	0.15	0.00
		None	8	-	4.90	0.5	0.0	0.0	-	-	-	0.5	0.05	0.19	0.14	0.00
		Phragmites	8	-	5.44	3.9	0.0	0.0	-	-	-	3.9	0.09	1.55	1.55	0.99
		Phragmites	8	-	5.38	5.3	0.0	0.0	-	-	-	5.3	0.09	1.64	1.61	0.85
		Schoenoplectus	8	-	5.13	5.4	0.0	0.0	-	-	-	5.4	0.07	1.68	1.55	0.80
		Schoenoplectus	8	-	5.18	6.2	0.0	0.0	-	-	-	6.2	0.07	1.70	1.62	0.96
WC	0-2.5	None	8	-	6.49	0.5	0.0	0.0	-	-	-	0.5	0.05	0.21	0.12	0.00
		None	8	-	6.33	1.4	0.0	0.0	-	-	-	1.4	0.05	0.19	0.17	0.05
		Phragmites	8	-	6.08	1.5	0.0	0.0	-	-	-	1.5	0.08	1.46	1.45	0.88
		Phragmites	8	-	6.31	1.9	0.0	0.0	-	-	-	1.9	0.10	1.62	1.39	0.70
		Schoenoplectus	8	-	6.14	2.0	0.0	0.0	-	-	-	2.0	0.09	1.66	1.19	0.42
		Schoenoplectus	8	-	6.22	2.4	0.0	0.0	-	-	-	2.4	0.08	1.68	1.67	1.29
	2.5-10	None	8	-	6.45	1.0	0.0	0.0	-	-	-	1.0	0.05	0.20	0.20	0.05
		None	8	-	6.38	1.4	0.0	0.0	-	-	-	1.4	0.05	0.18	0.18	0.05
		Phragmites	8	-	5.65	2.9	0.0	0.0	-	-	-	2.9	0.08	1.59	1.48	0.75
		Phragmites	8	-	5.64	3.8	0.0	0.0	-	-	-	3.8	0.09	1.59	1.45	0.99
		Schoenoplectus	8	-	5.34	3.9	0.0	0.0	-	-	-	3.9	0.08	1.61	1.47	0.81
		Schoenoplectus	8	-	5.41	4.8	0.0	0.0	-	-	-	4.8	0.08	1.64	1.56	0.86

** Net acidity in italics assumes RIS content of <0.01% S*

Table 8-32 (continued). Characteristics of the Tolderol and Waltowa soil materials (mesocosm experiment).

Site	Depth (cm)	Treatment	Week	Moisture Content (%)	pH_{KCl}	TAA (mol H^+ t^{-1})	ANC (% $CaCO_3$)	Retained acidity (mol H^+ t^{-1})	Pyritic Sulfur (%S)	Elemental Sulfur (%S)	Acid Volatile Sulfide (%S_{AV})	Net acidity (mol H^+ t^{-1})	Total N (%N)	Total C (%C)	Total Organic C (%C)	Hydrolysable Organic C (%C)
TS	0-2.5	None	16	20.63	5.86	2.0	0.0	0.0	<0.01	<0.001	<0.01	2.0	0.05	0.20	0.19	0.06
		None	16	20.35	6.11	2.4	0.0	0.0	<0.01	<0.001	<0.01	2.4	0.05	0.17	0.17	0.04
		Phragmites	16	27.02	6.17	1.5	0.0	0.0	<0.01	<0.001	<0.01	1.5	0.08	1.21	1.11	0.51
		Phragmites	16	27.06	6.45	1.4	0.0	0.0	<0.01	<0.001	<0.01	1.4	0.09	1.46	1.40	0.61
		Schoenoplectus	16	29.13	6.22	1.5	0.0	0.0	<0.01	<0.001	<0.01	1.5	0.09	1.50	1.40	0.74
		Schoenoplectus	16	27.59	6.10	2.9	0.0	0.0	<0.01	<0.001	<0.01	2.9	0.08	1.33	1.25	0.62
	2.5-10	None	16	21.74	5.08	3.9	0.0	0.0	<0.01	0.003	<0.01	3.9	0.05	0.18	0.18	0.04
		None	16	21.28	5.06	5.3	0.0	0.0	<0.01	<0.001	<0.01	5.3	0.06	0.19	0.15	0.01
		Phragmites	16	29.33	5.42	3.9	0.0	0.0	<0.01	<0.001	<0.01	3.9	0.09	1.61	1.51	0.69
		Phragmites	16	27.78	5.37	5.7	0.0	0.0	<0.01	<0.001	<0.01	5.7	0.09	1.63	1.55	1.04
		Schoenoplectus	16	30.57	5.14	5.4	0.0	0.0	<0.01	<0.001	<0.01	5.4	0.07	1.68	1.62	0.96
		Schoenoplectus	16	28.84	5.06	6.7	0.0	0.0	<0.01	<0.001	<0.01	6.7	0.07	1.74	1.56	0.89
WC	0-2.5	None	16	19.90	6.48	0.5	0.0	0.0	<0.01	0.002	<0.01	0.5	0.04	0.20	0.19	0.06
		None	16	19.86	6.19	1.4	0.0	0.0	<0.01	0.002	<0.01	1.4	0.04	0.20	0.13	0.01
		Phragmites	16	26.51	6.49	0.5	0.0	0.0	<0.01	0.002	<0.01	0.5	0.08	1.16	1.08	0.55
		Phragmites	16	25.20	6.26	1.4	0.0	0.0	<0.01	0.002	<0.01	1.4	0.10	1.22	1.09	0.49
		Schoenoplectus	16	25.65	6.47	0.5	0.0	0.0	<0.01	0.002	<0.01	0.5	0.08	1.30	1.28	0.73
		Schoenoplectus	16	27.35	6.15	1.9	0.0	0.0	<0.01	0.002	<0.01	1.9	0.08	1.20	1.17	0.42
	2.5-10	None	16	18.94	6.42	1.0	0.0	0.0	<0.01	0.003	<0.01	1.0	0.04	0.19	0.12	0.00
		None	16	19.64	6.28	1.4	0.0	0.0	<0.01	0.003	<0.01	1.4	0.04	0.18	0.15	0.03
		Phragmites	16	24.05	5.49	3.9	0.0	0.0	<0.01	0.002	<0.01	3.9	0.08	1.38	1.36	0.60
		Phragmites	16	23.03	6.27	1.4	0.0	0.0	<0.01	<0.001	<0.01	1.4	0.07	1.35	1.32	0.81
		Schoenoplectus	16	28.68	6.70	2.0	0.0	0.0	<0.01	<0.001	<0.01	2.0	0.07	1.45	1.36	0.88
		Schoenoplectus	16	28.57	5.53	4.8	0.0	0.0	<0.01	0.001	<0.01	4.8	0.07	1.62	1.59	1.14

Table 8-33. Iron fractionation results (µg/g).

Site	Depth (cm)	Treatment	Week	$MgCl_2$		HCl	CBD	Pyritic	Residual (including organic)
				Fe^{2+}	Fe^{3+}	Total Fe	Fe^{2+}	Fe^{2+}	Total Fe
TS	0-2.5	None	0	0.00	0.00	231.87	262.75	0.00	1305
		None	0	0.00	0.00	190.44	225.07	0.00	1384
		Phragmites	0	0.00	0.95	220.55	268.83	0.00	1259
		Phragmites	0	0.00	1.08	240.44	292.25	0.00	1215
		Schoenoplectus	0	0.34	0.73	179.36	268.13	0.00	1200
		Schoenoplectus	0	0.00	0.81	218.31	268.30	0.00	1162
	2.5-10	None	0	0.31	1.68	173.78	226.25	0.00	1747
		None	0	0.00	1.67	155.49	211.26	0.00	1781
		Phragmites	0	2.89	0.85	151.28	218.38	0.00	1574
		Phragmites	0	3.02	0.89	149.98	199.79	0.00	1594
		Schoenoplectus	0	6.26	0.36	152.25	193.35	0.00	1494
		Schoenoplectus	0	6.48	0.78	160.01	200.73	0.00	1479
WC	0-2.5	None	0	0.00	0.00	325.41	161.40	0.00	863
		None	0	0.00	0.00	347.87	183.60	0.00	818
		Phragmites	0	0.00	0.00	295.90	154.97	0.00	798
		Phragmites	0	0.00	0.00	285.62	158.91	0.00	805
		Schoenoplectus	0	0.00	0.00	291.01	156.32	0.00	752
		Schoenoplectus	0	0.00	0.00	304.33	205.47	0.00	690
	2.5-10	None	0	0.00	0.38	214.25	157.84	0.00	1027
		None	0	0.00	0.32	218.37	151.86	0.00	1029
		Phragmites	0	1.08	0.06	196.50	142.04	0.00	1009
		Phragmites	0	1.53	0.09	202.24	143.17	0.00	1002
		Schoenoplectus	0	1.61	0.77	202.41	149.92	0.00	1044
		Schoenoplectus	0	1.45	0.70	193.80	158.46	0.00	1045
TS	0-2.5	None	16	44.81	0.57	253.75	162.96	0.00	1335
		None	16	46.96	0.00	243.60	154.36	0.00	1353
		Phragmites	16	42.32	0.00	172.63	47.62	0.00	1404
		Phragmites	16	49.05	0.00	165.25	47.69	0.00	1404
		Schoenoplectus	16	51.37	0.00	182.62	51.18	0.00	1230
		Schoenoplectus	16	55.78	0.00	126.10	47.11	0.00	1286
	2.5-10	None	16	84.58	0.00	135.10	73.72	0.00	1851
		None	16	104.84	0.00	133.62	78.53	0.00	1828
		Phragmites	16	106.66	0.00	38.82	54.34	0.00	1457
		Phragmites	16	101.20	0.00	42.58	53.54	0.00	1459
		Schoenoplectus	16	112.54	0.00	34.41	43.02	0.00	1386
		Schoenoplectus	16	105.63	0.00	46.96	49.94	0.00	1374
WC	0-2.5	None	16	4.87	1.39	264.69	127.74	0.00	950
		None	16	5.28	1.24	299.97	141.58	0.00	901
		Phragmites	16	17.97	0.46	245.10	97.46	0.00	843
		Phragmites	16	4.81	0.28	178.80	81.00	0.00	939
		Schoenoplectus	16	20.75	0.36	170.91	72.13	0.00	839
		Schoenoplectus	16	18.58	0.26	180.77	76.20	0.00	828
	2.5-10	None	16	22.56	0.48	224.43	386.41	0.00	765
		None	16	20.39	0.36	188.34	108.70	0.00	1081
		Phragmites	16	58.30	0.00	64.54	69.05	0.00	1005
		Phragmites	16	15.55	0.08	128.43	74.58	0.00	977
		Schoenoplectus	16	78.90	0.00	44.94	74.26	0.00	1038
		Schoenoplectus	16	31.87	0.00	137.09	87.46	0.00	978

Table 8-34. Metal(loid) fractionation results for Waltowa surface sediment (0-2.5 cm) with *Phragmites* (µg/g).

