Improving Ammonia and Phosphorus Removal
in
Subsurface Flow Wetlands

Presented to

Texas On-Site Wastewater Treatment Research Council

by

Margaret G. Forbes
Joe C. Yelderman, Jr.
Tina Potterton
Adam Clapp
and Robert D. Doyle

Baylor University
Wastewater Research Program

Teresa D. Golden
University of North Texas
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EXECUTIVE SUMMARY

This study provides information that can be used to improve design and operation of wetland wastewater treatment systems. While all of the subsurface flow wetland units exhibited good (~70 - 80%) reduction of total suspended solids and $CBOD_5$, there were differences in phosphorus and nitrogen removal among the various treatment designs.

Passive aeration, particularly intermittent loading (WET3), reduced ammonia levels and increased nitrification compared to the continuously loaded control unit. The intermittently loaded unit had the lowest NH_3-N in the study at a mean ($\pm$ standard deviation) of 10.9 $\pm$ 9.0 mg l^{-1} and the highest concentrations of NO_3-N (mean 7.2 $\pm$ 6.8 mg l^{-1}) . Similar trends were evidenced in the unit with elevation drops (WET5), but results for that unit were complicated by a leak and possibly by simultaneous nitrification-denitrification.

While all of the newly constructed wetlands had good phosphorus removal, the intermittently loaded unit produced the lowest dissolved phosphorus levels (mean 1.4 mg l^{-1}) for a removal rate of 67%. In contrast, the 3-year old gravel unit (WETBIG) removed only about 18% of incoming phosphate-P. X-ray diffraction analyses of the expanded shale suggest that the formation of calcium carbonate promotes the growth of the calcium phosphates on the surfaces of the media, resulting in long-term, irreversible storage of wastewater phosphorus.

Intermittent loading was an effective treatment method and may have potential to improve overall treatment as well as serve as an effective management technique for treatment wetlands. Expanded shale aggregate is an effective media but we were not able to demonstrate differences between gravel and shale units as hypothesized. We were not able to demonstrate differences between unplanted units and planted units. The study had limitations due to the high temporal variability of wastewater parameters, the small size of the systems, and the short time frame over which the study was conducted. We suggest that intermittent loading be investigated with extended retention times to achieve optimal nitrogen and phosphorus removal. In addition, a longer study period would facilitate the investigation of the sequestration of phosphorus into long-term crystal growth on the surface of wetland media.

INTRODUCTION

Cultural eutrophication of surface waters is a widespread problem that results primarily from nutrient enrichment from a variety of sources including municipal wastewater and on-site systems. Many on-site systems do not have suitable soils to adequately treat septic tank effluent and thus additional treatment is required between the septic tank and the discharge field. Reduction of high ammonia-nitrogen (NH_3-N) is necessary due to its potential toxicity to aquatic organisms as well as its contribution to eutrophication. Phosphorus (P) has been shown to be the limiting nutrient in most freshwater systems and P discharges are likely to be regulated in the foreseeable future.

Constructed wetlands have become a cost-effective, low energy, low technology solution for secondary and tertiary treatment of wastewater. However, there is a need to improve their design and operation with respect to long-term removal of nitrogen and phosphorus. Our research builds on previous work at the Baylor Wastewater Research Program (BWRP) in which a subsurface flow (SSF) wetland produced an average total nitrogen effluent of approximately 30 mg l^{-1}. Most of the nitrogen was in the form of NH_3-N (Davila et al. 2006). Although the wetland effluent still exhibited toxicity to test organisms, it was less than that of the septic effluent (Rodriguez et al. 2006). The concentration of NH_3-N known to cause sublethal effects is 12.3 mg l^{-1} (EPA 1999). Continued operation of the SSF wetland at Baylor has resulted in further reduction of ammonium levels; however, the levels remain above 12.3 mg l^{-1}.

NH_3-N removal can be challenging during cold weather even in conventional treatment plants due to the temperature sensitivity of *Nitrobacter* and *Nitrosomas* nitrifying microbes. Using SSF wetlands for NH_3-N removal has additional challenges primarily related to the low dissolved oxygen levels in SSF systems. The short retention time in most SSF wetlands means there will be constant competition from carbon-utilizing microbes which tend to out-compete nitrifiers for available oxygen.

Phosphorus (P) reduction in a subsurface flow wetland occurs primarily via sorption to sediments or substrates, thus it is important to select a substrate with a high P-sorption capacity. Expanded shale, a light-weight aggregate manufactured by Texas Industries, Inc., has both a very high P-sorption capacity and a high hydraulic conductivity (Forbes et al. 2004). The material was used to remove dissolved phosphorus from an activated sludge effluent in north Texas, which was primarily (>90%) dissolved P. The shale has not, to our knowledge, been used to remove P from septic tank effluent, which has much higher levels of TP and particulate-P. Neither the ultimate P-sorption capacity nor the expected "life" of the material is known. We believe that phosphate associates with aluminum in the crystal lattice work of the shale, and may also form calcite crystals (Kaasik et al. 2008, Forbes et al. 2005). Over longer time periods (weeks to months), these calcite crystals may transition into more insoluble crystals, eventually forming extremely insoluble crystalline substances such as hydroxyapatite. If these processes are confirmed, the ultimate life of the SSF wetland with respect to P removal would be considerably longer than predicted by laboratory tests.

The objectives of our research were to improve the nitrogen and phosphorus removal capacity of SSF wetlands receiving septic tank effluent. Because nitrification is enhanced by increasing oxygen levels, we investigated two methods for increasing oxygen: passive aeration and intermittent loading. These two treatments were compared to a system that has continuous loading and relies solely on radial oxygen loss from plant roots and diffusion for oxygenation. To evaluate phosphorus removal capacity, we compared units with expanded shale to units with only gravel substrate. We also examined exposed shale with X-Ray Diffraction (XRD) to determine changes in the crystalline structure of the filter material. The presence of P-containing crystals would suggest that long-term sequestration of P is occurring.

METHODS

Study Design

To test various SSF wetland designs, we built five pilot-scale SSF wetland cells (2 ft wide x 10 ft long x 1.25 ft deep) adjacent to the existing larger SSF wetland (10 ft x 50 ft) at the Baylor Wastewater Research Program facility. Unit 1 (WET1) served as a control, and was constructed using alternating sections of expanded-shale aggregate (shale) and Grade 3 Concrete Rock (gravel). Each section was planted with *Schoenoplectus californicus* (C.A. Mey.; giant bulrush). The unit was dosed under the NSF/ANSI Standard 40 design loading protocol currently used at the facility. The hydraulic loading rate was 20 gpd/cell (1 gal per sq ft per day), yielding a hydraulic retention time of approximately two days. The remaining units were identical to the control except for the following details: Unit 2 (WET2) had no plants; Unit 3 (WET3) was intermittently loaded instead of continuously loaded but it received the same total volume of effluent on a weekly basis; Unit 4 (WET4) had no shale (gravel only); and Unit 5 (WET5) had elevation drops where the water dripped from one sub-unit to the next and air ports to facilitate oxygen exchange between the atmosphere and the submerged media. A schematic of the wetland designs is shown in Figure 1. A photo of the units taken soon after planting is shown in Figure 2. The following hypotheses were tested:

Hypothesis 1. Plants contribute measurably to higher dissolved oxygen concentrations and ammonia removal. (Compare Unit 2 to Control).

Hypothesis 2. Intermittent loading provides higher dissolved oxygen concentrations and better ammonia removal than continuous loading. (Compare Unit 3 to Control).

Hypothesis 3. Passive aeration (air ports, screened elevation drops, etc.) provides higher dissolved oxygen concentrations and a higher percent ammonia removal than aeration through wetland plants alone. (Compare Unit 5 to Control)

Hypothesis 4. Expanded shale removes more dissolved phosphorus than gravel. (Compare Unit 4 to Control).

Hypothesis 5. Expanded shale exposed to septic tank effluent exhibits crystalline formations of Ca-P and Al-P (Compare shale from any Unit 1, 2, 3, or 5 to stockpiled shale).

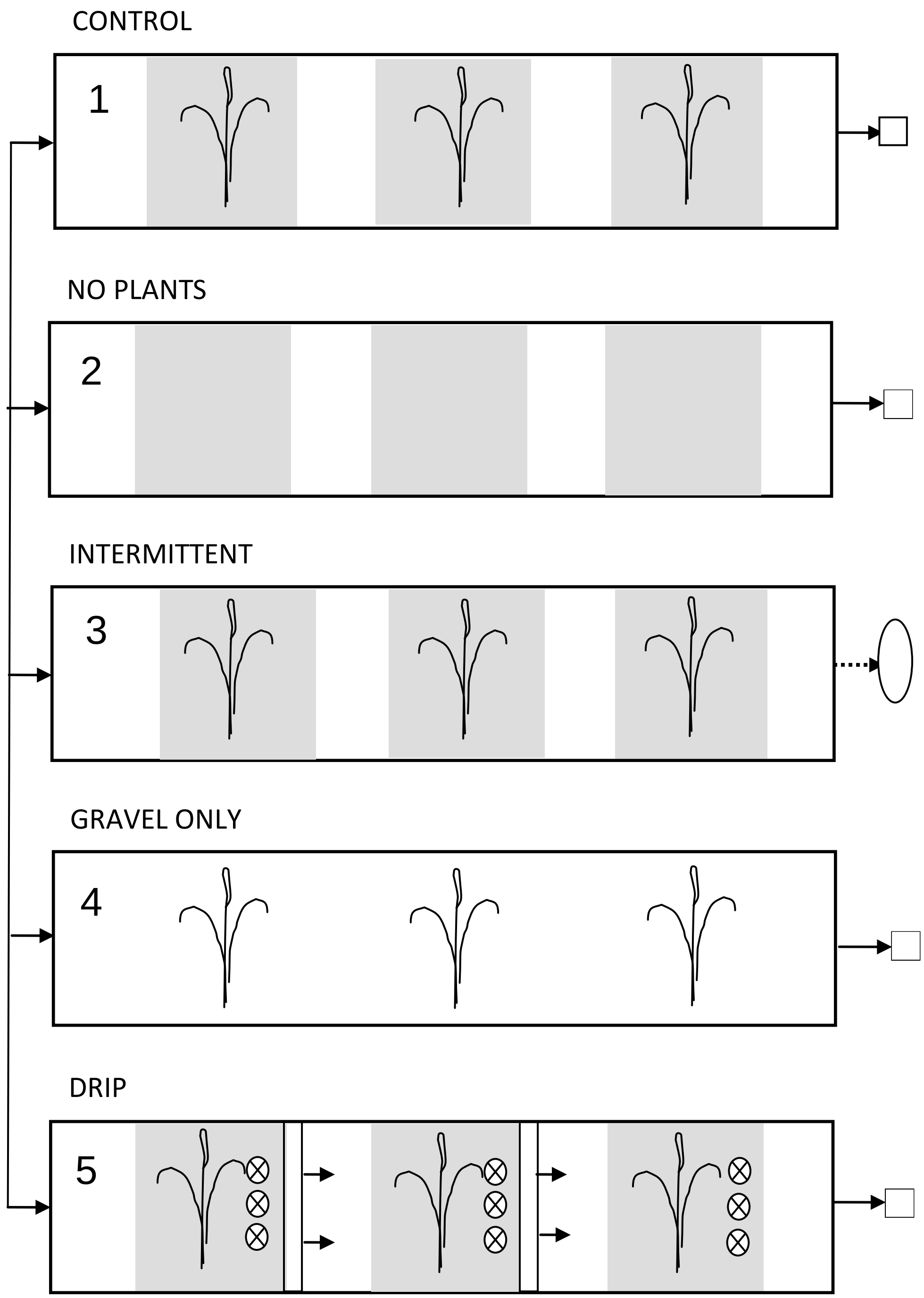

Figure 1. Experimental wetland units showing differences in design and operation. Squares represent 24-hr composite sample locations except for Unit 3 (oval) which was a grab sample. Grey indicates expanded shale sections. Units were 10 ft long x 2 ft wide x 1.25 ft deep.

