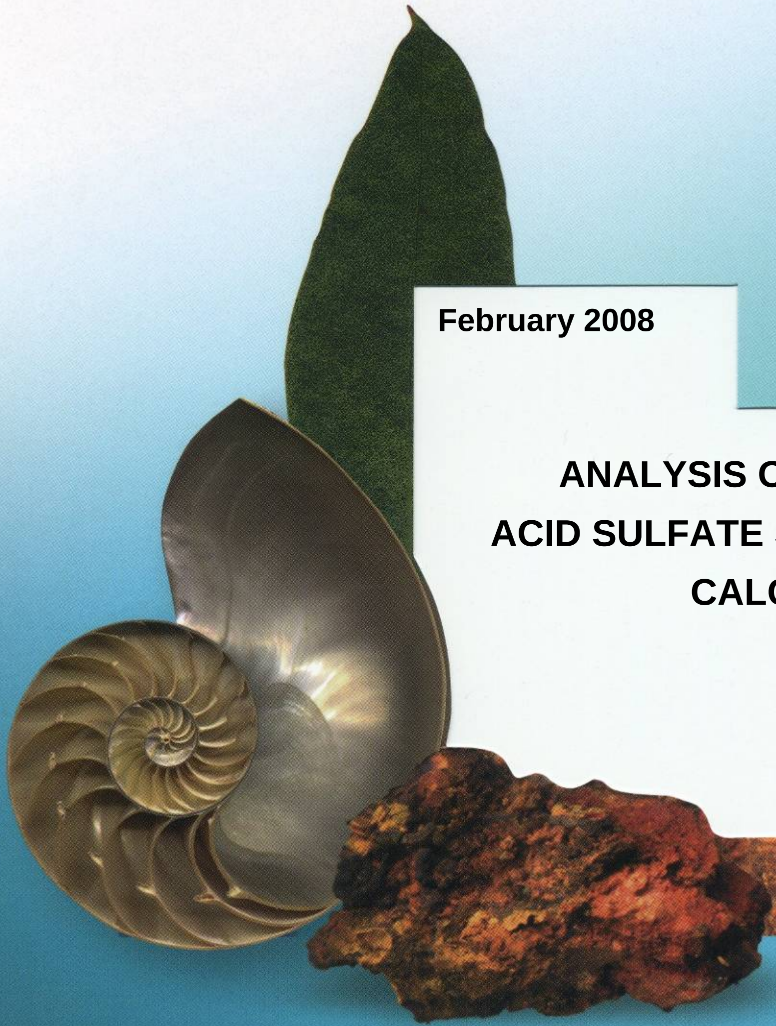
Centre for ecosystem management

EDITH COWAN UNIVERSITY
PERTH WESTERN AUSTRALIA



February 2008

ANALYSIS OF DELWANEY DRAIN ACID SULFATE SOIL TREATMENT USING CALCITE PELLETS

By, Mr. Ryan Sawyer
Dr. Clint McCullough
A/Prof. Mark Lund

CENTRE FOR ECOSYSTEM MANAGEMENT

February 2008

ANALYSIS OF DELWANEY DRAIN ACID SULFATE SOIL TREATMENT USING CALCITE PELLETS

By, **Mr. Ryan Sawyer**
Dr. Clint McCullough
A/Prof. Mark Lund

Centre for Ecosystem Management Report No. 2008-02

Prepared for,

Water Corporation and City of Stirling

Mr. Ryan Sawyer BSc (Hons), MSc Candidate,

Dr. Clint McCullough BSc, MSc (Hons), PhD (Aquatic Ecotoxicologist),

A/Prof. Mark Lund BSc (Hons), PhD (Aquatic Ecologist)