Site	Depth (cm)	Treatment	Week	Fraction	Arsenic (As)	Cobalt (Co)	Copper (Cu)	Nickel (Ni)	Zinc (Zn)
WC	0-2.5	Phragmites	0	$MgCl_2$	0.10	0.05	0.16	0.10	0.79
		Phragmites	0	$MgCl_2$	0.19	0.05	0.14	0.19	0.52
		Phragmites	0	HCl	0.60	0.09	0.30	0.38	1.00
		Phragmites	0	HCl	0.53	0.09	0.32	0.66	0.63
		Phragmites	0	CBD	0.16	0.05	0.05	0.21	0.00
		Phragmites	0	CBD	0.19	0.05	0.09	0.19	0.09
		Phragmites	0	OM & Residue	0.07	0.32	0.66	1.03	0.85
		Phragmites	0	OM & Residue	0.02	0.34	0.62	0.68	1.39
		Phragmites	16	$MgCl_2$	0.14	0.03	0.00	0.07	0.00
		Phragmites	16	$MgCl_2$	0.30	0.00	0.05	0.00	0.00
		Phragmites	16	HCl	0.20	0.08	0.64	0.78	1.73
		Phragmites	16	HCl	0.15	0.06	0.31	0.36	1.18
		Phragmites	16	CBD	0.07	0.03	0.07	0.07	0.14
		Phragmites	16	CBD	0.00	0.05	0.05	0.00	0.00
		Phragmites	16	OM & Residue	0.37	0.33	0.56	0.20	1.08
		Phragmites	16	OM & Residue	0.32	0.37	0.85	0.76	1.77

APPENDIX 5. Vegetation sampling results

Table 8-35. Metal(loid) (mg/kg) and total organic carbon (%) contents of the vegetation at the Tolderol site (October 2013).

Site	Vegetation Type	Stem/ Leaf	TOC	Iron	Aluminium	Silver	Arsenic	Lead	Cadmium	Chromium	Cobalt	Copper	Manganese	Nickel	Selenium	Zinc
Tolderol (site 1)	Phragmites australis	Stem	-	467	613	<1	0.4	<1	<0.5	<1	0.2	2	100	1.8	<0.1	9
Tolderol (site 1)	Phragmites australis	Leaf	-	919	1,064	<1	0.7	<1	<0.5	1.6	0.2	4	459	1.5	<0.1	22
Tolderol (site 2)	Phragmites australis	Stem	-	327	376	<1	0.4	<1	<0.5	<1	0.1	1	88	2.2	<0.1	25
Tolderol (site 2)	Phragmites australis	Leaf	-	478	620	<1	0.4	<1	<0.5	1.0	0.1	2	215	1.1	<0.1	20
Tolderol (site 2)	Phragmites australis*	Stem/Leaf	43.8	107	<50	<1	0.2	<1	<0.5	1.2	0.1	2	149	1.1	<0.1	18
Tolderol (site 3)	Phragmites australis	Stem	-	244	335	<1	0.4	<1	<0.5	<1	<0.1	1	79	1.2	0.6	27
Tolderol (site 3)	Phragmites australis	Leaf	-	512	635	<1	0.3	<1	<0.5	1.2	0.1	3	233	1.6	<0.1	21
Tolderol (site 4)	Phragmites australis	Stem	-	416	519	<1	0.4	<1	<0.5	<1	0.1	2	67	2.3	<0.1	24
Tolderol (site 4)	Phragmites australis	Leaf	-	658	828	<1	0.4	<1	<0.5	1.5	0.2	3	198	2.4	<0.1	20
Tolderol (site 5)	Phragmites australis	Stem	-	258	261	<1	0.3	<1	<0.5	1.1	0.1	<1	63	1.1	<0.1	33
Tolderol (site 5)	Phragmites australis	Leaf	-	561	582	<1	0.4	<1	<0.5	1.4	0.1	2	227	1.4	<0.1	20
Tolderol (site 6)	Phragmites australis	Stem	-	282	215	<1	0.4	<1	<0.5	<1	<0.1	2	71	1.1	<0.1	39
Tolderol (site 6)	Phragmites australis	Leaf	-	686	692	<1	0.5	<1	<0.5	1.5	0.2	3	230	1.6	<0.1	25
Tolderol (site 7)	Phragmites australis	Stem	-	565	537	<1	0.5	<1	<0.5	1.4	0.2	2	104	1.8	<0.1	17
Tolderol (site 7)	Phragmites australis	Leaf	-	625	689	<1	0.5	<1	<0.5	1.5	0.2	3	236	2.3	<0.1	21
Tolderol (site 8)	Phragmites australis	Stem	-	372	387	<1	0.5	<1	<0.5	1.0	0.1	1	92	1.5	<0.1	21
Tolderol (site 8)	Phragmites australis	Leaf	-	639	576	<1	0.4	<1	<0.5	1.4	0.1	2	225	<1	<0.1	23
Tolderol (site 9)	Phragmites australis	Stem	-	322	327	<1	0.3	<1	<0.5	1.1	0.1	1	51	1.3	<0.1	14
Tolderol (site 9)	Phragmites australis	Leaf	-	487	455	<1	0.5	<1	<0.5	1.4	0.1	2	153	1.3	<0.1	24

* Sample used in laboratory experiments

Table 8-36. Metal(loid) (mg/kg) and total organic carbon (%) contents of the vegetation at the Waltowa site (October 2013).

Site	Vegetation Type	Stem/ Leaf	TOC	Iron	Aluminium	Silver	Arsenic	Lead	Cadmium	Chromium	Cobalt	Copper	Manganese	Nickel	Selenium	Zinc
Waltowa (site 10)	Phragmites australis	Stem	-	74	<50	<1	0.4	<1	<0.5	<1	<0.1	2	96	<1	<0.1	42
Waltowa (site 10)	Phragmites australis	Leaf	-	202	103	<1	0.2	<1	<0.5	<1	<0.1	3	227	1.9	<0.1	26
Waltowa (site 11)	Schoenoplectus validus	Stem	-	493	684	<1	0.8	<1	<0.5	2.0	0.2	5	192	2.0	2.0	15
Waltowa (site 12)	Phragmites australis	Stem	-	86	<50	<1	0.3	<1	<0.5	<1	<0.1	1	104	<1	0.6	18
Waltowa (site 12)	Phragmites australis	Leaf	-	102	<50	<1	<0.1	<1	<0.5	1.1	<0.1	2	201	2.4	<0.1	25
Waltowa (site 13)	Schoenoplectus validus	Stem	-	197	234	<1	0.8	<1	<0.5	1.2	<0.1	3	108	1.1	2.0	11
Waltowa (site 13)	Schoenoplectus validus*	Stem	41.8	107	<50	<1	0.2	<1	<0.5	1.2	<0.1	2	149	1.1	<0.1	18
Waltowa (site 14)	Schoenoplectus validus	Stem	-	410	634	<1	0.8	<1	<0.5	1.2	0.2	5	256	1.3	1.7	16
Waltowa (site 15)	Phragmites australis	Stem	-	202	257	<1	0.3	<1	<0.5	<1	<0.1	2	51	<1	<0.1	17
Waltowa (site 15)	Phragmites australis	Leaf	-	323	447	<1	0.1	<1	<0.5	1.1	<0.1	4	108	<1	<0.1	21
Waltowa (site 16)	Schoenoplectus validus	Stem	-	330	461	<1	0.6	<1	<0.5	1.2	0.1	3	221	1.4	1.4	13
Waltowa (site 17)	Phragmites australis	Stem	-	119	134	<1	0.4	<1	<0.5	<1	<0.1	2	45	<1	0.8	22
Waltowa (site 17)	Phragmites australis	Leaf	-	180	114	<1	0.2	<1	<0.5	1.6	<0.1	3	130	1.7	<0.1	35
Waltowa (site 18)	Phragmites australis	Stem	-	36	<50	<1	0.2	<1	<0.5	<1	<0.1	<1	37	<1	<0.1	10
Waltowa (site 18)	Phragmites australis	Leaf	-	107	<50	<1	0.2	<1	<0.5	1.2	<0.1	2	149	1.1	<0.1	18

* Sample used in laboratory experiments

APPENDIX 6. Additional data

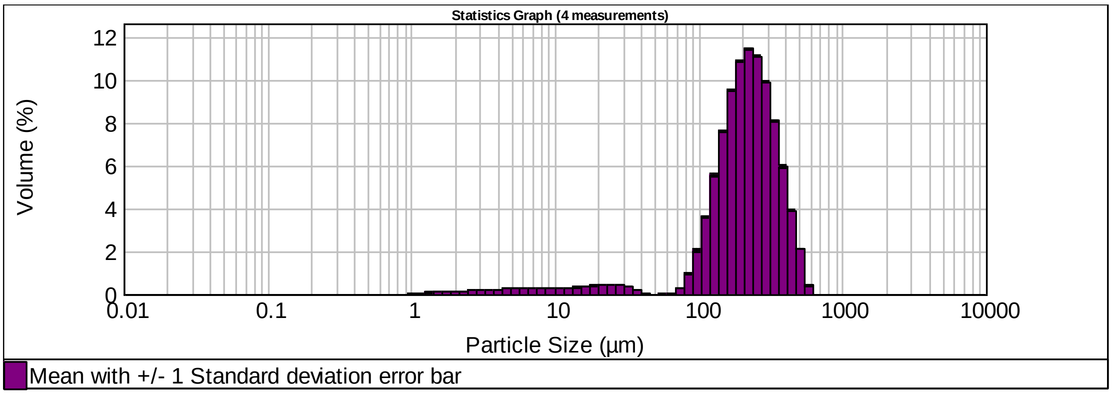


Figure 8-1. Particle size analysis data for the Tolderol sediment (0-2.5 cm).

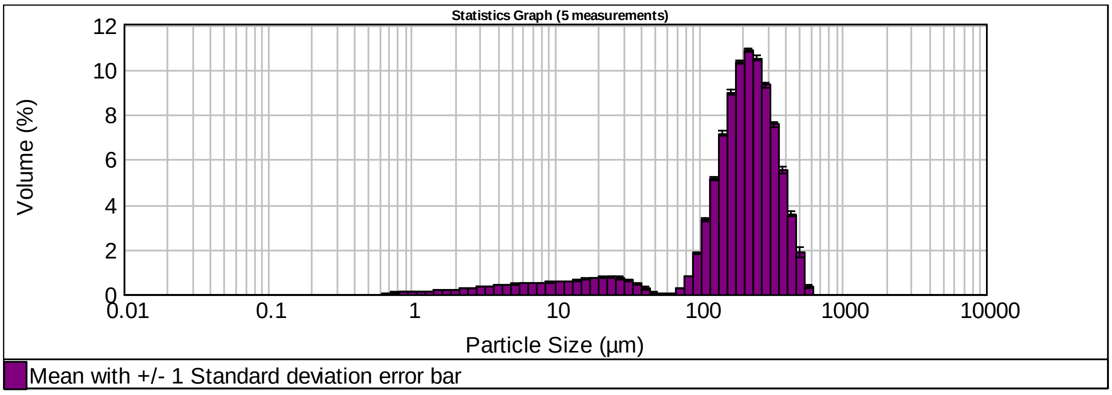


Figure 8-2. Particle size analysis data for the Tolderol sediment (2.5-10 cm).

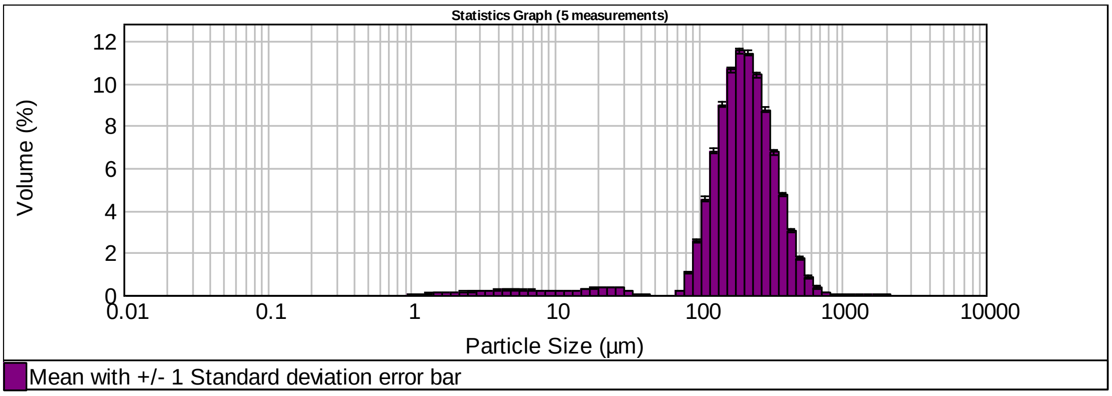


Figure 8-3. Particle size analysis data for the Waltowa sediment (0-2.5 cm).