Figure 2. Photo of experimental SSF units. The units are shown in reverse order; in the foreground is Unit 5 (drip), then Unit 4 (gravel only), Unit 3, Unit 2 (no plants) and Unit 1 (control). Note the big wetland in the background left.

Hypotheses were evaluated using two-sample t-tests (Microsoft Excel 2007). Linear regressions and differences among zones were modeled using analyses of variance (ANOVA) followed by Tukey-Kramer multiple comparison tests (JMP 7.0). Data were logarithmically transformed when necessary to meet assumptions of normality. Effects of sampling date were accounted for in two-way ANOVAs.

Inflow (septic tank effluent) and outflow of the units were sampled weekly using a 24-hour composite sampler. Grab samples were also collected from the Waco Municipal Area Regional Wastewater (WMARRS) inflow (RAW), the distribution tank that transfers wastewater from the WMARRS facility to the BWRP septic tank (BWRP), the big wetland effluent (WETBIG) and the WMARRS effluent (EFF). Grab samples were collected once at intermediate locations in the SSF units, but the flow path distances were too short to detect differences in parameters so we did not continue the intermediate sampling. Instead, we increased the frequency of total phosphorus and total nitrogen analyses from every other week to every week. Table 1 lists the parameters measured, their abbreviations, and the methods used.

Prior to analyses, samples for dissolved nutrients (NH_3, NO_2 + NO_3, and PO_4) were filtered through a 0.45 micron glass fiber filter. Duplicate filters were then used to determine total suspended solids by drying in a 103-105 ºC oven. Total and dissolved nutrients were measured with a Lachat Quickchem 8500 Flow Injection Autoanalyzer at the Center for Reservoir and Aquatic Systems Research (CRASR) laboratory. $CBOD_5$'s were determined in triplicate using a nitrification inhibitor. Temperature, pH, and specific conductance were measured using an YSI XLM 600 multiparameter datasonde.

The structure and mineral composition of the light weight shale before and after effluent exposure was studied by X-ray diffraction (XRD) performed by Dr. Teresa Golden at the University of North Texas Chemistry Department. Samples of each batch were gently ground to produce random powders and each sample was run in triplicate. Analysis was performed with a Siemens D500 diffractometer using Cu Kα radiation (λ=0.15405 nm). The tube source was operated at 35 kV and 24 mA. Scans were run from 5 – 75^{o} 2θ with a step size of 0.05 and dwell time of 1 sec. The resulting XRD diffraction patterns were compared to standard JCPDF files of the ICDD database to determine the presence of specific crystalline compounds.

Table 1. Water quality parameters, abbreviations, equipment, and method references.

Parameter	Abbreviation	Units	Equipment	Reference
Temperature	Temp	ºC	YSI 640 XLM Datasonde	APHA 1998
Specific Conductance	SpC	$mS\ cm^{-1}$	YSI 640 XLM Datasonde	APHA 1998
pH	pH	unitless	YSI 640 XLM Datasonde	APHA 1998
Dissolved Oxygen	DO	$mg\ l^{-1}$	YSI 5000 Benchtop	APHA 1998
Turbidity	Turb	NTU	Hach 2100N Turbidimeter	APHA 1998
Total Suspended Solids	TSS	$mg\ l^{-1}$	Drying Oven	APHA 1998
Carbonaceous Biological Oxygen Demand	$CBOD_5$	$mg\ l^{-1}$	Incubator	APHA 1998
Ammonium-Nitrogen	NH_3	$mg\ l^{-1}$	Lachat Autoanalyzer	EPA 350.1
Nitrite+Nitrate-Nitrogen	$NO_2 + NO_3$	$mg\ l^{-1}$	Lachat Autoanalyzer	EPA 353.2
Total Nitrogen	TN	$mg\ l^{-1}$	Lachat Autoanalyzer	EPA 353.2
Soluble Reactive Phosphate	PO_4	$mg\ l^{-1}$	Lachat Autoanalyzer	EPA 365.1
Total Phosphorus	TP	$mg\ l^{-1}$	Lachat Autoanalyzer	EPA 365.1

RESULTS and DISCUSSION

Our weekly sampling began mid-December 2007 and ended mid-December 2008. On occasion, freezing temperatures, electrical outages, and other mechanical problems resulted in loss of sample or in grab samples being collected instead of composite samples. Unit 5 (drip) developed a slow leak that was not detectable for several months. This resulted in the rejection of data collected between June through October for that unit. In early September, a data review led us to modify Unit 2 (no plants) by adding plants and connecting it to Unit 3 in series. All data collected followed data quality control and quality assurance protocols developed under CRASR's Quality Management Plan. These protocols include spikes, analytical duplicates, minimum detection levels, laboratory control standards, and other tasks that provide data of known quality.

The following analysis is organized by parameter, and begins with an overview of data from RAW to EFF, including both WETBIG and the control unit of the experimental wetlands (WET1). Then, the wetland units are compared to each other to evaluate the hypotheses presented earlier. Relevant statistical tests and resulting probability values are noted in parentheses.

Total Suspended Solids

Values for total suspended solids (TSS) ranged from a maximum of 1820 mg l^{-1} in the RAW wastewater to a minimum of below detection in some of the SSF wetlands. The data were non-normal and were log-transformed prior to statistical analyses. Samples that were below detection levels were assigned a value of 1 mg l^{-1}. The geometric mean TSS for the study period in the RAW wastewater was 231 mg l^{-1} and 27 mg l^{-1} in the SEPTIC tank (Fig. 3), a reduction of 88%. Both WETBIG and WET1 further reduced TSS to a geometric mean ($\pm$ standard error) of 6.7 $\pm$ 2.7 and 5.8 $\pm$ 2.0 mg l^{-1} respectively. Thus the wetlands reduced the septic tank solids by 75-79%. Furthermore, TSS reduction by both the septic tank and the SFF wetlands do not appear to be related to season or temperature. There was no statistically significant difference among the six wetland units (Fig. 4).

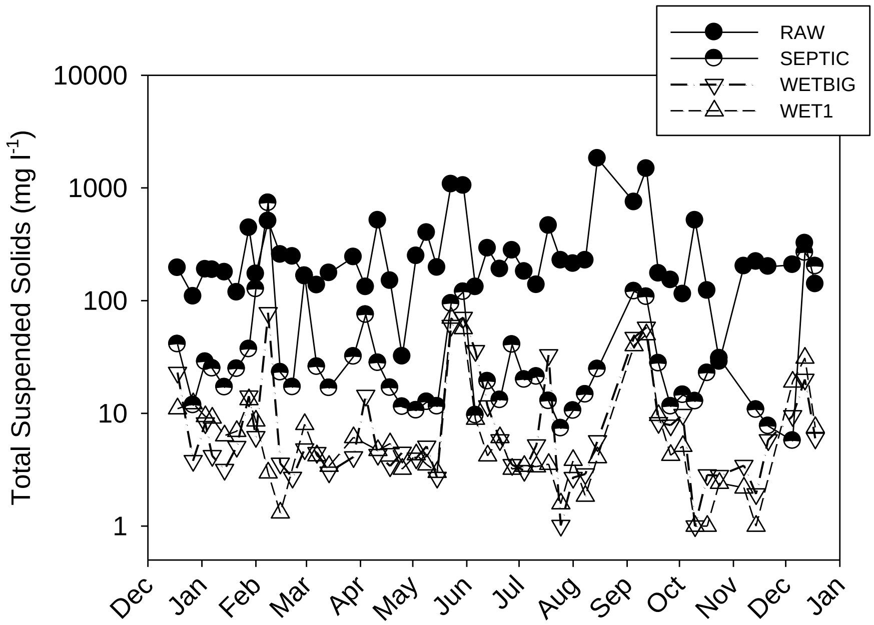

Figure 3. Total suspended solids by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1. Note the log scale on the Y-axis.

Solids removal in the SSF wetlands is most likely due to filtration by the substrate, as opposed to particulate settling which occurs in the septic tank. However, there is also some settling that occurs in the small chambers in front of the SSF wetlands and some decomposition of organic matter in the form of solids that occurs in the treatment system media. Although not statistically significant, effluent from the "all gravel" systems of WETBIG and WET 4 had higher TSS values than the other units which contained the finer-grained expanded shale aggregate media. This may indicate the shale improves filtration and possibly decomposition. However, it is important to note that WETBIG has operated for 3 years and with the annual cleaning of the sediment trap at the front of the unit, the unit did not clog or require new media to maintain good TSS removal.

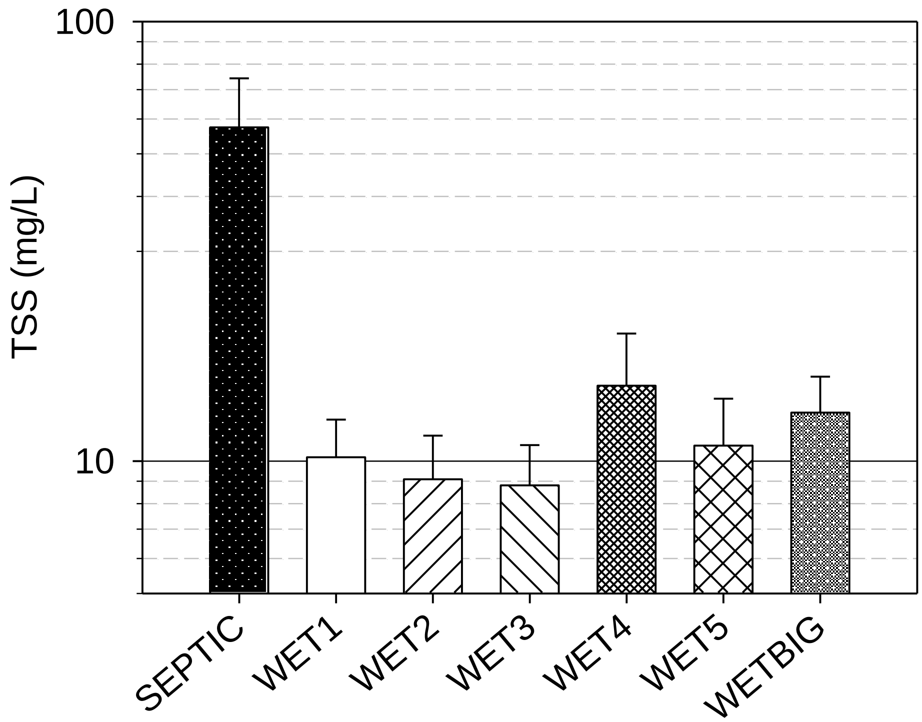

Figure 4. Total suspended solids means and standard errors for septic tank effluent and SSF wetland units. Note the log scale on the Y-axis.