1. Executive Summary

1. Perth urban stormwater is channelled by drainage networks into local receiving water bodies. These drainage networks often include constructed wetlands intended for removal of high nutrient and/or metal/metalloid concentrations.
2. Where development has triggered acid sulphate soils to commence discharging acid waters, these can be intercepted by the stormwater drainage network. These discharges can be moved by stormwater into constructed wetlands. The impact these acid waters might have on the performance of constructed wetlands is not known.
3. Calcite ($CaCO_3$) pellets produced during water purification at the Neerabup Groundwater Treatment Plant in Perth, have a capacity for neutralising acid waters.
4. The Delwaney Drain and Brushfield Wetland are part of the stormwater drainage network within the City of Stirling that discharges into Lake Gwelup. The network, particularly Brushfield Constructed Wetland, is known to be impacted by discharges from acid sulfate soils. The Delwaney Drain has been modified by Water Corporation to contain calcite pellets, aiming to treat this acidic discharge in the drain.
5. This project aims to assess the impact that acidic discharges from acid sulphate soils are having on water quality within the Brushfield wetland, what impact the wetland might have on the acidic water, and lastly what impact calcite pellets in the Delwaney Drain might be having on water quality.
6. Monitoring indicates that acid sulfate soil contamination is present within Brushfield Wetland and the extent of contamination fluctuates based on time of year and the relative dominance of groundwater/stormwater influx. Even during periods of low pH at the mid-point and output of Brushfield Wetland, pH remains relatively high at the input drain.
7. The pH of water within Brushfield Wetland is dependent on the occurrences of storms and stormwater flow. At the input, mid-point and output mean daily pH differed signicantly dependent on storm or baseflow periods. Brushfield Wetland

water became increasingly acidic as storm flows ebbed. It is unclear whether decreased pH is caused by acidic groundwater influx or acid generation within wetland sediments.

8. Delwaney Drain monitoring suggests that the current application of calcite pellets does not intercept highly acid sulfate soil contaminated water ingress to Brushfield Wetland. Furthermore, physicochemical characteristics and acid sulfate soil contamination indicators do not appear to vary along the drain indicating insignificant water quality treatment by the calcite.

9. The calcite pellets may still be effective in another location but a variety of factors must be considered, namely placement and placement methodology, potential for armouring, and effective lifespan of calcite pellets.

Frontispiece

Water remaining in Delwaney Drain at main input to Brushfield Wetland after a three day period with low rainfall (September 12, 2007).

This document should be referenced as follows.

Sawyer, W. R. A.; McCullough, C. D. & Lund, M. A. (2008). *Analysis of Delwaney Drain acid sulfate soil treatment using calcite pellets*. Centre for Ecosystem Management Report No. 2008-02, Edith Cowan University, Perth, Australia. 24 pp.

2. Contents

3. Background

Stormwater can degrade receiving aquatic ecosystems in urban areas through high concentrations of nutrients and toxic substances (Makepeace et al., 1995). Effective stormwater treatment is vital to avoid significant degradation of urban aquatic receiving environments (Goonetilleke et al., 2005; Makepeace et al., 1995). Urban stormwater is channelled through drainage networks which frequently include water quality treatment constructed wetlands, which are known to improve surface drainage quality (Lawrence & Breen, 1998; Tyrrell, 1995). Environmental acidification detrimentally impacts wetland water quality treatment processes including adsorption and precipitation (Stumm & Morgan, 1996; Tyrrell, 1995), absorption (Fyson, 2000) and bacterially mediated reactions (Postgate, 1984). Acid sulfate soil contamination of stormwater drainage networks is therefore likely to impact on the effectiveness of constructed wetlands for stormwater treatment.

Current acid sulfate soil treatment strategies primarily rely on anaerobic processes and/or chemical neutralisation. Water Corporation has been trialling the use of calcite pellets for chemical neutralisation, by installing pellets within a stormwater drain believed to be affected by acid sulfate soil discharges. Calcite pellets are a by-product of drinking water purification processes that may assist in acid neutralisation within aerobic systems.