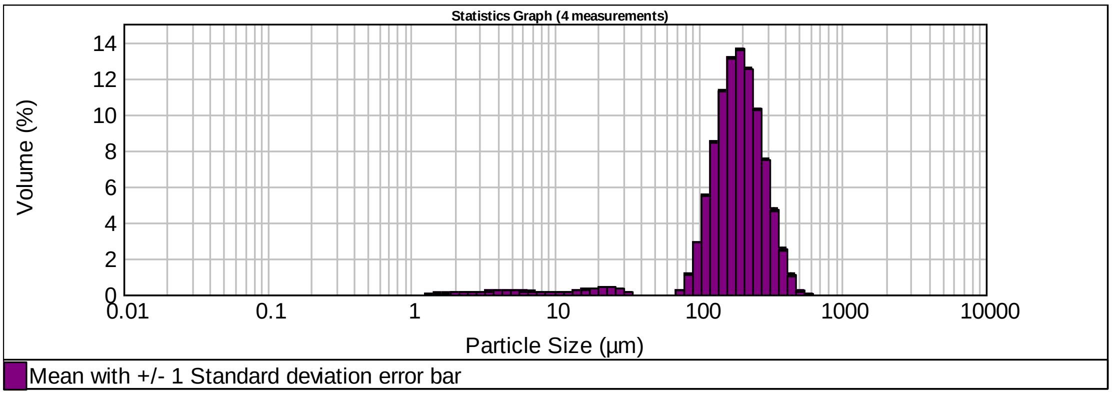


Figure 8-4. Particle size distribution data for the Waltowa sediment (2.5-10 cm).

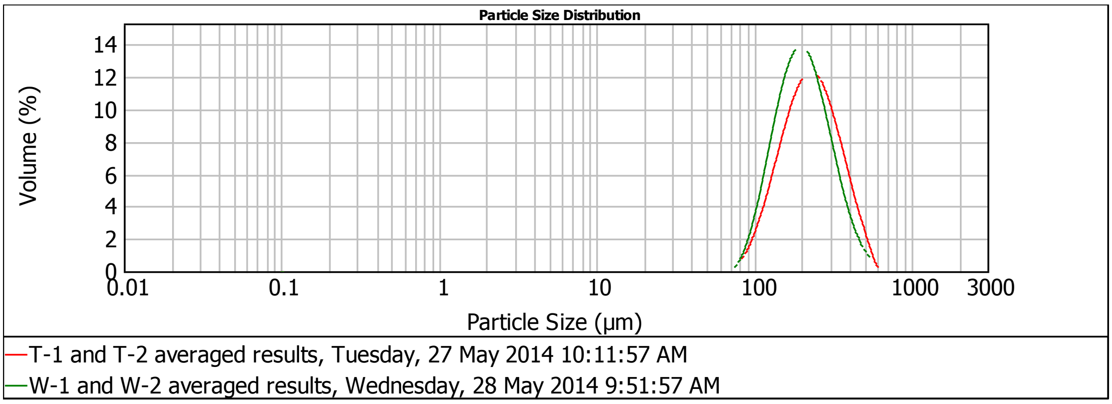


Figure 8-5. Comparison of the particle size analysis data for the Tolderol and Waltowa sediment (0-10 cm).

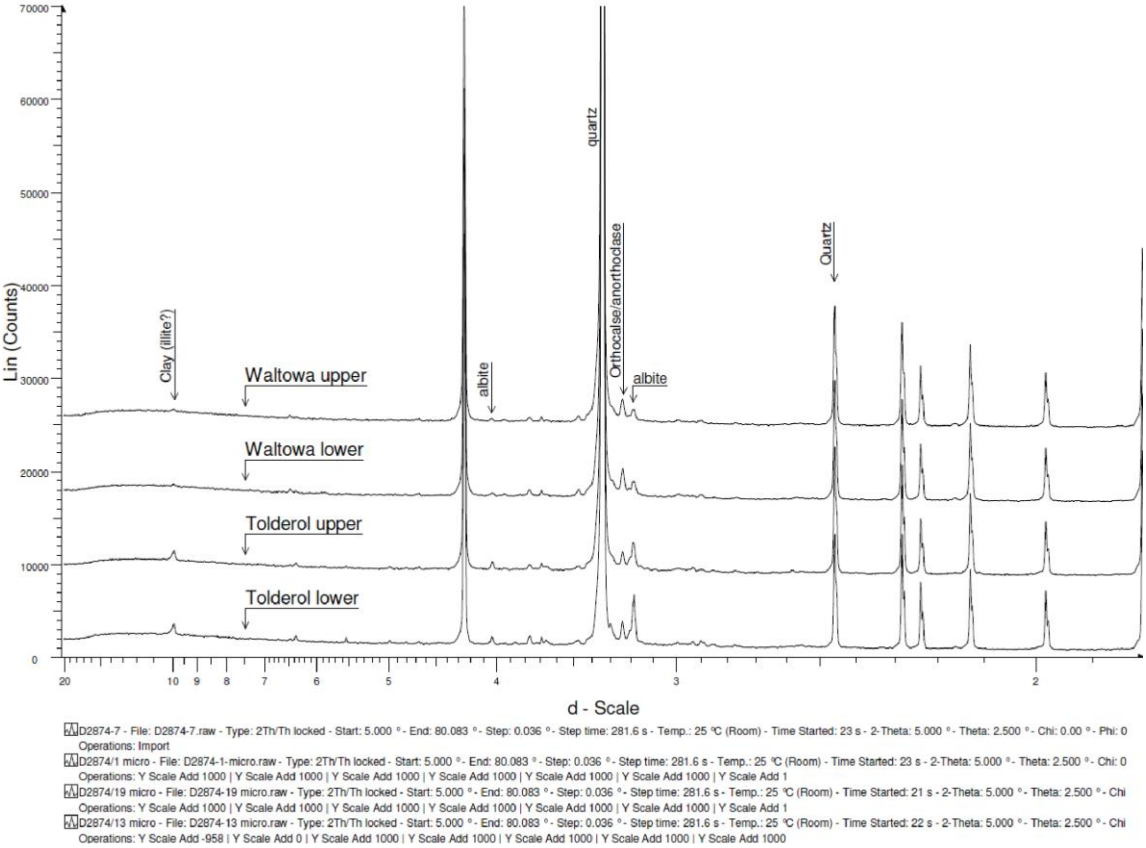


Figure 8-6. X-ray diffractograms for the Tolderol and Waltowa sediments (Day 0).

Table 8-37. HCl extractable metal(loid) content (mg/kg) for the Tolderol and Waltowa sediments (March 2013) (source: Sullivan *et al.* 2013).

Site	Depth (cm)	Fe	Al	Ag	As	Pb	Cd	Cr	Cu	Mn	Ni	Se	Zn
TS	0 - 2.5	867	150	0.01	0.66	0.68	<0.01	3.20	0.77	12.47	0.57	<0.01	4.61
TS	2.5 - 5	516	139	<0.01	0.51	0.55	<0.01	1.58	0.61	5.89	0.33	<0.01	1.83
TS	5 - 10	701	142	0.03	0.53	0.62	<0.01	2.90	0.51	7.07	0.35	<0.01	1.37
WC	0 - 2.5	747	123	0.02	0.96	0.88	<0.01	1.85	0.81	12.55	0.62	0.01	5.68
WC	2.5 - 5	618	127	0.01	0.54	1.08	<0.01	1.39	0.92	6.42	0.72	0.02	3.34
WC	5 - 10	593	186	<0.01	0.54	2.12	<0.01	1.15	1.27	5.69	0.86	0.02	2.18

APPENDIX 7. Additional plots

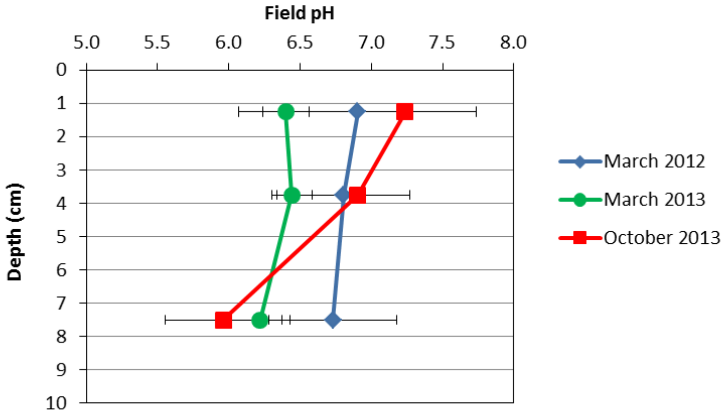


Figure 8-7. Field pH at the Tolderol scald site (March 2012-October 2013).

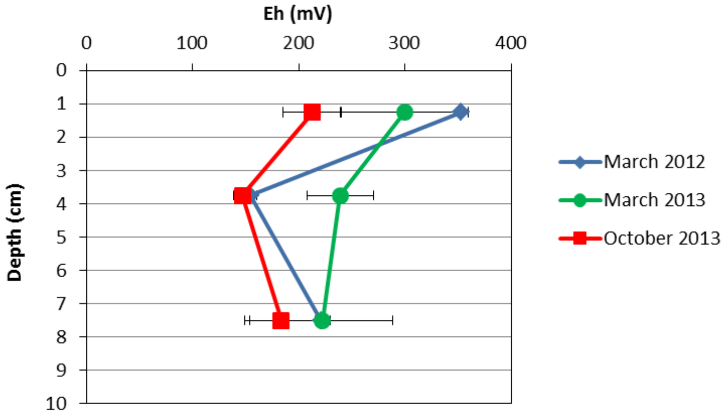


Figure 8-8. Field Eh at the Tolderol scald site (March 2012-October 2013).

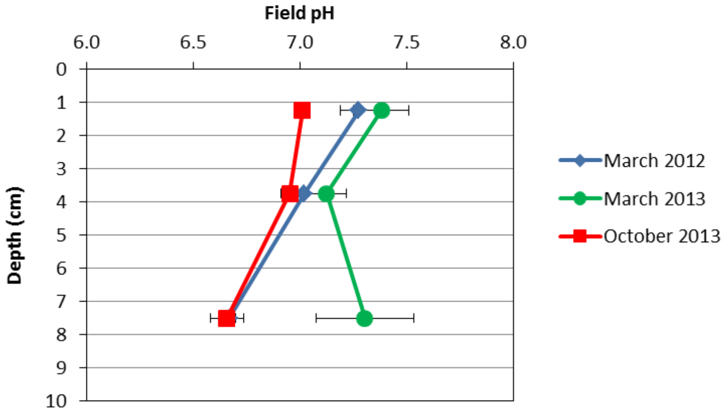


Figure 8-9. Field pH at the Waltowa Cotula site (March 2012-October 2013).