Carbonaceous Biological Oxygen Demand

Values for carbonaceous biological oxygen demand ($CBOD_5$) ranged from a maximum of 540 mg l^{-1} in the RAW wastewater to a minimum of below detection in some of the SSF wetlands. The data were non-normal and were log-transformed prior to statistical analyses. Samples that were below detection levels were assigned a value of 1 mg l^{-1}. The geometric mean $CBOD_5$ for the study period in the RAW wastewater was 196 mg l^{-1} and the septic tank geometric mean was 39 mg l^{-1} (Fig. 5), a reduction of 80%. Both WETBIG and WET1 further reduced $CBOD_5$ to a geometric mean of 8.5 $\pm$ 1.9 and 7.6 $\pm$ 2.3 mg l^{-1} respectively. Thus the wetlands reduced the septic tank $CBOD_5$ by 78-81%.

There appeared to be a downward trend in $CBOD_5$ concentrations over the course of the study. WETBIG, although older, maintained good $CBOD_5$ removal. There was no statistically significant difference in mean $CBOD_5$ among the six wetland units (Fig. 6) when using a Tukey-Kramer multiple range test. However, a two-sample t-test comparison found that WET3 had lower mean CBOD5 than WET4 (marginally significant at $p = 0.052$). The intermittent unit may have had slightly better $CBOD_5$ removal due to the enhanced aeration and subsequent oxidation of solids.

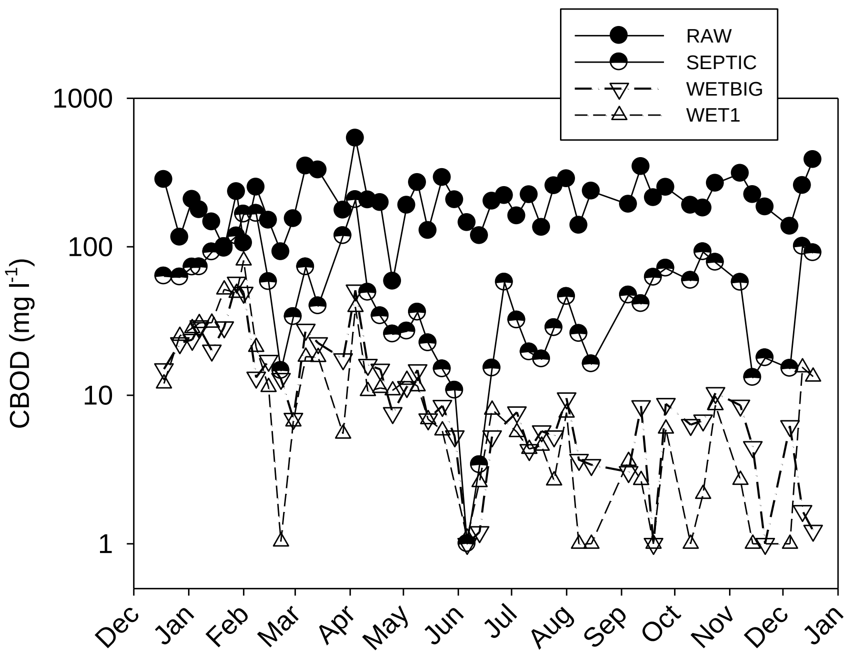

Figure 5. $CBOD_5$ by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1. Note the log scale on the Y-axis.

In general, trends in $CBOD_5$ removal were similar to trends in TSS removal, which suggests that much of the $CBOD_5$ is present in particulate form. The apparent downward trend in $CBOD_5$ concentrations throughout the study may be due to both enhanced filtration and the development of biofilms in the SSF wetlands.

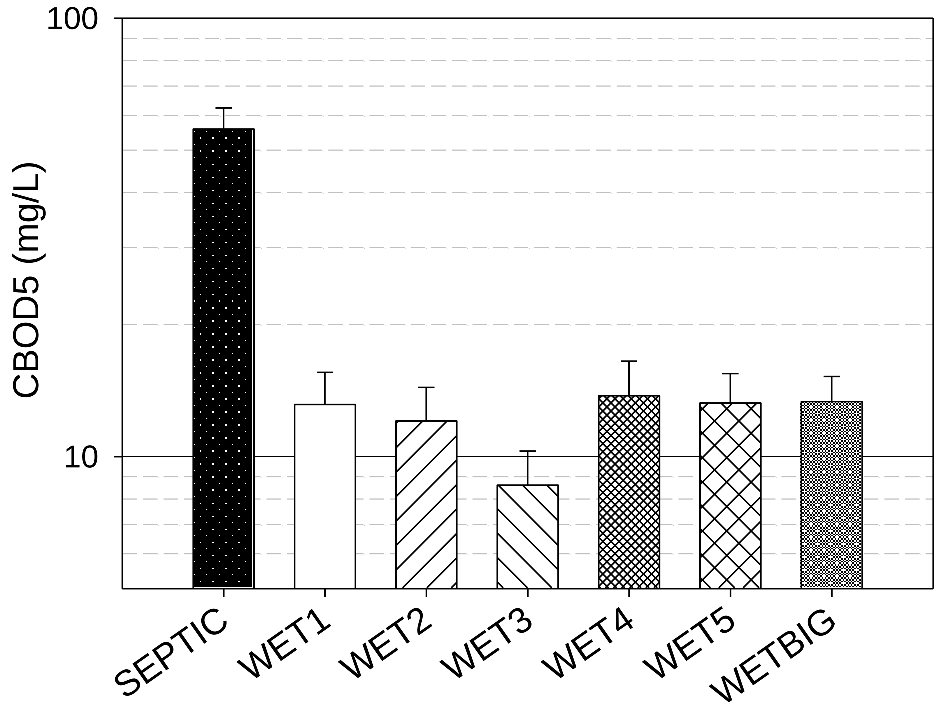

Figure 6. $CBOD_5$ means and standard errors of septic tank effluent and SFF wetlands. Note Y-axis log scale. Note that arithmetic means shown above are greater than geometric means which are used to determine statistical significance.

Dissolved Oxygen

Dissolved oxygen (DO) ranged from a minimum of less than 1% (all sample locations) to a maximum of 118% in WET3. DO levels increased system-wide following rainfall events and this contributed to the large range of values. In general, DO levels were between 20% and 80% in the wetland units. Hypothesis 1 predicted that plants increase DO levels in SSF wetlands. We found no statistical difference between mean DO in Unit 2 (no plants) and the control (two-sample t-test, $p=0.44$). However, all of the SSF wetlands had significantly higher percent DO than the SEPTIC tank effluent (two-way ANOVA, $p<0.0001$).

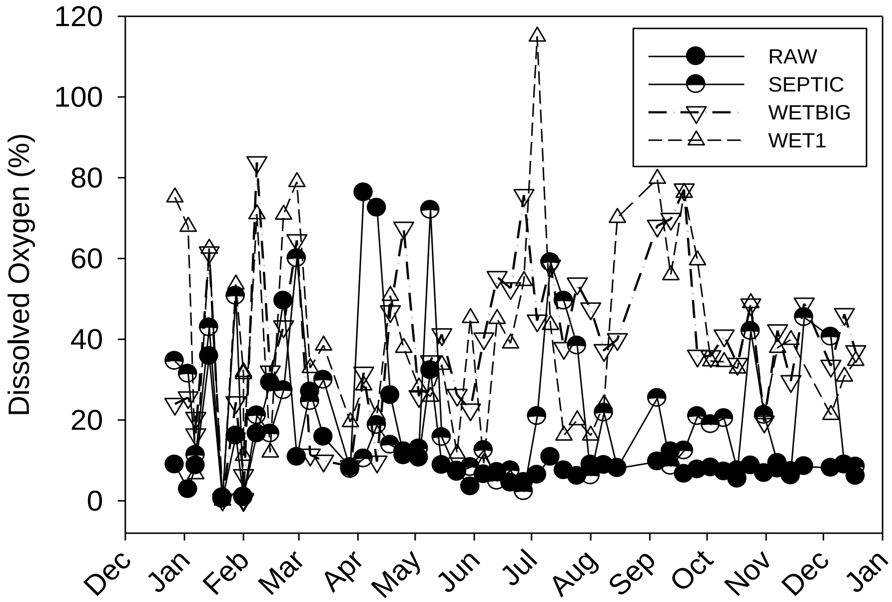

Figure 7. Dissolved oxygen (%) by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1.

An important benchmark value for DO concentrations is 2.0 mg l^{-1}, below which oxygen is considered limiting to aerobic organisms. We calculated the frequency of samples with DO concentrations less than 2.0 mg l^{-1} and found that 58% of the SEPTIC tank samples were below 2.0 mg l^{-1}. In the small wetlands, 12% of the samples from WET3 had DO less than 2.0 mg l^{-1} (minimum frequency) compared to 29% of samples from WET2 (maximum frequency). In WETBIG, 25% of the samples were below 2.0 mg l^{-1}.

Dissolved Oxygen values for effluent means did not show statistically significant trends. Although we hypothesized that plants would increase DO concentrations, the DO produced by plant roots would likely be used immediately by microbes breaking down organic material and nitrifying ammonium, thus it may not be possible to detect differences in DO using our sampling approach. Different experimental designs that would allow for more detailed in-situ DO measurements over space and time may reveal more about the contribution of the plants.

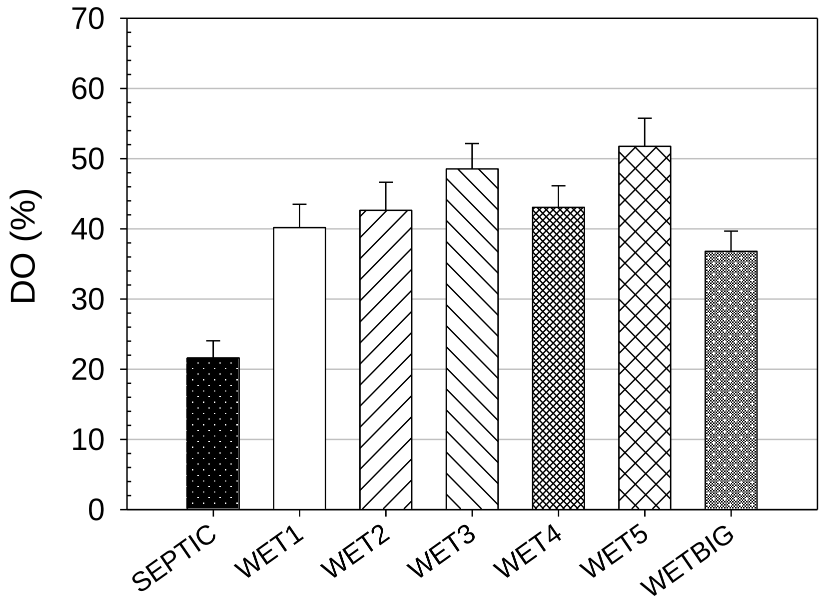

Figure 8. Average dissolved oxygen (%) and standard errors in septic tank effluent and SSF wetland units.