This report outlines the results of a monitoring program conducted on the application of calcite pellets within Delwaney Drain in Gwelup, a suburb of the City of Stirling, Western Australia. The Delwaney Drain is a section of a stormwater drainage network that also includes the constructed Brushfield Wetland. Acid sulfate soil contamination is a known problem within the City of Stirling (Appleyard et al., 2006; Appleyard et al., 2004; Hinwood et al., 2006), and oxidation of the soils is known to have caused periodic decreases in the Brushfield Wetland's pH to approximately pH 4 since the early 2000s (D. Rajah, City of Stirling, personal communication, 2007). The Brushfield Wetland is the final section of the drainage network and discharges this potentially contaminated water directly into Lake Gwelup, a biologically and culturally significant reserve covering an area of approximately 73 hectares including the 18 hectare lake (City of Stirling, 2006).

4. Delwaney Drain Monitoring Results

Brushfield Wetland and Delwaney Drain were monitored between July and December, 2007. The sampling sites, shown in Figure 1, were monitored using ISCO 6700 automated sampling units with ISCO 630 bubble flow modules, YSI 600XLM sondes and manual grab sampling (see Appendix 1 for images of the sampling sites). The Brushfield Wetland receives influent stormwater from one main input drain that channels water from the Delwaney Drain and two below-ground drains, as well as four local roadway drains surrounding the wetland.

Figure 1:Aerial view of the Brushfield Wetland (orange outline), Delwaney Drain (red outline), two below-ground drains (green arrows) and four local roadway drains (blue arrows). Yellow circles represent the Brushfield Wetland monitoring sites (input, mid-point and output) and purple circles indicate Delwaney Drain monitoring sites (north and south).

This monitoring yielded the following results:

1. There is evidence of acid sulfate soil contamination within Brushfield Wetland. The extent to which contamination occurs varies throughout the year. In particular pH measured at the monitoring sites was low (pH 3-4) at the beginning and end of winter (Figure 2). The initial period of low pH water is thought to be due to the release of acid sulfate soil contaminants that oxidised within Brushfield Wetland sediments over the preceding summer. The low pH values measured at the end of winter may be caused by acidic groundwater influx, which likely increases during this period (Figure 4).