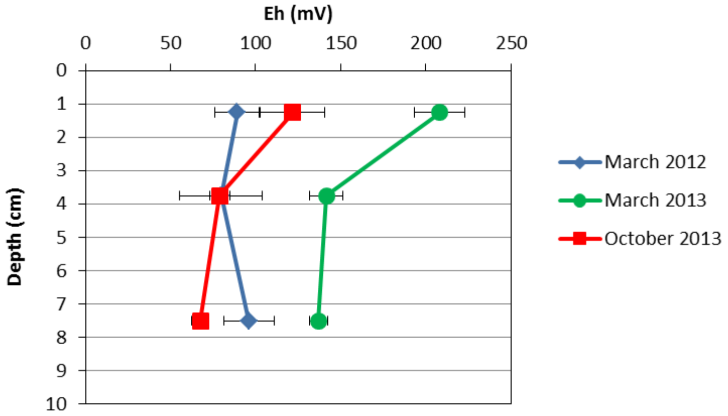


Figure 8-10. Field Eh at the Waltowa Cotula site (March 2012-October 2013).

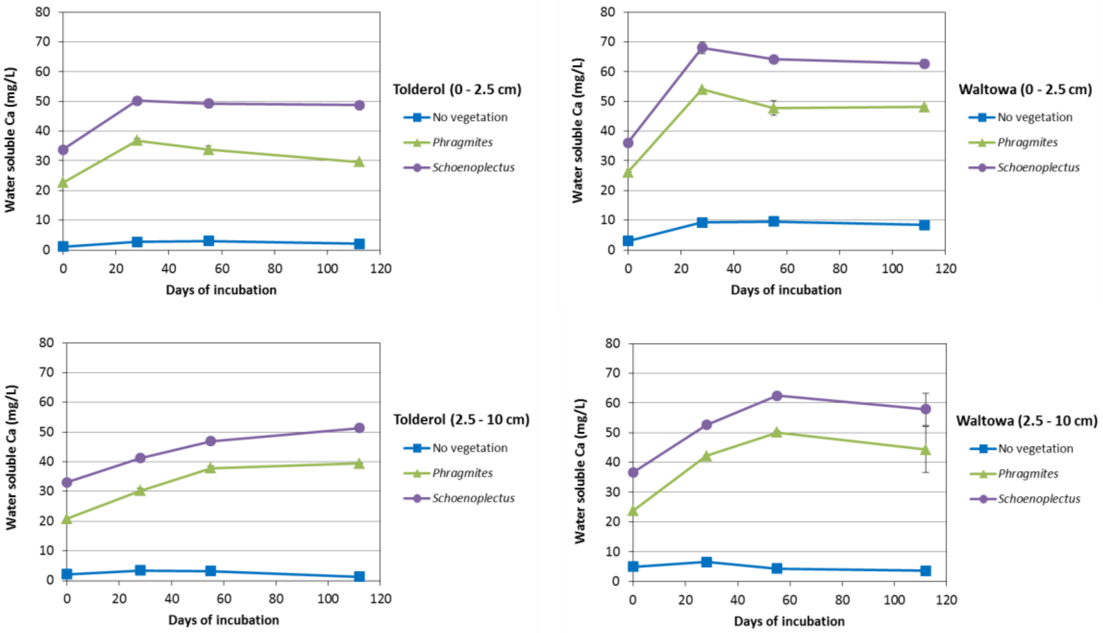


Figure 8-11. Tolderol and Waltowa surface water calcium dynamics (mesocosm experiment).

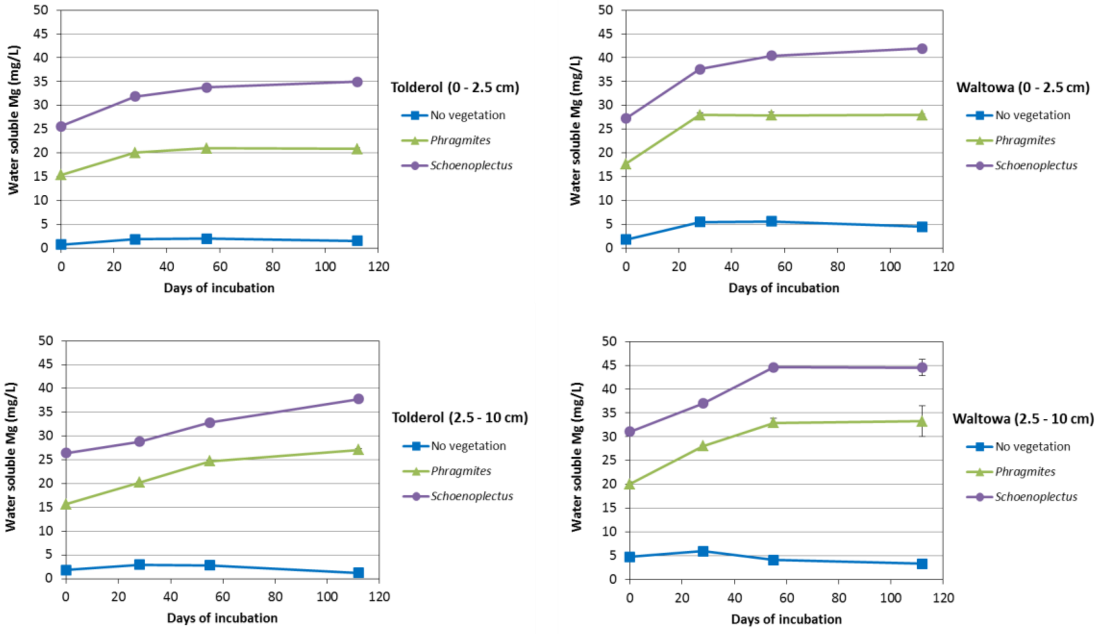


Figure 8-12. Tolderol and Waltowa surface water magnesium dynamics (mesocosm experiment).

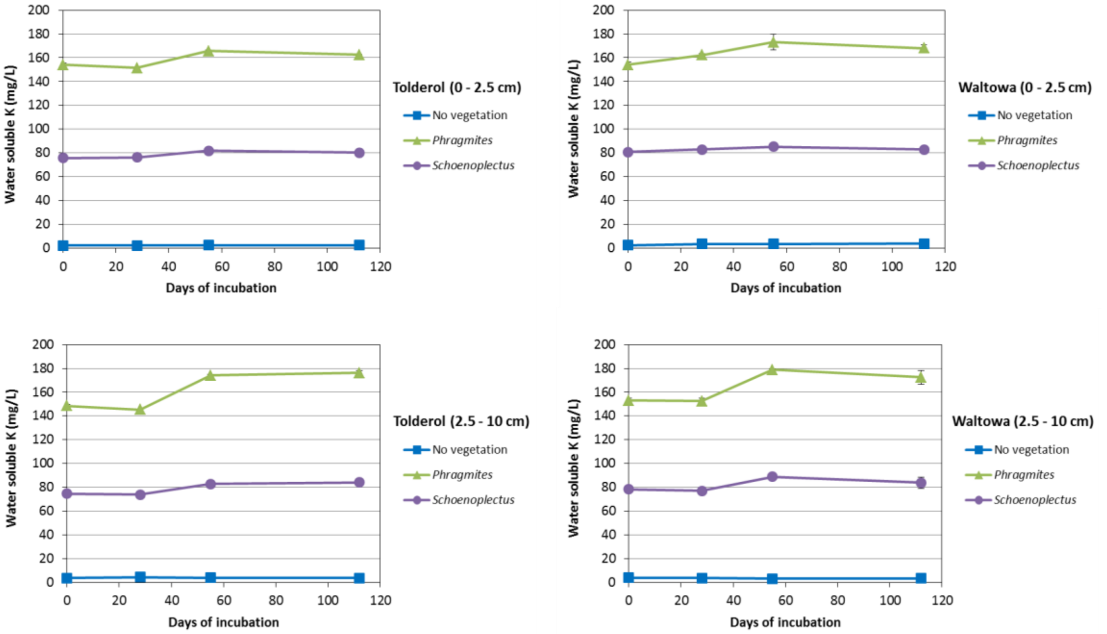


Figure 8-13. Tolderol and Waltowa surface water potassium dynamics (mesocosm experiment).

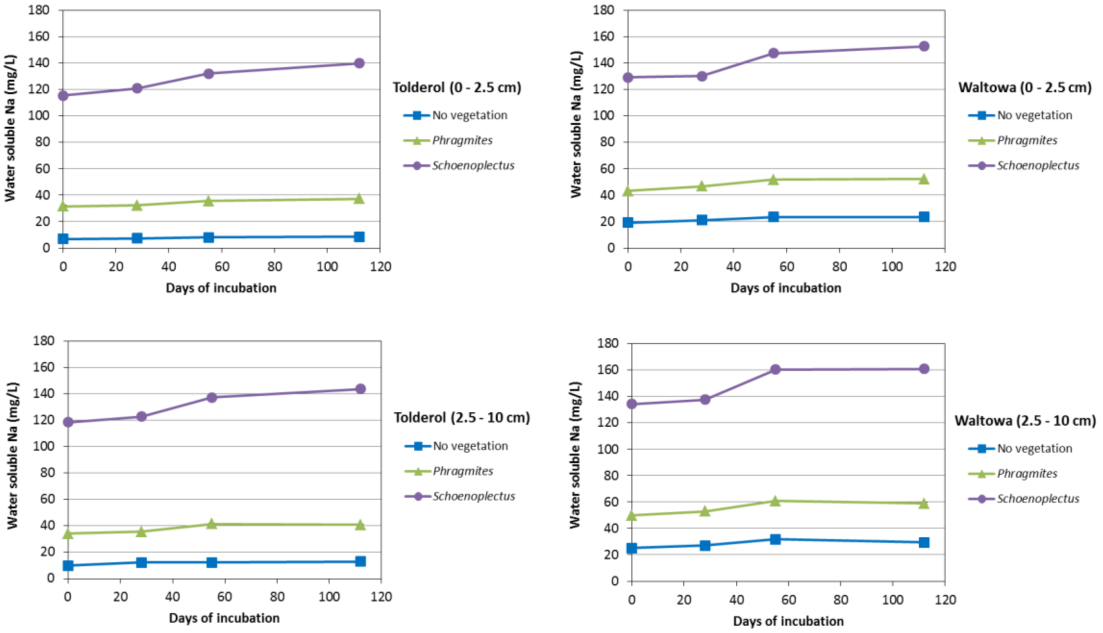


Figure 8-14. Tolderol and Waltowa surface water sodium dynamics (mesocosm experiment).

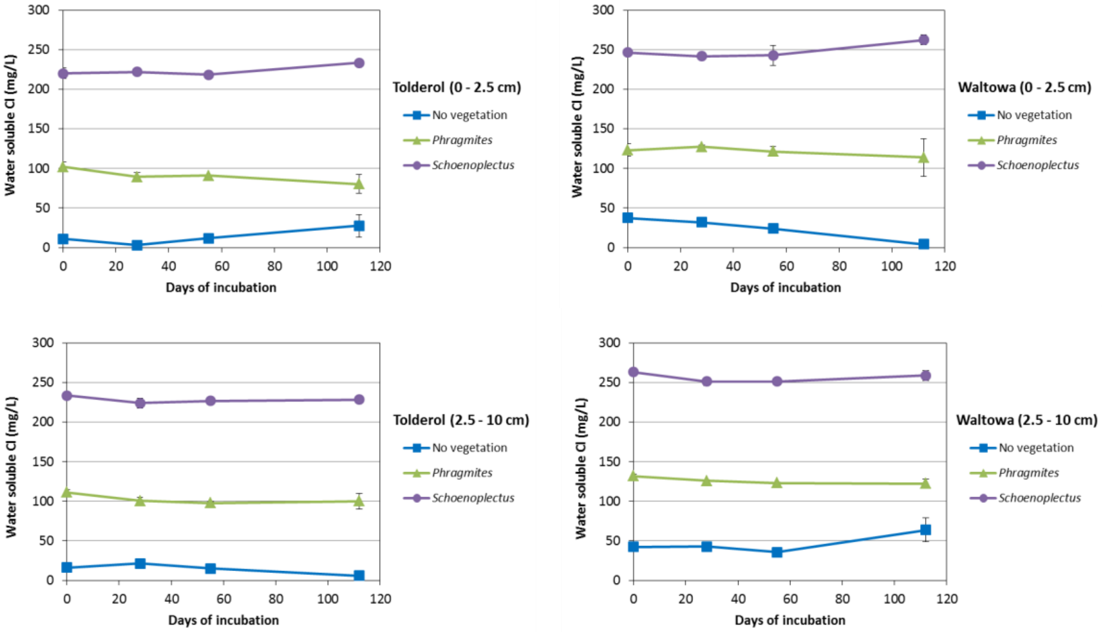


Figure 8-15. Tolderol and Waltowa surface water chloride dynamics (mesocosm experiment).