Ammonia-Nitrogen

The mean (± standard deviation) NH_3-N in RAW was 22.4 ± 11.0 mg l^{-1} and septic tank effluent NH_3-N was 143 % higher at 32.2 ± 9.3 mg l^{-1}. The mean WETBIG effluent was 21% lower than septic at 25.3 ± 6.8 mg l^{-1}. The average NH_3-N for WET1 – WET5 was 16.7 mg l^{-1}. All of the wetland units had significantly lower NH_3-N concentrations than the SEPTIC tank effluent (two-way ANOVA, Fig. 10). Mean NH_3-N in WET2 (no plants) was 23.2 ± 7.8 compared to 24.5 ± 9.8 in the control unit, and that difference was not statistically significant (t-test, p=0.518). Therefore Hypothesis 1 was rejected for NH_3-N as well as for DO. Hypothesis 2 stated that WET3 would have lower NH_3-N than the control and this was supported by a two-sample t-test ($p<<0.001$). WET3 mean NH_3-N was the lowest at 10.9 ± 9.0 mg l^{-1}. Hypothesis 3 also stated that WET5 (drip unit) would have lower NH_3-N than the control. Mean NH_3-N for WET5 was 20.5 + 11.2, nearly twice as high as WET3. Nonetheless, comparing WET5 to WET1 during the modified time period (omitted data due to leak) demonstrated that WET5 was significantly lower than WET1 (two-sample t-test, p=0.015). Some very low values occurred toward the end of the study (October – December 2008) in WET1 for reasons that were not clear (Fig. 9).

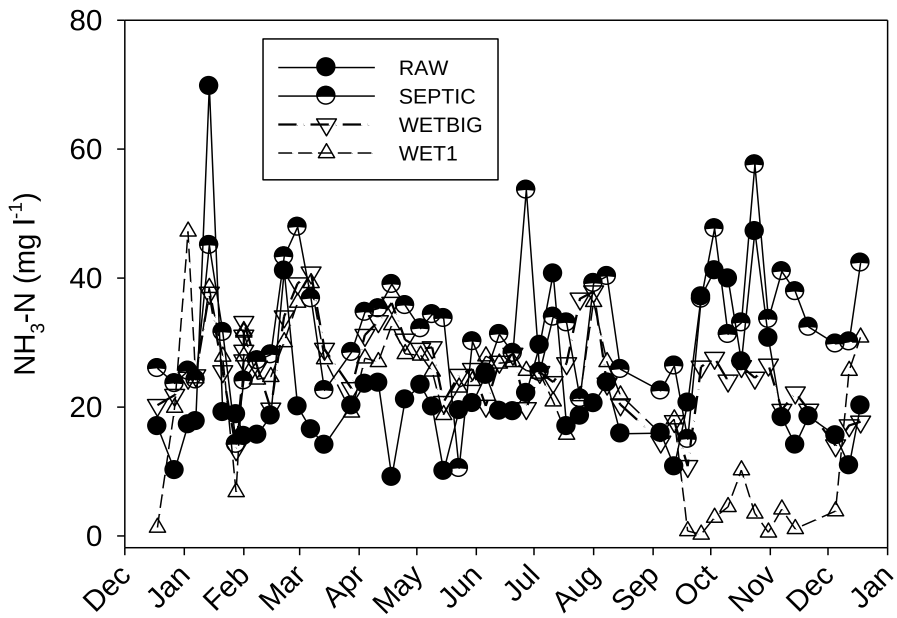

Figure 9. Ammonia-N concentrations by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1.

Decreases in NH_3-N are probably the result of nitrification rather than uptake by plants as evidenced by the significant decrease in NH_3-N by the intermittently loaded unit (Fig. 10) and the lack of difference between the unplanted unit (WET2) and the control (WET1). This is also supported by the higher values for nitrate -nitrogen (NO_3-N) discussed below. Furthermore, a closer examination of WET3 and WET4 over time (Fig. 11) indicates that removal in both units improved over time despite more or less consistent levels entering from the septic tank. Values for WET1 were also very low for a period near the end of the study and do not follow the trends seen in the RAW, SEPTIC and WETBIG (Fig. 9). The reasons for these trends are unclear. However, both gravel-based WETBIG and WET4 differ in size and age and since WETBIG has had little to no maintenance for 3 years it may be experiencing some "aging" that decreases the nitrification process.

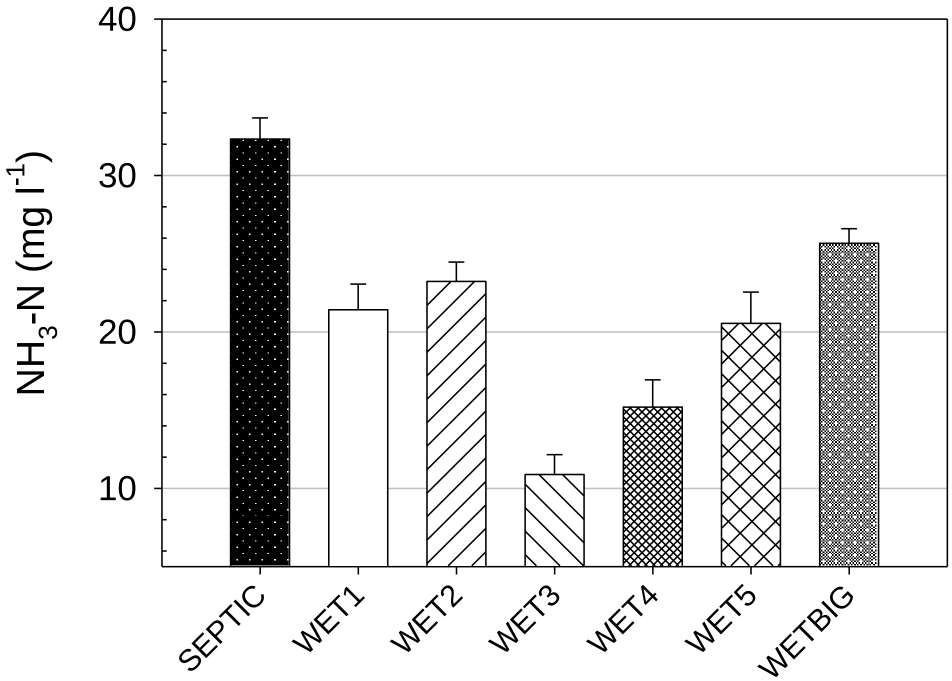

Figure 10. Means and standard errors of NH_3-N in septic tank effluent and SSF wetlands.

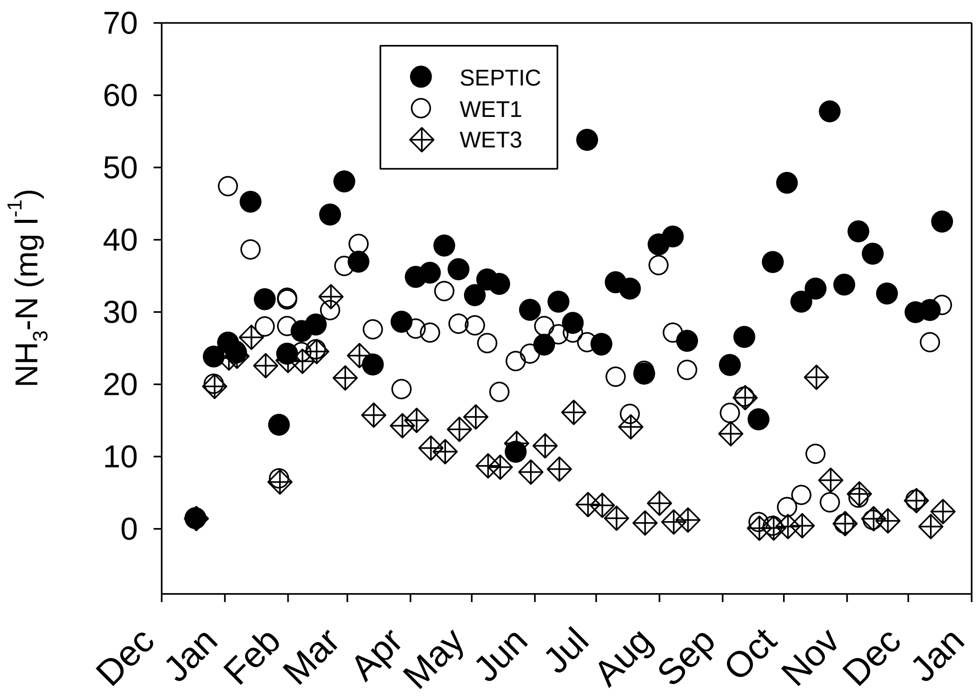

Figure 11. NH_3-N concentrations of SEPTIC, WET3 and WET4 over time.

<u>Nitrate -Nitrogen</u>

Nitrate -nitrogen (NO_3-N) in wastewater typically results from the nitrification of NH_3-N and is detected in advanced stages of the treatment process after reduction of $CBOD_5$ and if adequate oxygen is available. Nitrification and denitrification may occur concurrently, however, which obscures our ability to measure nitrification. In this case, nitrate remains low but total nitrogen concentrations decrease. Data from this study confirm that RAW and SEPTIC NO_3-N levels are very low (Fig. 13), with arithmetic means of 0.21 and 0.18 mg l^{-1} respectively. WET3 had the highest NO_3-N (Fig. 14, mean 7.2 $\pm$ 6.8 mg l^{-1}), compared to WET1 (0.60 $\pm$ 1.9 mg l^{-1}). This difference was statistically significant (two-sample t-test, $p<<0.0001$) which is further support for Hypotheses 2. We also hypothesized that WET5 would produce NO_3-N and that unit had a mean of 0.73 $\pm$ 1.19 mg l^{-1}. Although the difference between the control and WET5 was small, it was statistically significant (two-sample t-test, $p=0.020$). Thus, compared to SEPTIC, the intermittently loaded unit (WET3) increased NO_3-N concentrations by 4000% and the drip unit (WET5) increased NO_3-N by 400%. The gravel unit (WET4) also had good NO_3-N production due to production toward the end of the study period.