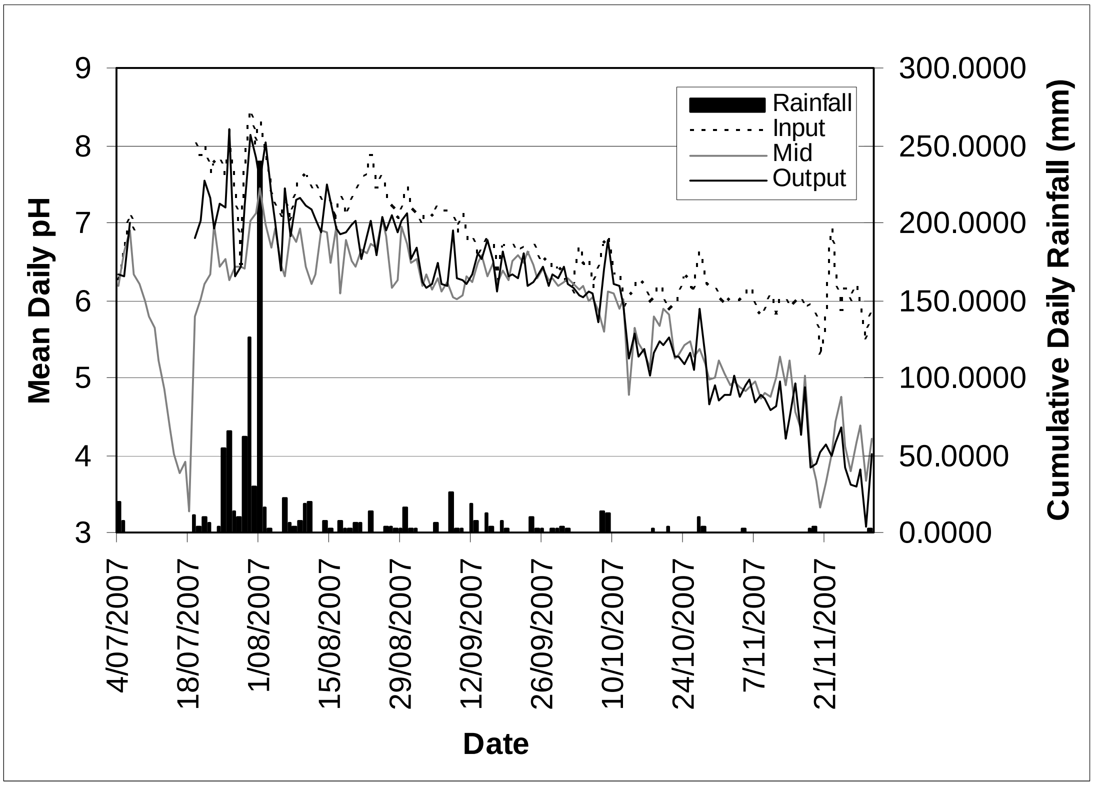


Figure 2: Cumulative daily rainfall and mean daily pH at the three Brushfield Wetland sampling sites. The short gap in early July for input and output data points is due to drying of these sections of the wetland and lack of flow.

2. At the end of winter the pH of water entering the Brushfield Wetland at the main input drain did not decrease below pH 5 whereas the pH at the mid-point and output sites dropped below pH 4 (Figure 2). As the Delwaney Drain was dry

during the late winter this difference is not related to the application of calcite pellets. As such, it was likely that acid sulfate soil contaminants within the wetland were due to acidic groundwater influx and/or acid generation within the wetland sediments. Treatment strategies focusing on the input drain therefore appear to have minimal effects on water quality entering Lake Gwelup.

3. pH was highly responsive to storm events with mean pH at each respective monitoring site differing significantly between base- and storm- flow periods (Figure 3). Additionally, during storms the pH typically decreased between the input and mid-point but would increase prior to discharge into Lake Gwelup. Alternatively pH remained relatively constant between the mid-point and output during base flow. The increases in pH between Brushfield Wetland mid-point and output sites during storm flow are probably due to the influx of additional stormwater from three roadway drains within this section of the wetland. This data also further supports that influent water at the main input drain is not a significant source of acid sulfate soil contamination within Brushfield Wetland.