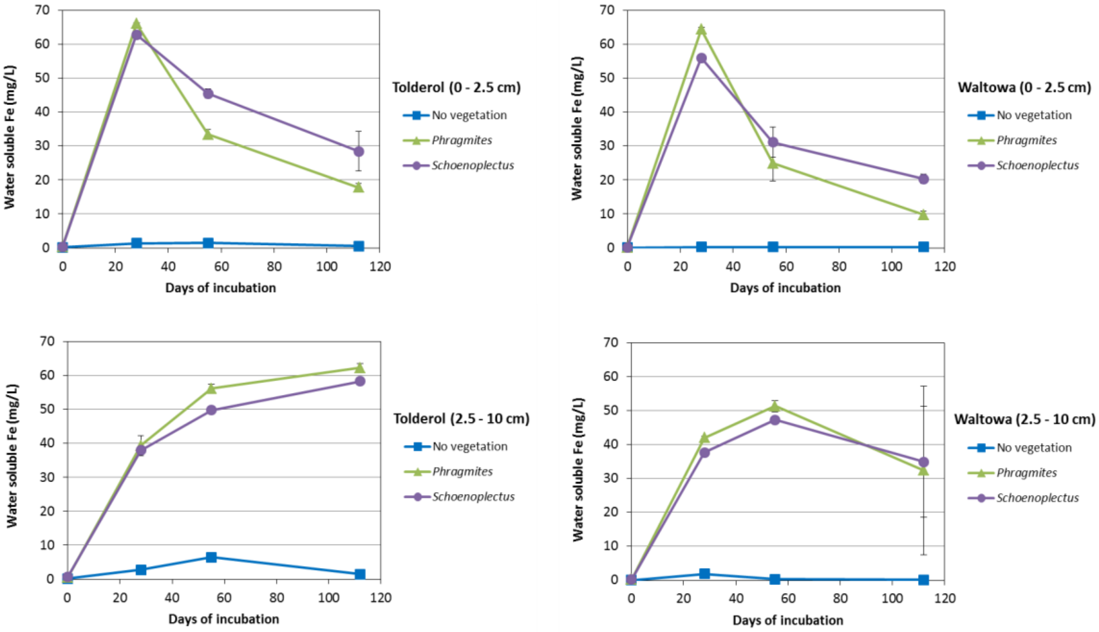


Figure 8-16. Tolderol and Waltowa surface water total iron dynamics (mesocosm experiment).

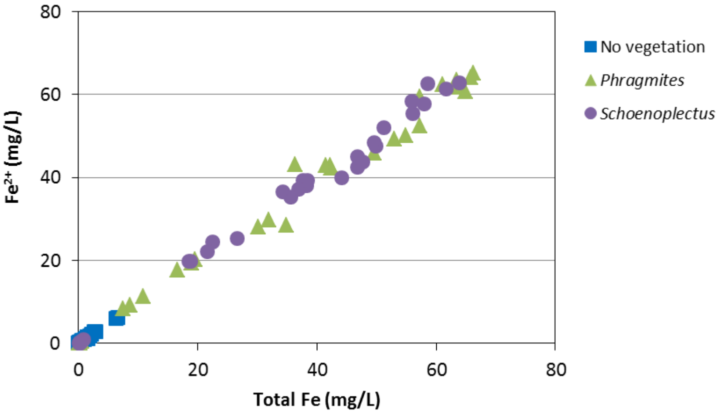


Figure 8-17. Comparison of the surface water total Fe and Fe^{2+} concentrations for the mesocosm experiment.

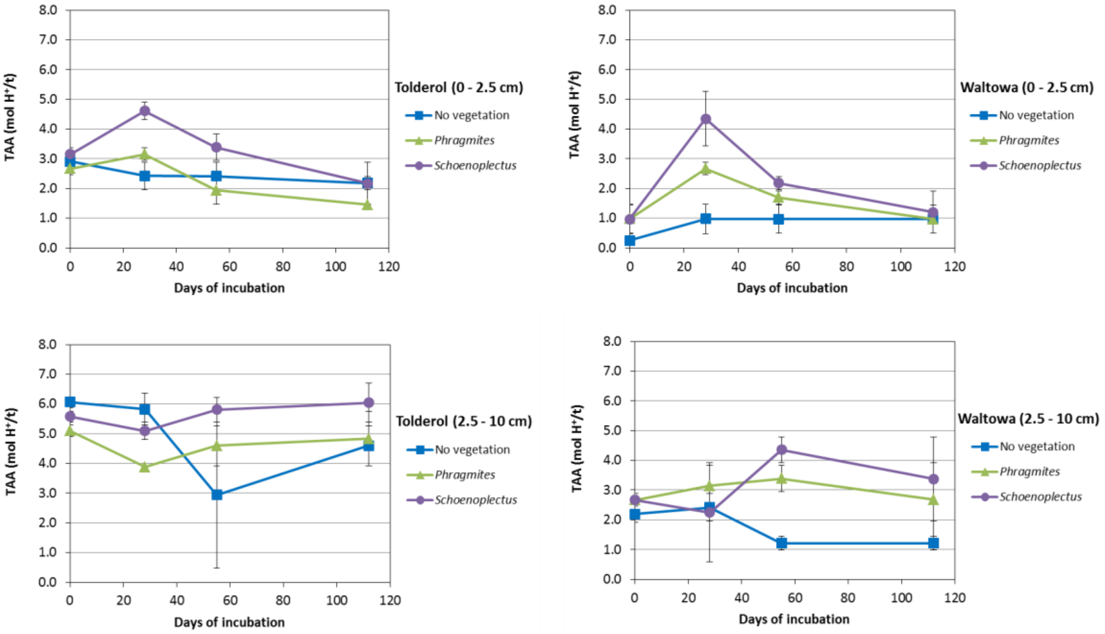


Figure 8-18. Tolderol and Waltowa sediment TAA dynamics (mesocosm experiment).

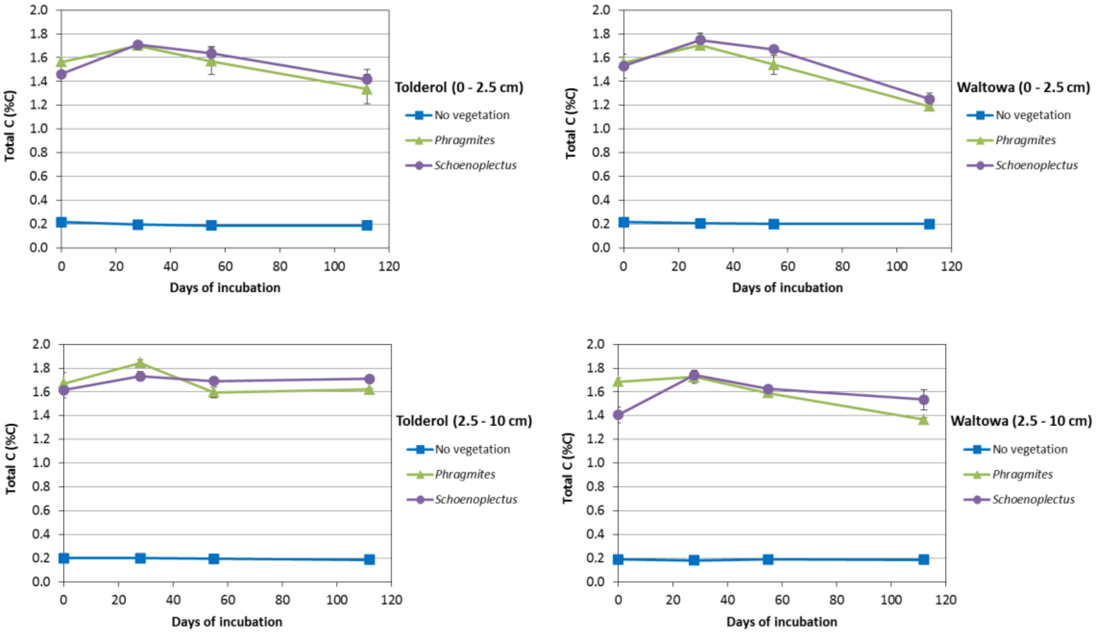


Figure 8-19. Tolderol and Waltowa sediment total carbon dynamics (mesocosm experiment).

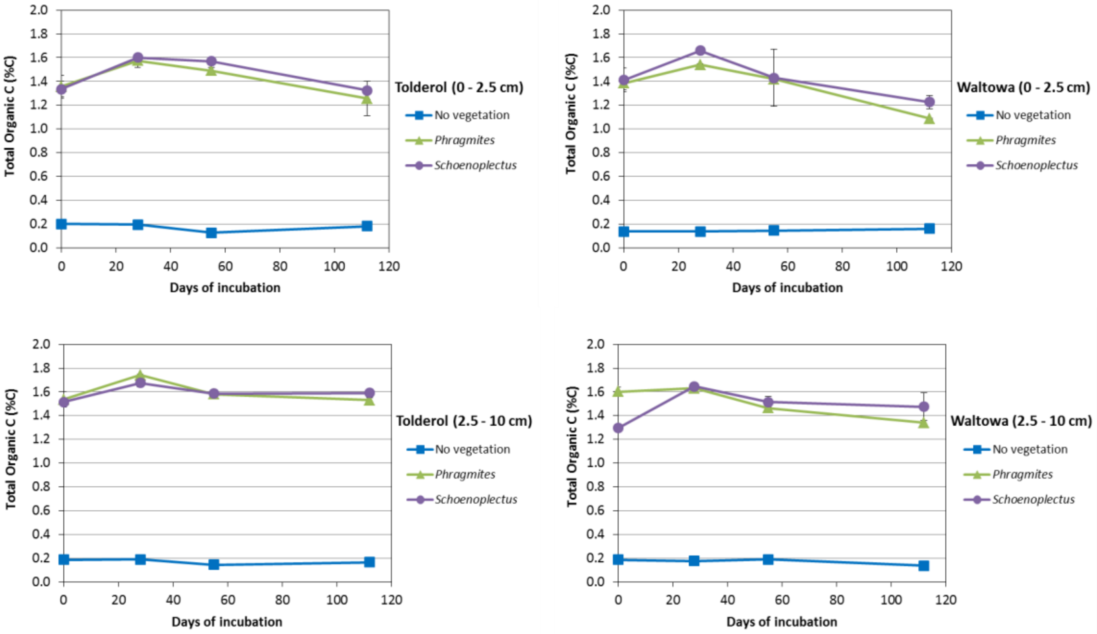


Figure 8-20. Tolderol and Waltowa sediment total organic carbon (TOC) dynamics (mesocosm experiment).