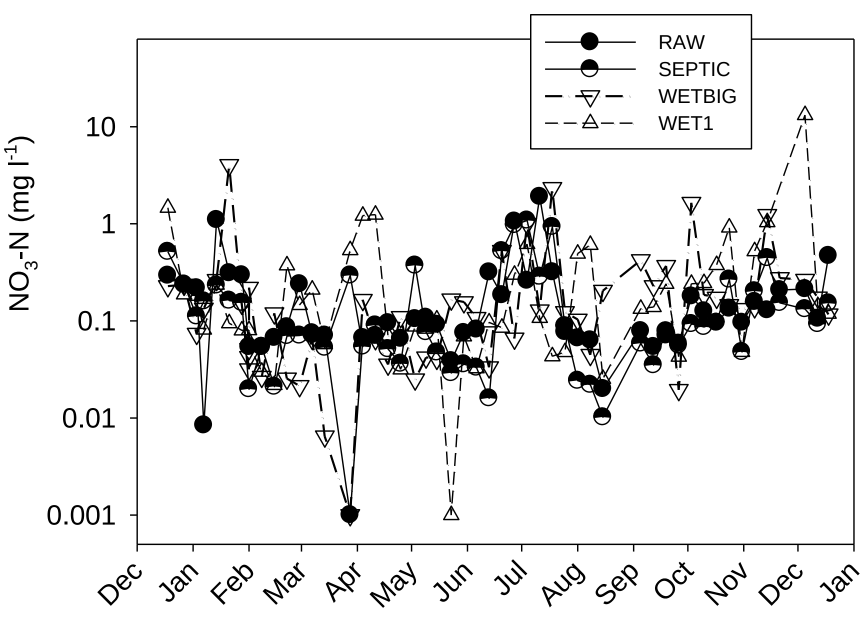

Figure 13. NO_3-N concentrations by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1. Note log scale on Y axis.

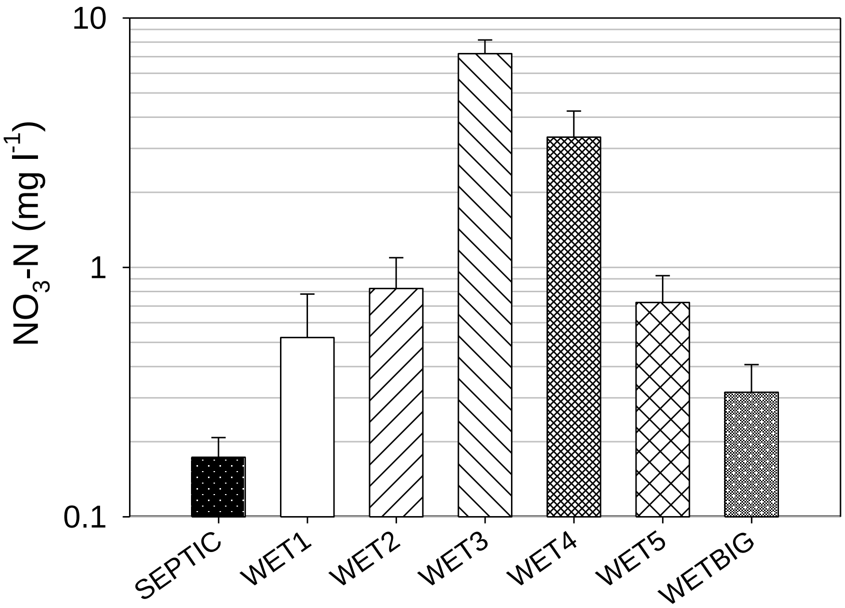

Figure 14. Means (bars) and standard deviations (error bars) of NO_3-N by septic tank effluent and SSF wetland units.

Total Nitrogen

Total nitrogen (TN) concentrations represent the sum of organically bound nitrogen, ammonia and nitrates. RAW wastewater and SEPTIC tank effluents had high TN (mean 39 and 43 mg l^{-1} respectively, Fig. 15). WETBIG had a mean TN of 25.2 mg l^{-1}, a reduction of 41% from the SEPTIC levels. The small SFF wetlands generally had better TN reduction, with WET3 and WET5 removing 55% of TN in SEPTIC to a mean of approximately 19 mg l^{-1} (Fig. 16). TN removal by WET3 was not statistically different than the control (two-sample t-test, $p=0.364$) indicating that ammonia was converted to nitrate but measureable denitrification did not occur. In contrast, WET5 was marginally significant (two-sample t-test, $p=0.061$) indicating that nitrification-denitrification may have occurred thus removing total nitrogen but not increasing nitrates detectably. Results for WET5 are complicated by the data that is missing due to the leak because the time period coincided with a period of good nutrient removal by the other wetland units.

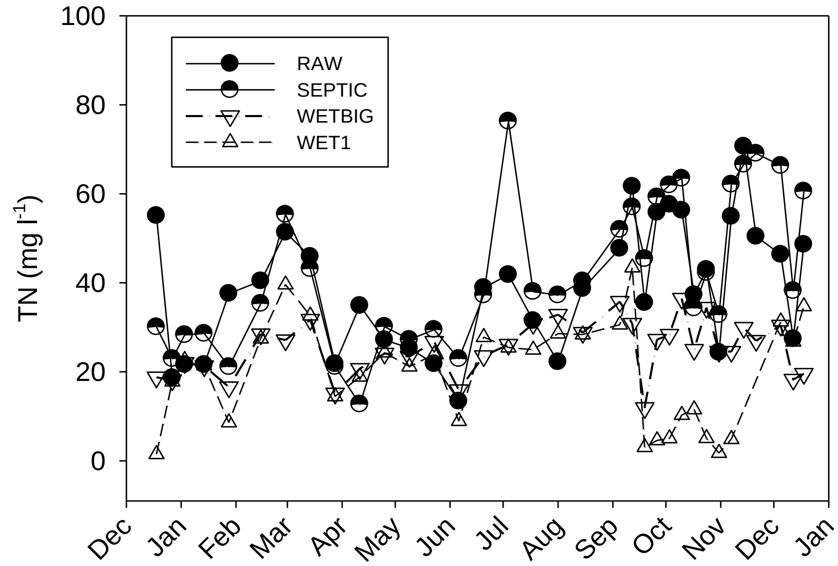

Figure 15. Total nitrogen concentrations by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1.

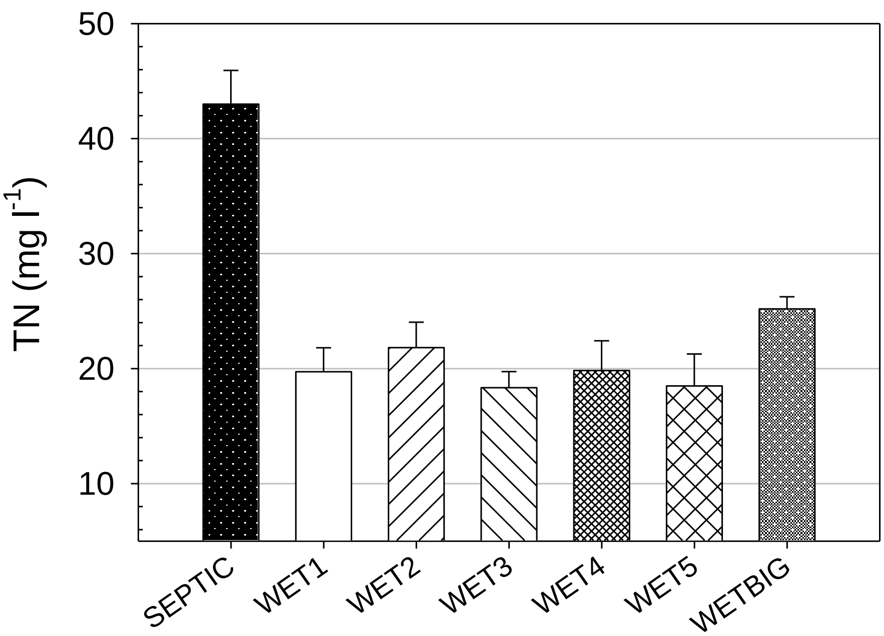

Figure 16. Means and standard errors of total nitrogen in septic tank effluent and SSF wetland units.

The total nitrogen results are encouraging both because the mean values of 4 out of 5 systems are below 20 mg/l and because the passive nitrification attempts in WET3 and WET5 had the lowest mean values for total N. We suspect that in WET5, nitrification and denitrification were occurring concurrently in the different step sections and reducing levels of total nitrogen. WET3 may not have had the anaerobic conditions necessary for denitrification. All the methods reduced the total N significantly from the SEPTIC and the smaller wetlands appeared to be more efficient than WETBIG. This difference may be the result of age as there was some clogging observed in the front of the WETBIG. Other than WETBIG, the highest mean for TN was observed in WET2 which did not contain plants. Although these differences were insignificant statistically, they may reflect plant uptake of nitrogen.

Phosphate-Phosphorus

Phosphate-phosphorus (PO_4-P) concentrations were high in RAW wastewater and SEPTIC tank effluent (means of 4.4 and 4.2 mg l^{-1} respectively, Fig. 17). WETBIG mean PO_4-P was 3.5 mg l^{-1}, a reduction of 18% from the SEPTIC levels. WET1 had a lower mean PO_4-P of 1.8 mg l^{-1}, a reduction of 58%. The remaining small SFF wetlands had similar levels of PO_4-P, with WET3 having the lowest mean of 1.4 mg l^{-1}, a removal rate of 67% (Fig. 18). This suggests that the intermittent dosing may improve dissolved P removal, perhaps by higher iron-P precipitation rates occurring under oxidized conditions. Both WET1 and WET4 had very low PO_4-P levels toward the end of the study for reasons that were not clear (Fig. 19); however, there was no statistical difference between WET1 and WET4 so there was no support for Hypothesis 4 that the unit with shale removed more dissolved phosphorus than units without shale. However, WETBIG, which also lacks shale, exhibited poorer PO_4-P removal than WET4. This may be the result of the aging (P-saturation) of WETBIG. The adsorption of P on the media should have occurred early (first few weeks) in the treatment but WET4 showed increasing removal toward the end of the study. The rapid plant growth in WET 4 compared to the established or more stable vegetation in WETBIG may explain some of these differences.

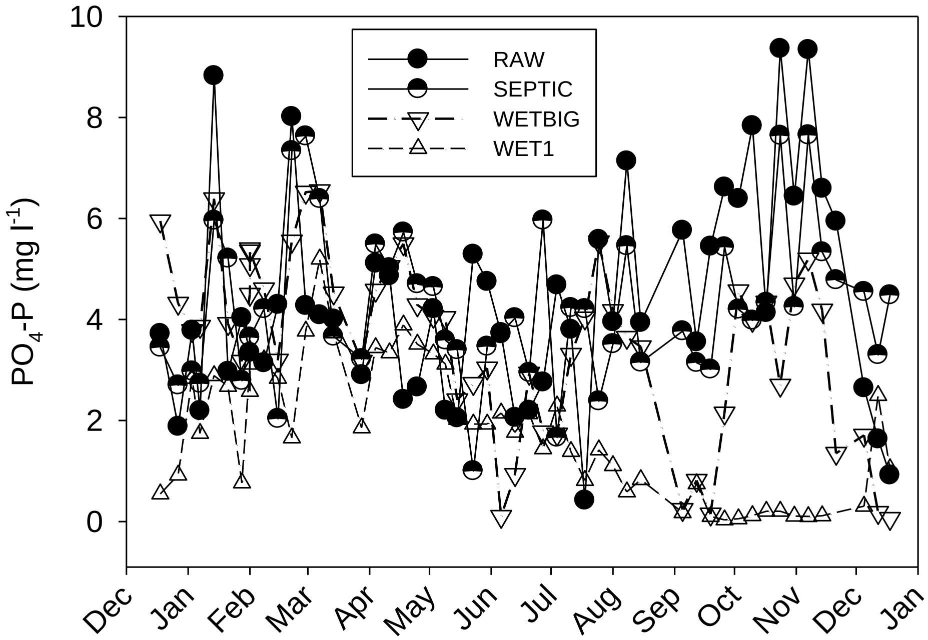

Figure 17. Phosphate-phosphorus (PO_4-P) concentrations by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1.