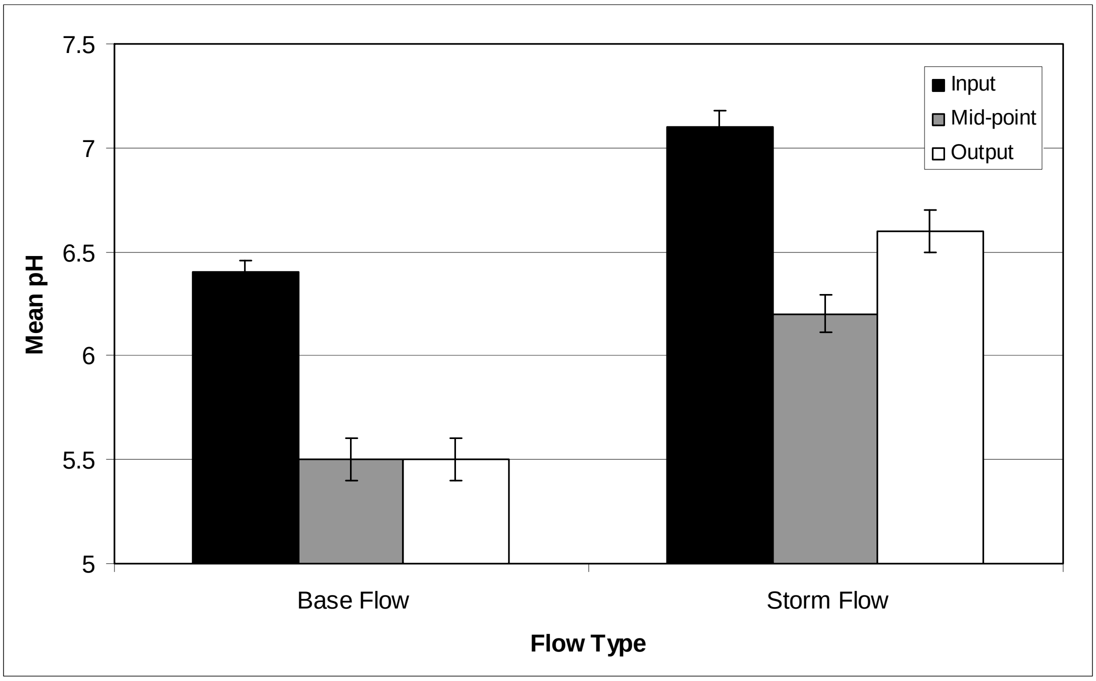


Figure 3: Mean pH at the input, mid-point and output of the Brushfield Wetland during base and storm flow. Error bars depict standard error.

4. The Delwaney Drain was full between the north and south sites (pre- and post-calcite treatment respectively) only three times throughout the monitoring period (monitoring occurred every 24 hours). During these occasions stormwater was the main influent water source for the Brushfield Wetland (Figure 4). The water quality within the Delwaney Drain during these three periods was not indicative of significant acid sulfate soil contamination:

    a. pH varied between the north and south sites by a maximum of <0.1 pH unit for each set of data. Across the three sampling sets the minimum measured was pH 6.3 and the maximum pH 6.8.

    b. Oxidation reduction potential varied between the north and south sites by a maximum absolute value of only 22 mV on any given sampling date. ORP values ranged between -81 mV and -59 mV.

    c. Specific conductance varied between the north and south sites by a maximum of <0.1 mS cm^{-1}.

    d. Dissolved oxygen did not exceed 0.2 mg L^{-1} at any time.

    e. With a range between 0.30-1.33, chloride:sulfate molar ratios did indicate the presence of acid sulfate soil contamination. On one occasion the indication of acid sulfate soil contamination seemed to decrease between the north and south sites. This is probably explained by the daily cumulative rainfall of 240 mm on that day and a subsequent dilution effect. The ratios compared between the north and south sites for the remaining two sample times varied by <0.07.

   These results indicate that the application of calcite pellets did not affect water quality within the Delwaney Drain. Furthermore, as indicated above acid sulfate soil contaminants appeared to follow an alternative pathway into the Brushfield Wetland.

5. A water budget was created accounting for all inputs (rainfall and all stormwater drain discharges) and outputs (evapotranspiration and output drain discharge into Lake Gwelup) other than groundwater influx/efflux. The water budget suggests that there was limited likelihood of groundwater influx until late September, at which point the Delwaney Drain was dry (Figure 4). As such, the Delwaney Drain

transports primarily uncontaminated stormwater and does not intercept acid sulfate soil contaminated groundwater. Furthermore groundwater is more likely to enter and affect water quality within Brushfield Wetland during later winter, while stormwater is the dominate influent water source during early winter.