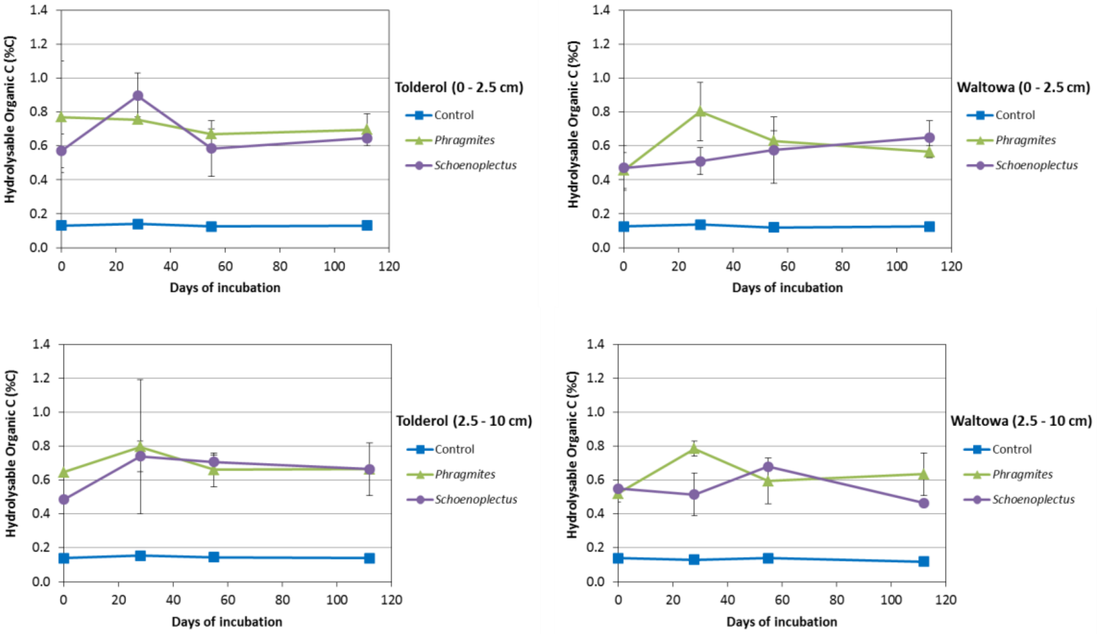


Figure 8-21. Tolderol and Waltowa sediment hydrolysable organic carbon dynamics (mesocosm experiment).

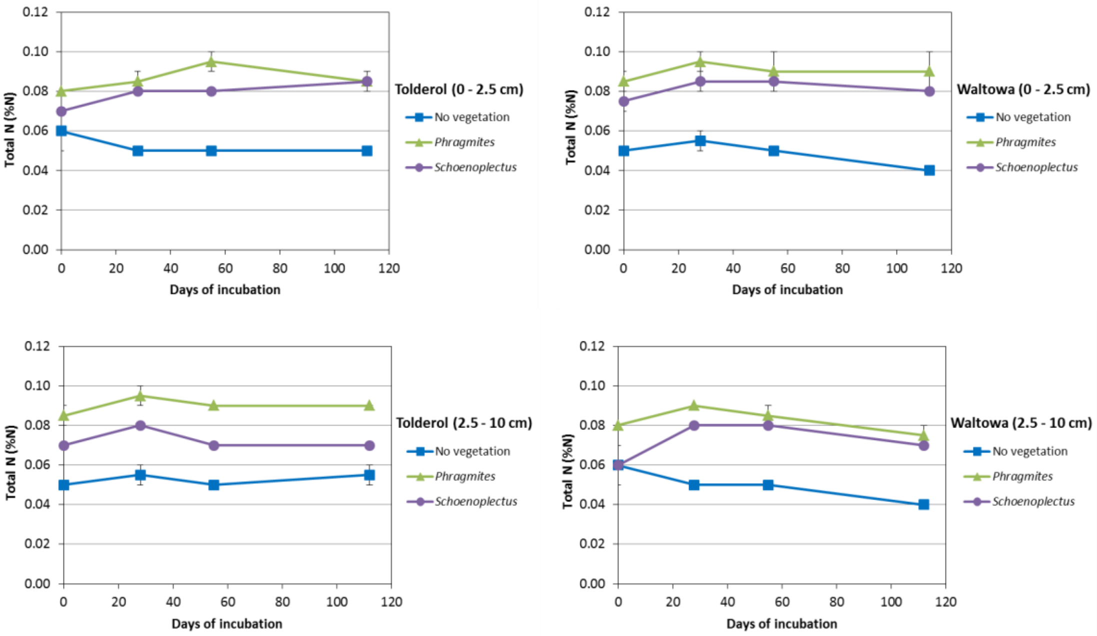


Figure 8-22. Tolderol and Waltowa sediment total nitrogen dynamics (mesocosm experiment).

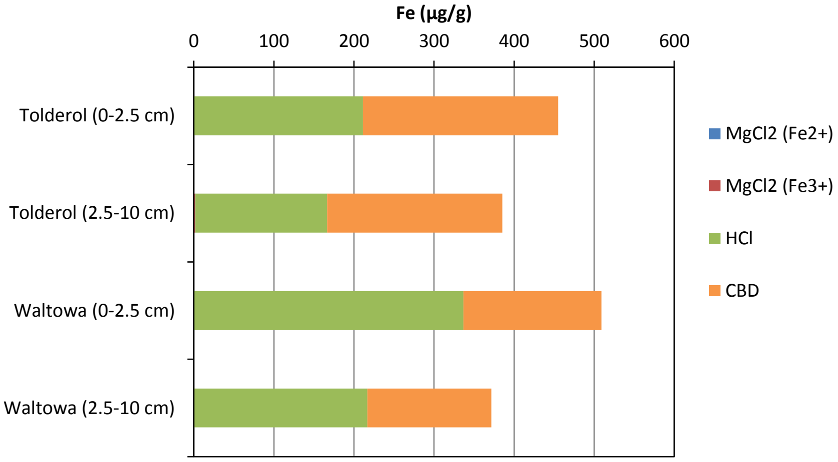


Figure 8-23. Iron fractionation data ($MgCl_2$, HCl and CBD fractions) for Tolderol and Waltowa sediments without the addition of vegetation (Day 0).

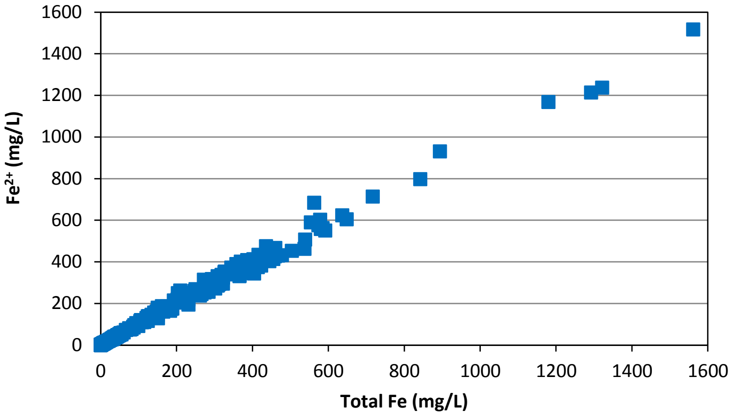


Figure 8-24. Comparison of the surface water total Fe and Fe^{2+} concentrations for the batch experiment.

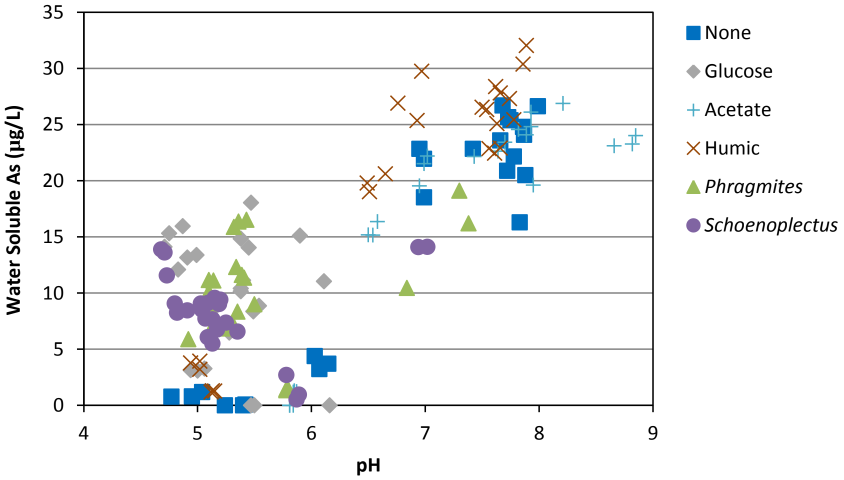


Figure 8-25. Comparison of the surface water pH and arsenic concentrations for the batch experiment (organic treatments).

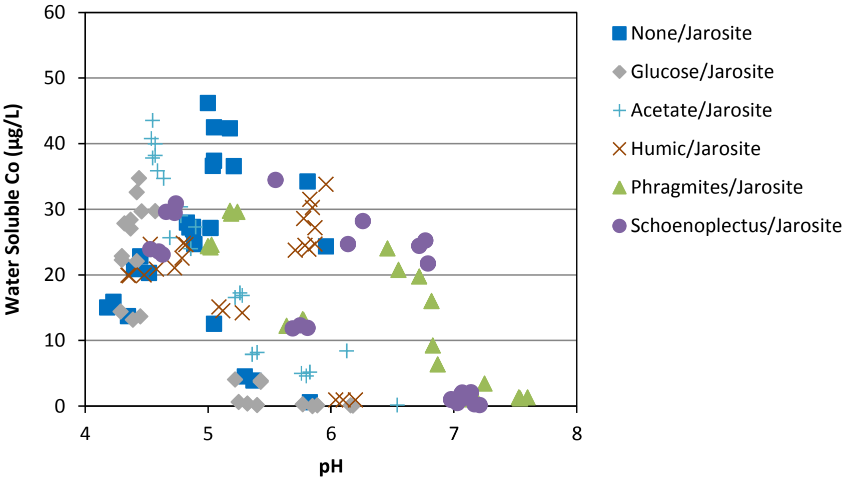


Figure 8-26. Comparison of the surface water pH and cobalt concentrations for the batch experiment (jarosite treatments).

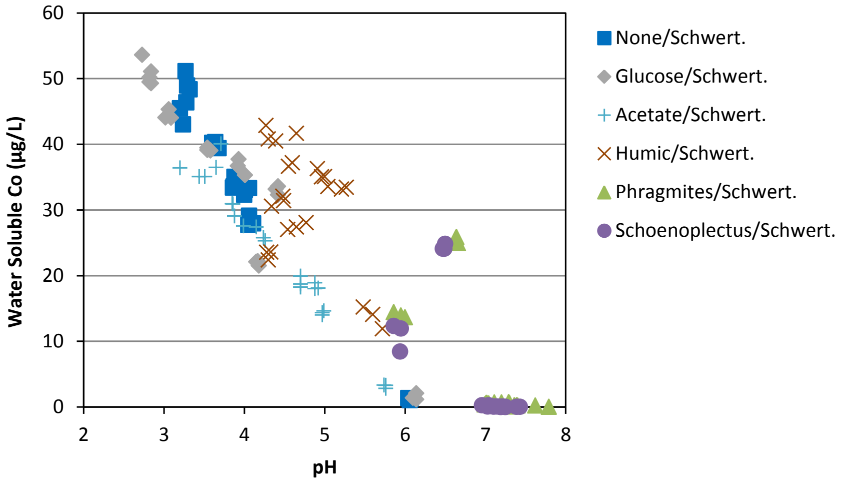


Figure 8-27. Comparison of the surface water pH and cobalt concentrations for the batch experiment (schwertmannite treatments).