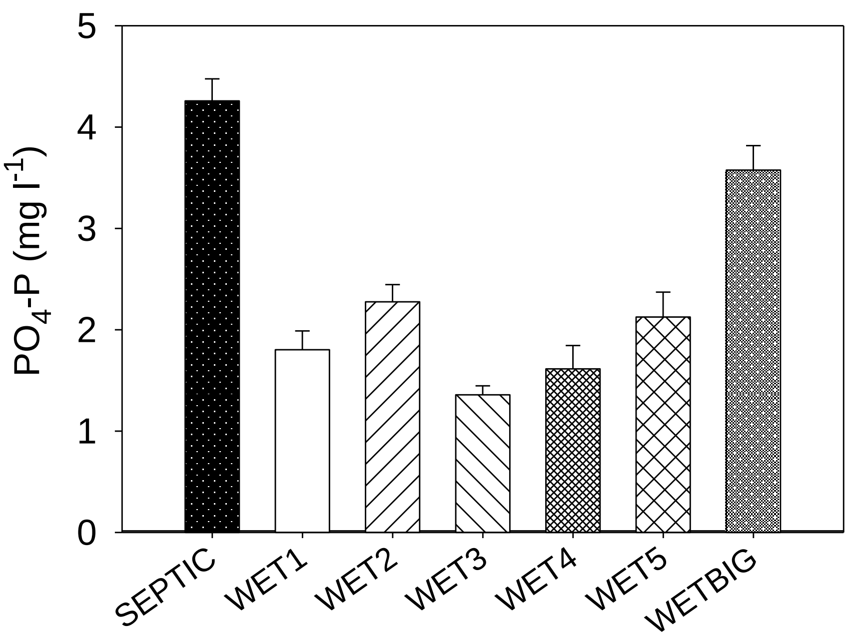

Figure 18. Means and standard errors of PO_4-P in septic tank effluent and SSF wetland units.

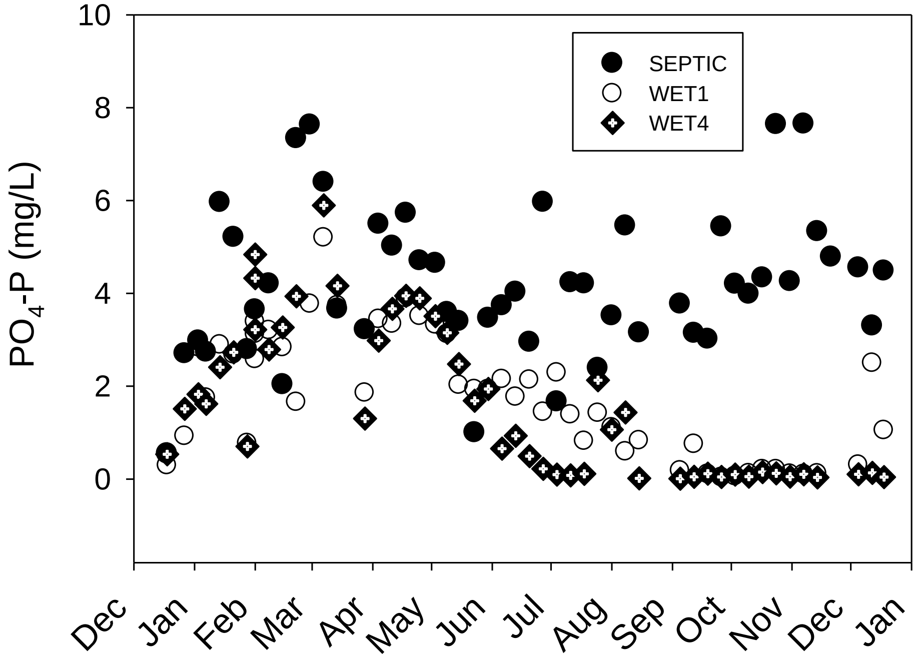

Figure 19. Comparison of PO_4-P in septic, control and gravel unit over time.

<u>Total Phosphorus</u>

Trends of total phosphorus (TP) were similar to trends observed for PO_4-P. Total P mean concentrations in RAW wastewater and SEPTIC tank effluents were 8.2 and 6.6 mg l^{-1} respectively (Fig. 20). The WETBIG mean was 4.1 mg l^{-1}, a reduction of 38% from SEPTIC levels. The small SFF wetlands generally had better TP reduction, with WET3 and WET4 removing 71-72% (Fig. 21). Differences in TP removal among the small SSF wetlands were not statistically significant; however they all had lower means than WETBIG (two-way ANOVA, Tukey-Kramer, α=0.05). Therefore, hypothesis 4 was not supported by these data.

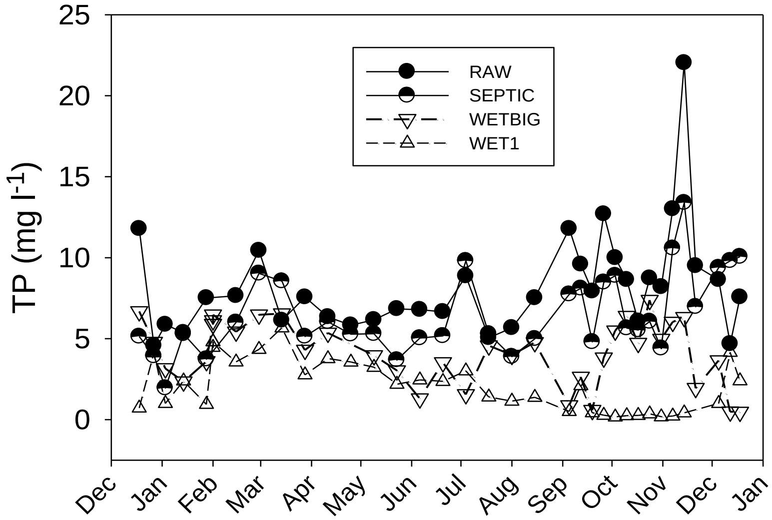

Figure 20. Total phosphorus (TP) concentrations by date for RAW wastewater, SEPTIC tank effluent, WETBIG, and WET1.

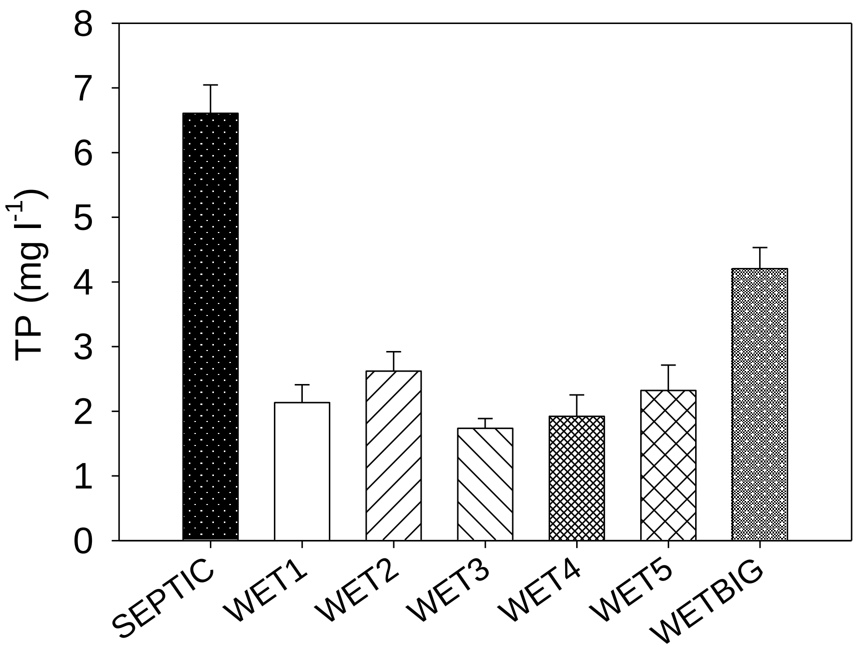

Figure 21. Means and standard errors of total phosphorus (TP) by septic tank effluent and SSF wetland units.

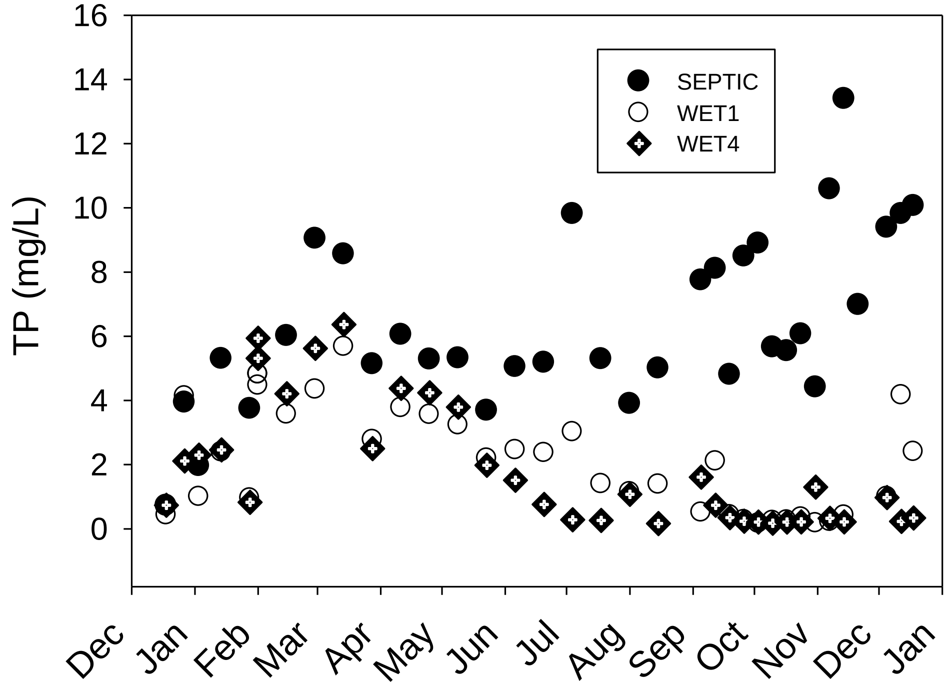

Figure 22. Comparison of TP in septic, control and gravel units over time.

X-Ray Diffraction

X-Ray Diffraction (XRD) was conducted on shale samples collected from WET1, WET2, WET3 and WET5, as well as stockpiled shale stored outside at the BWRP facility and shale stored at the Baylor laboratory. The XRD data from laboratory and stockpiled control samples (Fig. 23 and 24 respectively) indicates a predominate quartz phase (SiO_2) with a hexagonal crystal structure. Trace amounts of albite/feldspar ($Na(AlSi_3O_8)$) and MgO are also present in the controls.