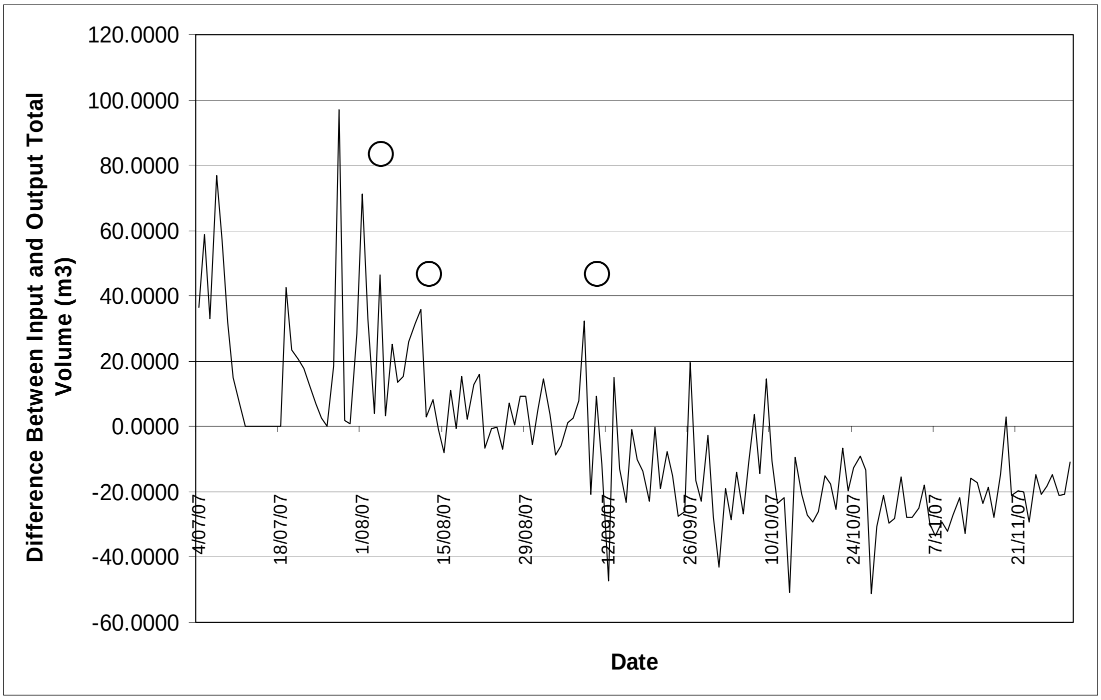


Figure 4: The difference between total input and total output of water within the Brushfield Wetland. Positive differences suggest water efflux from the Brushfield Wetland into groundwater while negative differences suggest groundwater influx. Three white circles denote the times sampling was possible within the Delwaney Drain.

6. Following winter, sections of the Delwaney Drain did not appear to have the quantity of calcite pellets remaining that were observed in June/July 2007. As shown in Appendix 1 these areas appeared to either not contain pellets or the depth of the pellets was below the shoring along the drain. It is also likely that only the surface layer of pellets were reacting with the water, rather than the entire depth of pellets. This would substantially limit the effectiveness of the pellets to neutralise large volumes of stormwater.

Sewage Contamination

During the monitoring period several results suggested that sewage was entering one or both of the below-ground stormwater drains leading to the Brushfield Wetland input drain. This was suggested due to:

1. Extremely low ORP values between -400 mV to -500 mV at the Brushfield Wetland input drain;
2. 0 mg L^{-1} dissolved oxygen at the Brushfield Wetland input drain (concentration below detection limits of the YSI 600XLM sondes used for monitoring the site);
3. A characteristic and distinctive odour at the Brushfield Wetland input drain.

The sewage leakage was believed to be into the below-ground drains as their physicochemical characteristics do not match those monitored within the Delwaney Drain during the two Delwaney Drain monitoring periods, when extreme ORP values were seen. In these cases ORP at the south sampling site of Delwaney Drain was between -81 mV to -64 mV (merely five to ten metres away from the Brushfield Wetland input drain sampling site). Due to a large variation, ORP, was also checked using two sonde instruments and in all cases the respective readings varied by less than 3%. This information has already been provided by email to Water Corporation for investigation.

5. Conclusions

Groundwater influx into Delwaney Drain, a believed source of acid sulfate soil contamination within the stormwater drainage network, did not appear to occur as the drain remained dry during the late winter when groundwater levels peaked. During limited periods where water actually flowed continuously through the drain, the application of calcite pellets within the Delwaney Drain did not appear to improve water quality entering the Brushfield Wetland. During periods of continuous flow the water was primarily uncontaminated stormwater and water quality did not change notably between the north and south sampling sites.

Brushfield Wetland became severely acid during early and late winter. Water quality within Brushfield Wetland seemed to be dependent on the occurrences and intensities of storms. Monitoring showed increasingly acidic waters within Brushfield Wetland as storm flow decreased. It remains to be determined whether the acidity is caused by acidic groundwater influx or acid generation within the wetland sediments. As Brushfield Wetland itself appears to accommodate all acid sulfate soil contaminants within the stormwater drainage network, any treatment strategy for improving water quality flowing into Lake Gwelup must focus on improving water quality within the Brushfield Wetland. Furthermore these strategies should treat water as it flows through Brushfield Wetland rather than at input stormwater drains as influent stormwater did not appear to be a significant source of acid sulfate soil contamination.