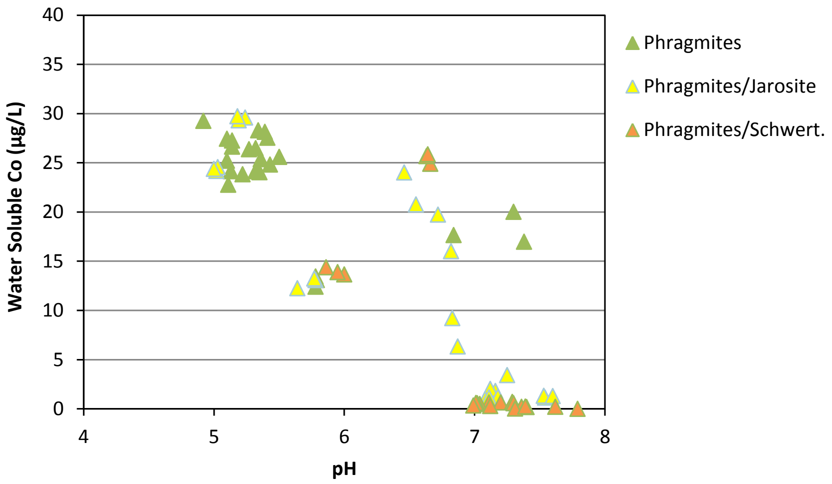


Figure 8-28. Comparison of the surface water pH and cobalt concentrations for the batch experiment (*Phragmites* treatments).

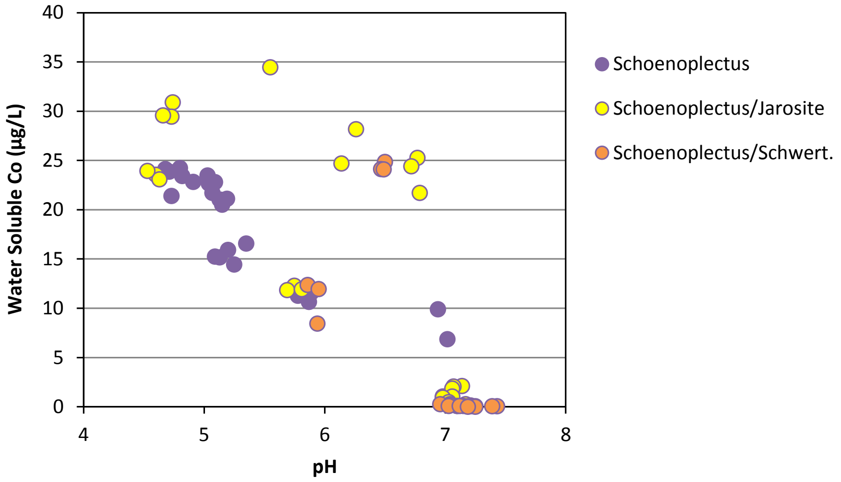


Figure 8-29. Comparison of the surface water pH and cobalt concentrations for the batch experiment (*Schoenoplectus* treatments).

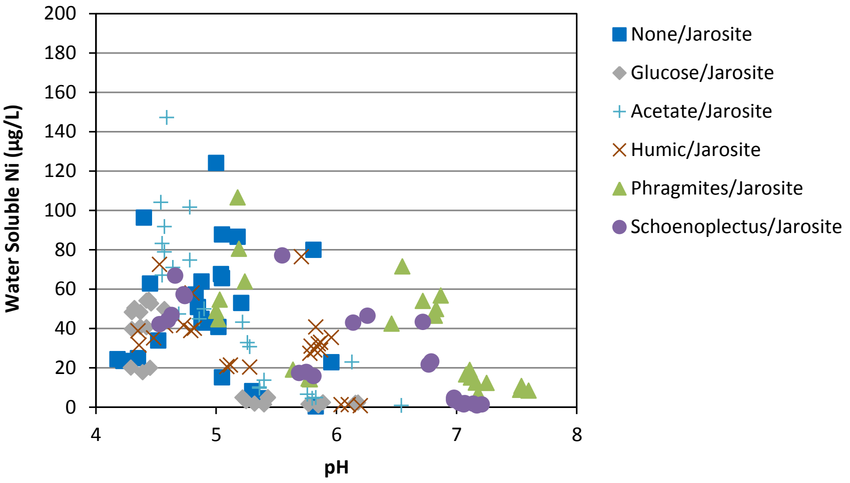


Figure 8-30. Comparison of the surface water pH and nickel concentrations for the batch experiment (jarosite treatments).

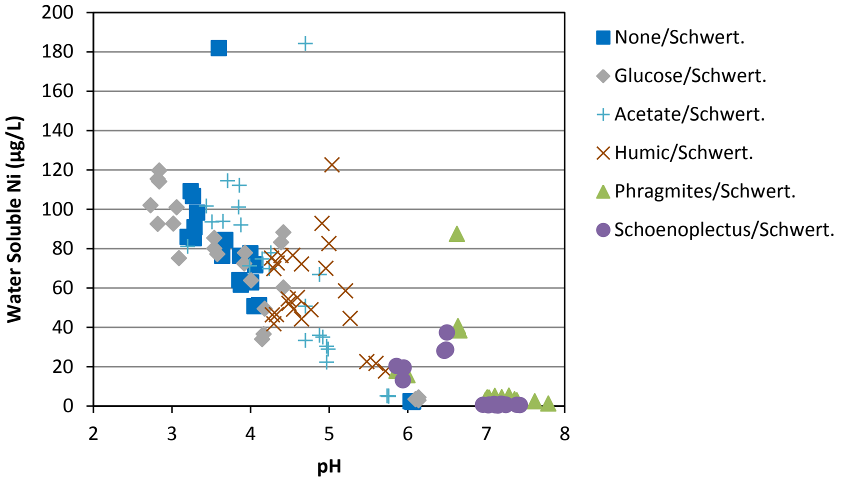


Figure 8-31. Comparison of the surface water pH and nickel concentrations for the batch experiment (schwertmannite treatments).

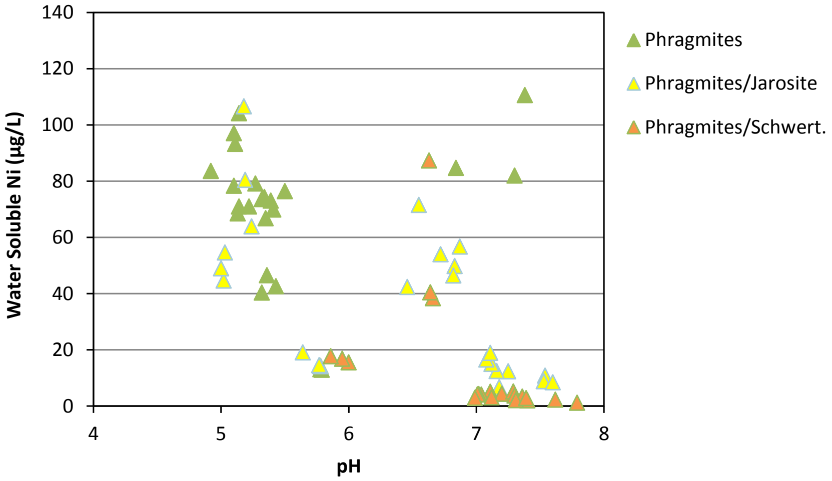


Figure 8-32. Comparison of the surface water pH and nickel concentrations for the batch experiment (*Phragmites* treatments).

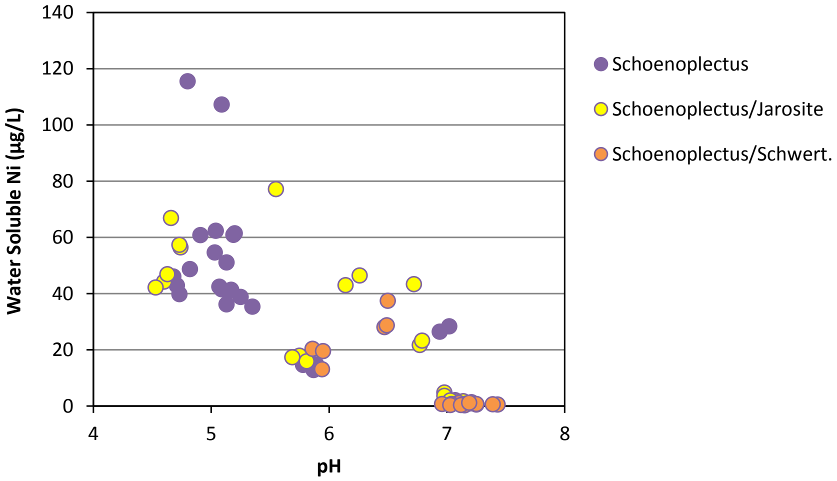


Figure 8-33. Comparison of the surface water pH and nickel concentrations for the batch experiment (*Schoenoplectus* treatments).

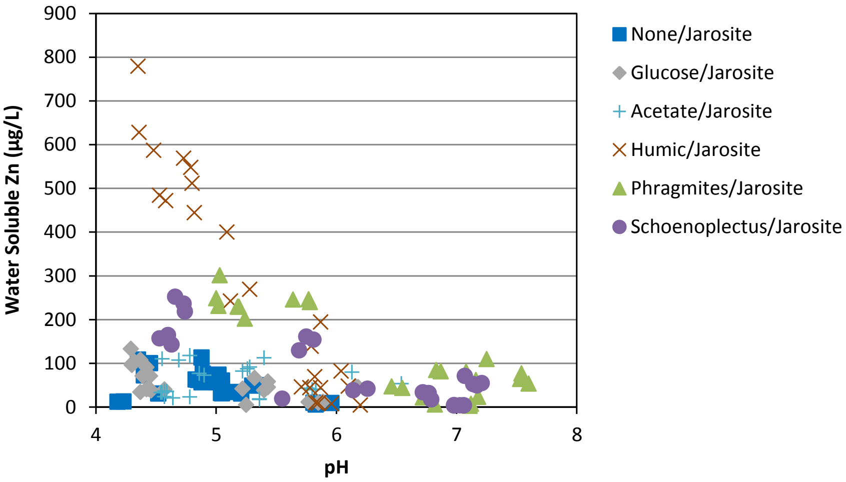


Figure 8-34. Comparison of the surface water pH and zinc concentrations for the batch experiment (jarosite treatments).

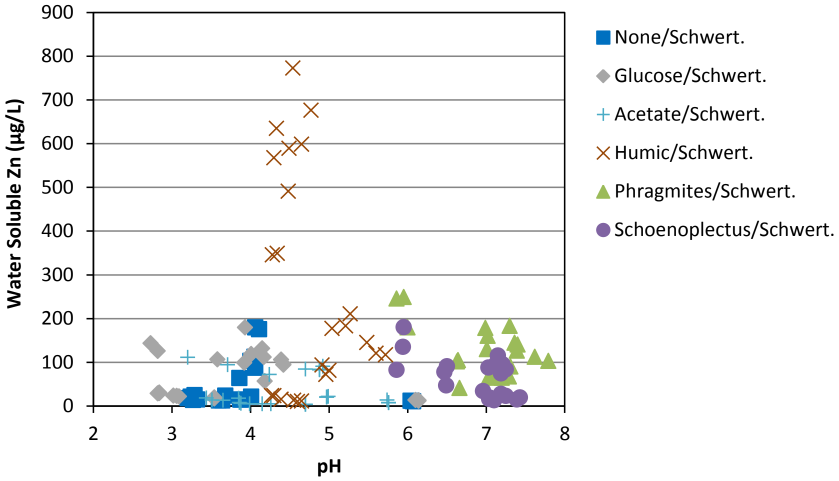


Figure 8-35. Comparison of the surface water pH and zinc concentrations for the batch experiment (schwertmannite treatments).