For SSF wetland units WET1, WET2, WET3, and WET5 TOP (Fig. 25-29) the XRD patterns remains essentially unchanged showing a predominate quartz phase. However, there are very small amounts of calcium phosphates present in the form of hydroxyapatite ($Ca_5(PO_4)_3(OH)$) and brushite ($CaPO_3(OH)\ 2H_2O$) in the patterns.

XRD shows the largest change occurring in the Unit 5 samples of the middle and bottom sections (Fig. 30-31). These patterns show a composition of ~50% quartz (SiO_2) and ~50% calcite ($CaCO_3$) as the major phases in the samples. In addition to these two major phases is an increased amount of calcium phosphates as hydroxyapatite (HA) and brushite. The XRD peaks for these minor constituents are sharp indicating well crystallized calcium phosphate phases. The XRD data suggest that the formation of calcium carbonate precipitates the growth of the calcium phosphates. Initial adsorption of phosphates onto the calcite particles help stabilize and lead to crystalline calcium phosphate growth. This crystal growth does appear to occur slowly as the XRD peaks are still small in the diffraction patterns. However apatite (calcium phosphate) may initially absorb onto the calcium carbonate particles in an amorphous form and not be detectable by X-ray diffraction during the initial extraction of phosphates.

While more investigation is warranted, the presence of calcium-phosphate crystal structures on the surfaces of shale particles exposed to wastewater indicates that phosphates are sequestered through crystal formation. Such processes would result in long-term, irreversible retention of phosphates from the overlying water.

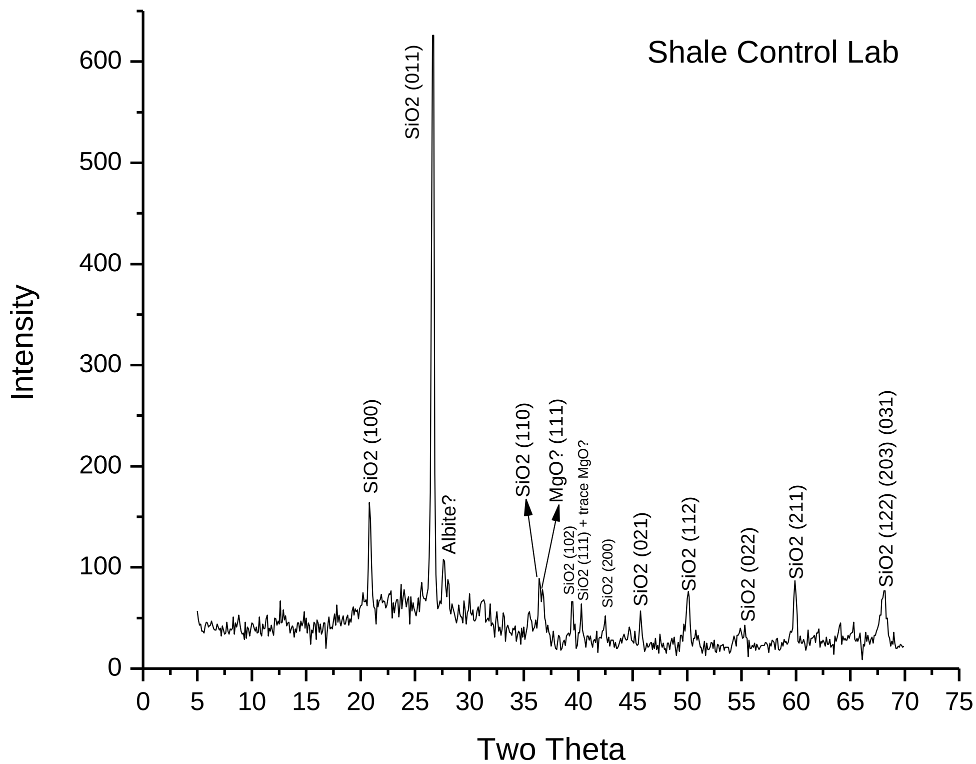

Figure 23. XRD patterns of laboratory expanded shale (control).

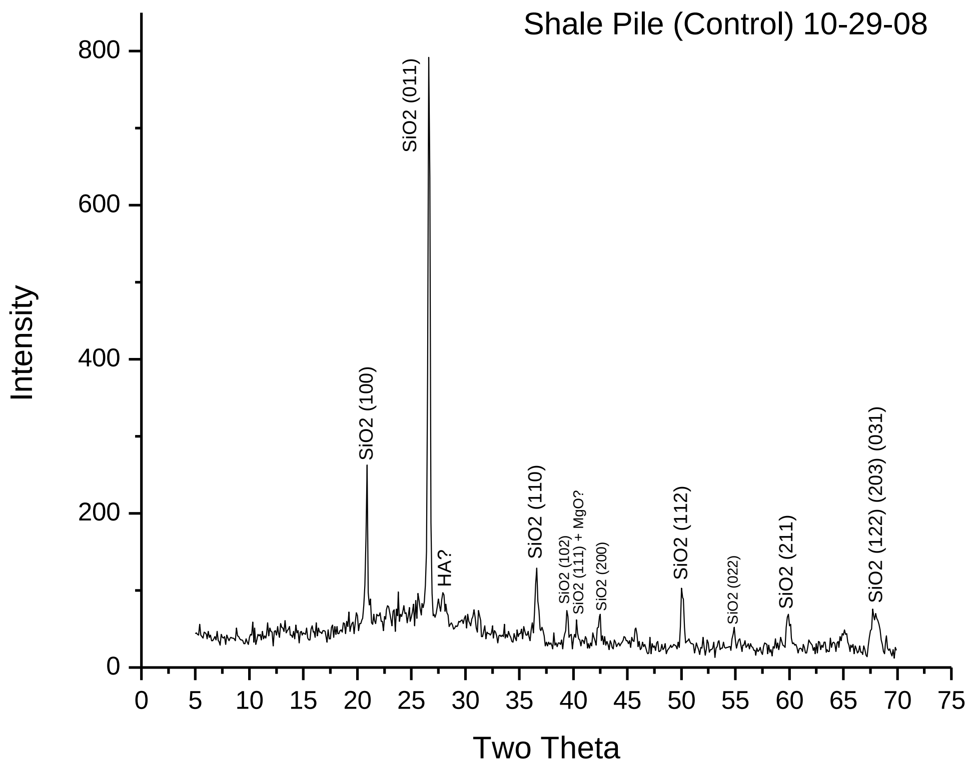

Figure 24. XRD patterns of stockpiled expanded shale (control).

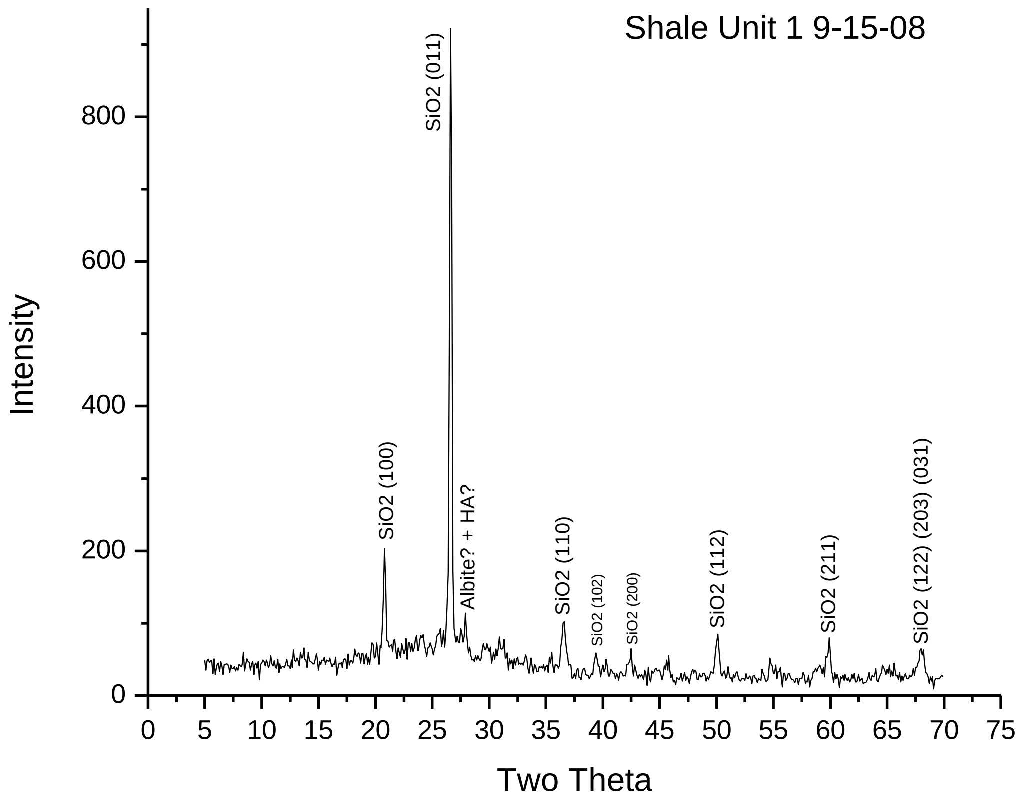

Figure 25. XRD patterns of expanded shale from WET1.

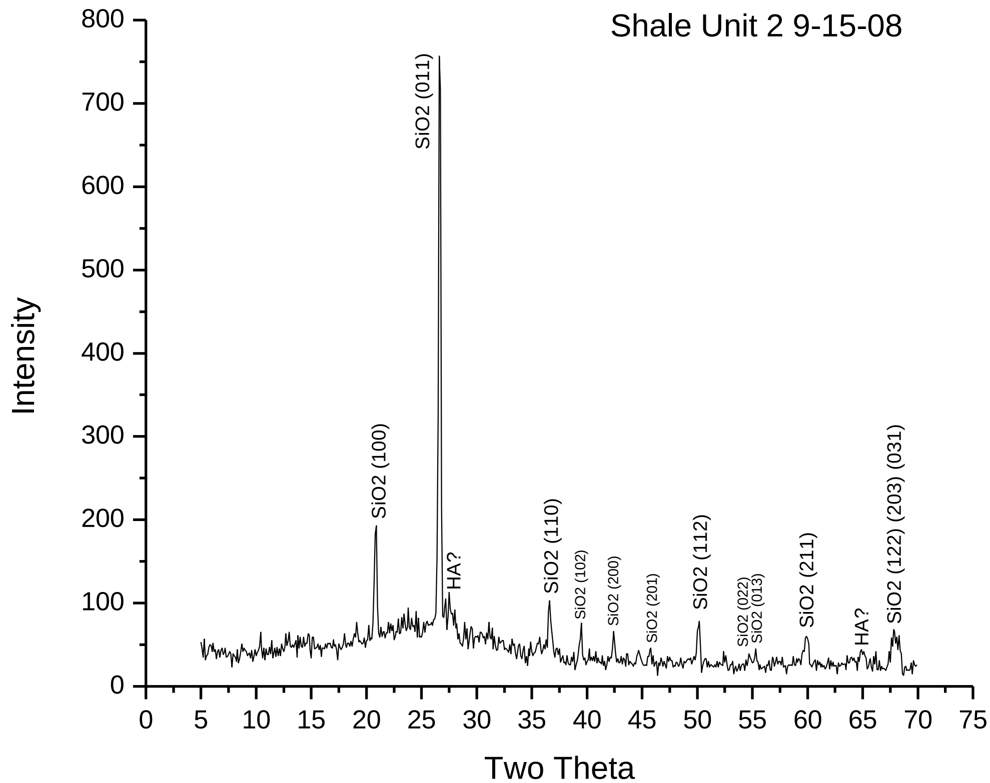

Figure 26. XRD patterns of expanded shale from WET2.