6. Recommended Future Work

1. Vegetation and sediment samples should be collected from Brushfield Wetland to determine the fate of contaminants and the possibility of acid generation within wetland sediments.

2. Groundwater samples and depth data should be analysed to consider the possibility whether significant acid sulfate soil contamination could have entered Brushfield Wetland via groundwater.

3. Water samples from Delwaney Drain and Brushfield Wetland should be analysed for nutrient and metal/metalloid concentrations.

4. Laboratory studies should be conducted to determine the efficacy of the calcite pellets for the treatment of actual acid sulfate soil contaminated water and urban stormwater collected from the study site.

5. The results of calcite pellet laboratory studies should be applied to develop a modified strategy that might make use of calcite pellets for the treatment of acid sulfate soil contamination. For example, pellets might be used in a treatment option further into Brushfield Wetland such as a reactive wall between the mid-point and output. Prior to any such application of the pellets the following should be determined:

    a. Potential of calcite pellet for armouring

    b. Effective lifespan of the pellets

    c. Application method and location

7. References

Appleyard, S. J., Angeloni, J., & Watkins, R. (2006). Arsenic-rich groundwater in an urban area experiencing drought and increasing population density, Perth, Australia. *Applied Geochemistry, 21*(1), 83-97.

Appleyard, S. J., Wong, S., Willis-Jones, B., Angeloni, J., & Watkins, R. (2004). Groundwater acidification caused by urban development in Perth, Western Australia: source, distribution, and implications for management. *Australian Journal of Soil Research, 42*, 579-585.

City of Stirling. (2006). Lake Gwelup Reserve Management Plan. In *Agenda of the Infrastructure and Community Development Committee Meeting of 25 July 2006* (pp. 138-147). Stirling, WA, Australia: City of Stirling.

Fyson, A. (2000). Angiosperms in acidic waters at pH 3 and below. *Hydrobiologia, 433*, 129-135.

Goonetilleke, A., Thomas, E., Ginn, S., & Gilbert, D. (2005). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental Management, 74*(1), 31-42.

Hinwood, A. L., Horwitz, P., Appleyard, S. J., Barton, C., & Wajrak, M. (2006). Acid sulphate soil disturbance and metals in groundwater: Implications for human exposure through home grown produce. *Environmental Pollution, 143*(1), 100-105.

Lawrence, I., & Breen, P. (1998). *Design Guidelines: Stormwater Pollution Control Ponds and Wetlands* (1 ed.). Canberra, ACT, Australia: Cooperative Research Centre for Freshwater Ecology.

Makepeace, D. K., D.W., S., & Stanley, S. J. (1995). Urban stormwater quality: summary of contaminant data. *Critical Reviews in Environmental Science and Technology, 25*(2), 93-139.

Postgate, J. R. (1984). *The sulphate-reducing bacteria*. New York: Cambridge University Press.

Stumm, W., & Morgan, J. J. (1996). *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters* (3 ed.). Brisbane, QLD, Australia: John Wiley and Sons, Inc.

Tyrrell, W. (1995). *A review of wetlands for treating coal mine wastewater, particularly in low rainfall environments in Australia* (AMEEF Occasional Paper No. 3). Melbourne, VIC, Australia: Australian Minerals and Energy Environment Foundation.

8. Appendix 1: Site Images

Figure 5: Brushfield Wetland (July 3, 2007).

Figure 6: Channel between Brushfield Wetland basin and output drain (September 5, 2007).

Figure 7: North sampling site of Delwaney Drain.

Figure 8: South sampling site of Delwaney Drain.

Figure 9: Delwaney Drain during the first possible monitoring period (August 1, 2007).

Figure 10: Section of Delwaney Drain showing decreased quantity of calcite pellets and exposed drain shoring (November 29, 2007).

Figure 11: Brushfield Wetland input drain sampling site.

Figure 12: Brushfield Wetland output drain sampling site showing ISCO 6700 autosampler.

Figure 13: Installation of YSI Sonde unit in Brushfield Wetland output drain.