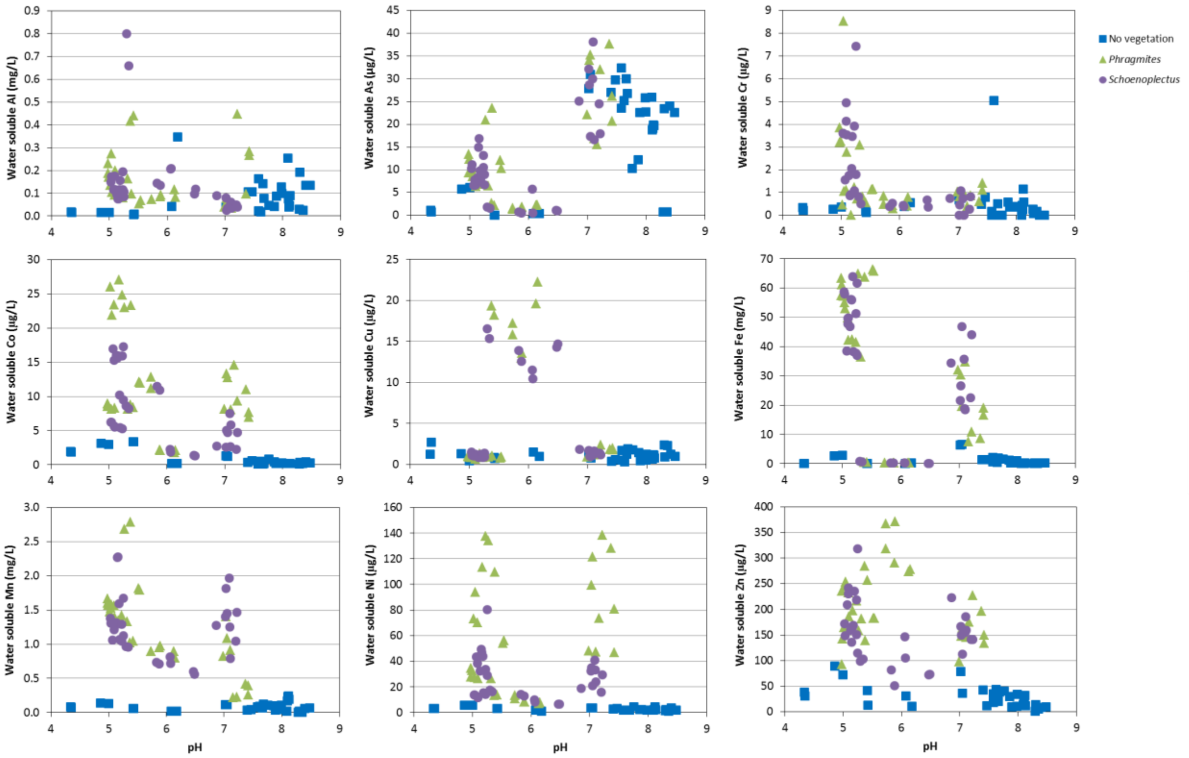
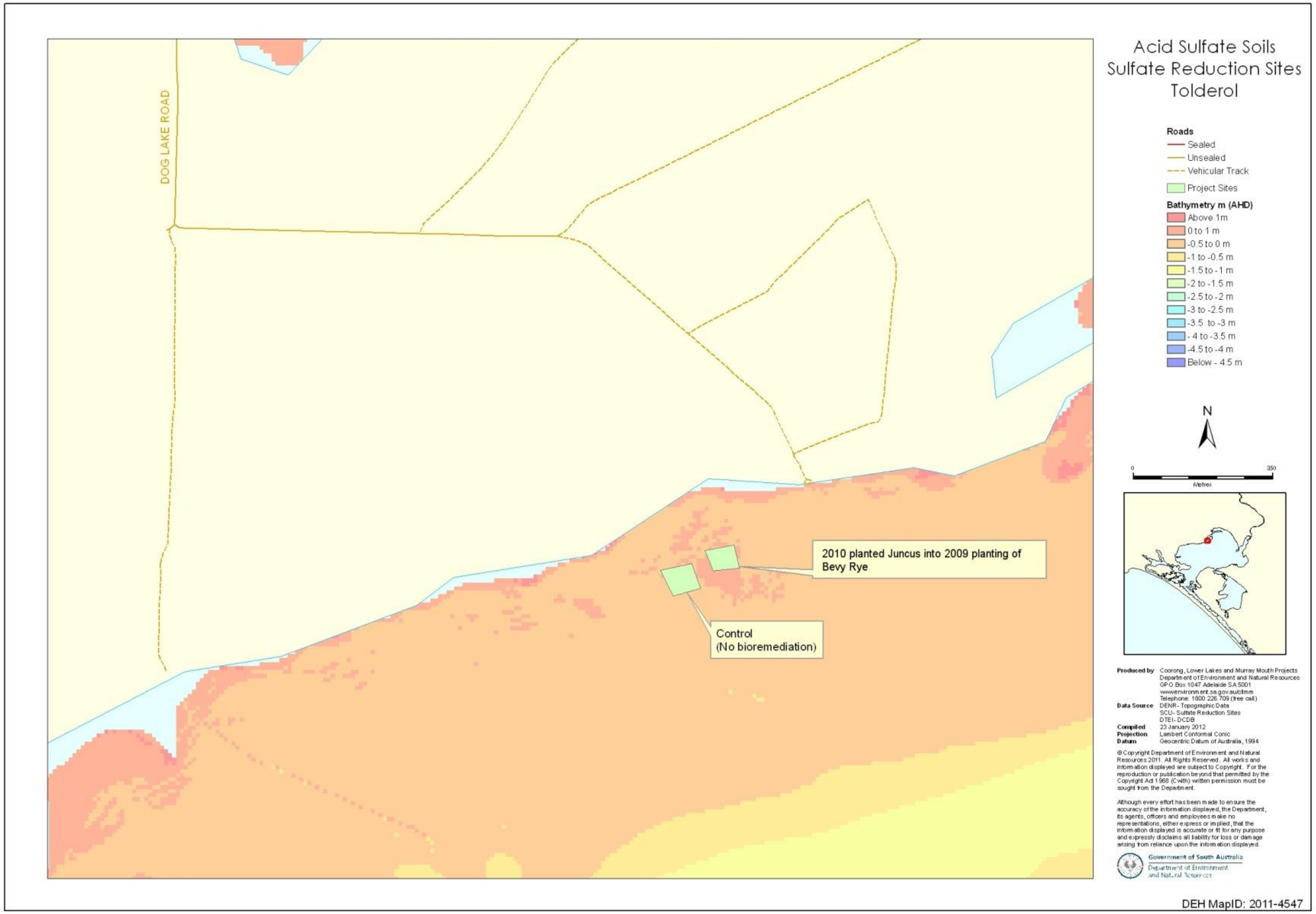


Figure 8-36. Water soluble metal(loid) concentrations as a function of pH for the mesocosm experiment.

APPENDIX 8. Additional information



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Telephone: 1800 226 709 (free call)
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SCU - Sulfate Reduction Sites
DTEI - DCDB
Compiled 23 January 2012
Projection Lambert Conformal Conic
Datum Geocentric Datum of Australia, 1994

Figure 8-37. Bathymetry map for the Tolderol study area (source: DEWNR).

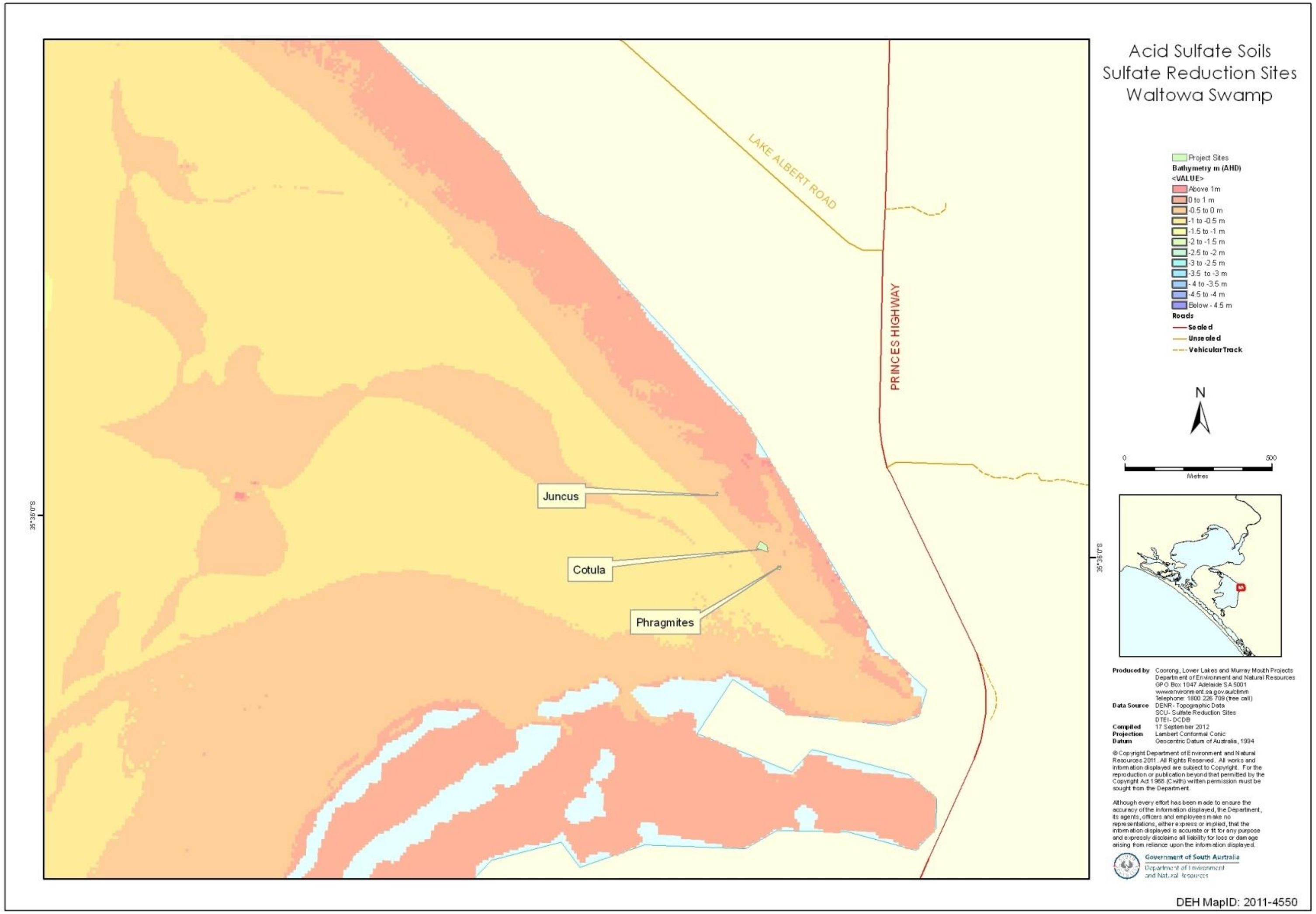

Figure 8-38. Bathymetry map for the Waltowa study area (source: DEWNR).

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