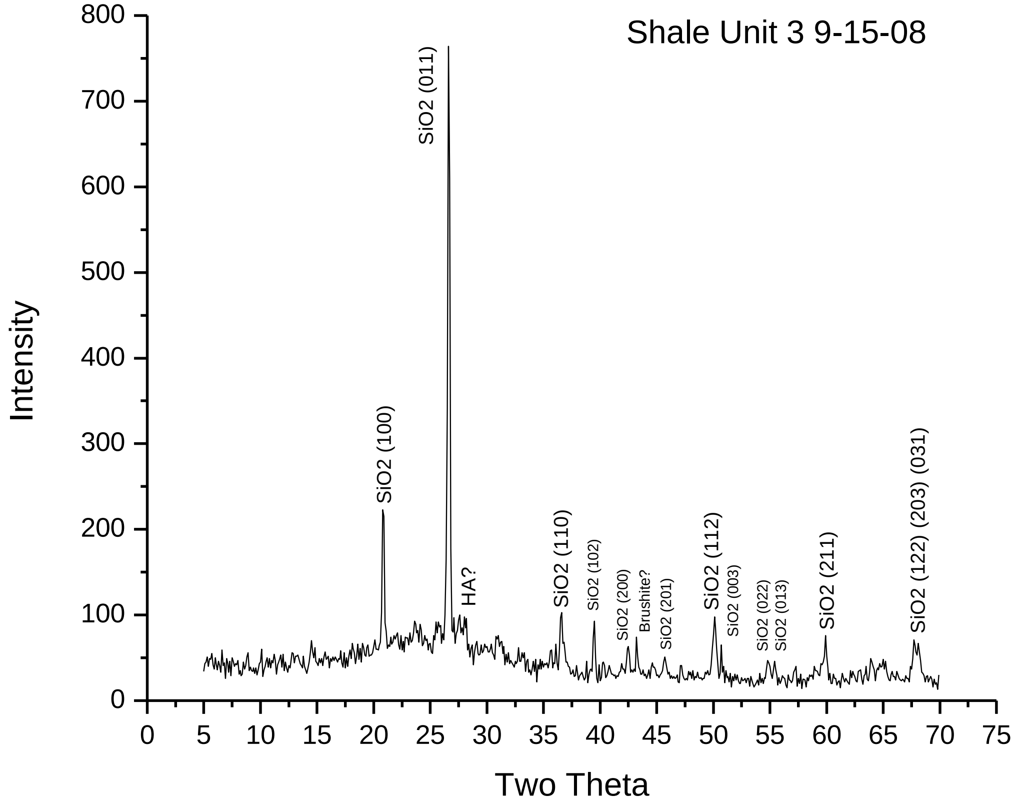

Figure 27. XRD patterns of expanded shale from WET3 September 2008.

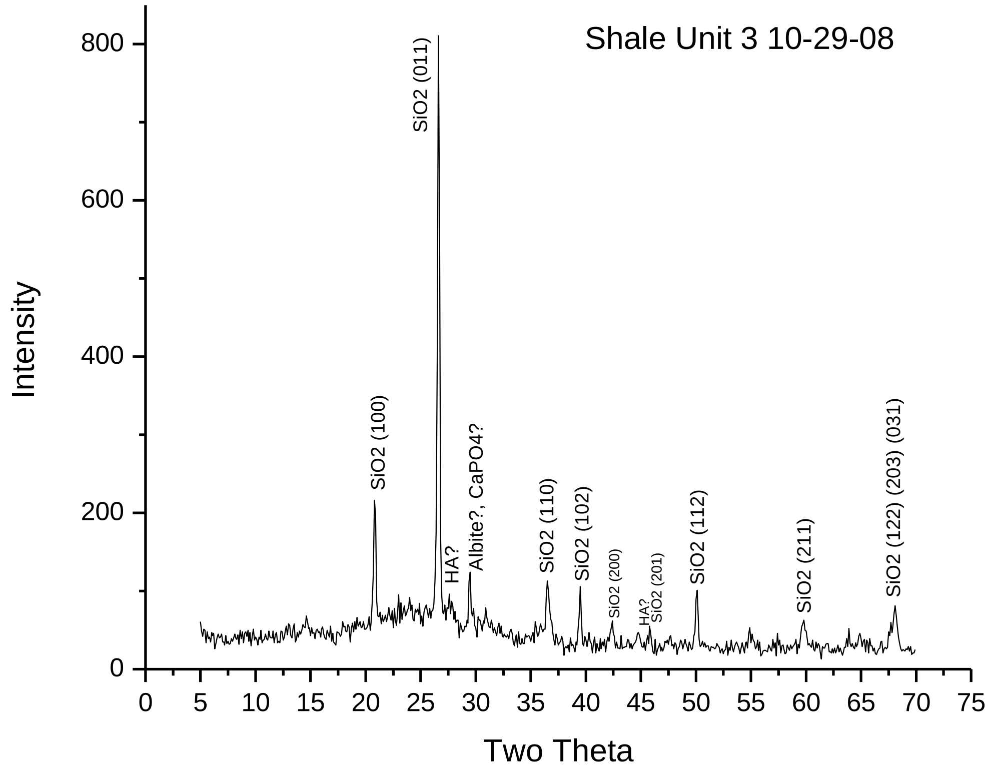

Figure 28. XRD patterns of expanded shale from WET3 October 2008.

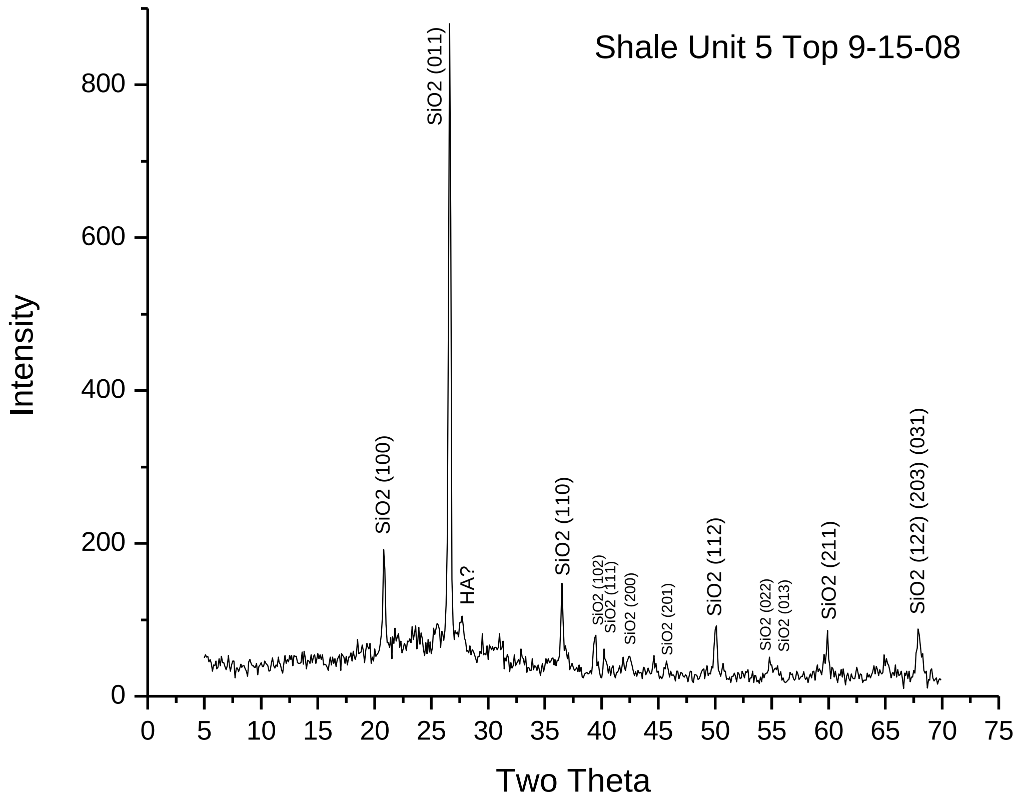

Figure 29. XRD patterns of expanded shale from WET5 TOP.

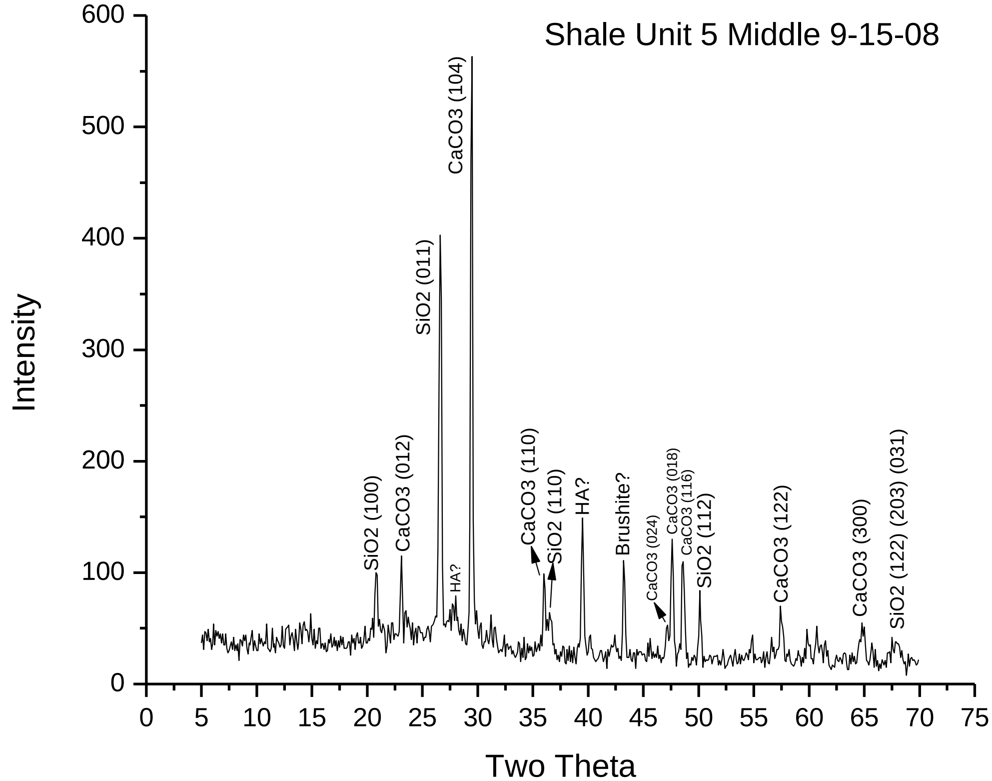

Figure 30. XRD patterns of expanded shale from WET5 Middle.

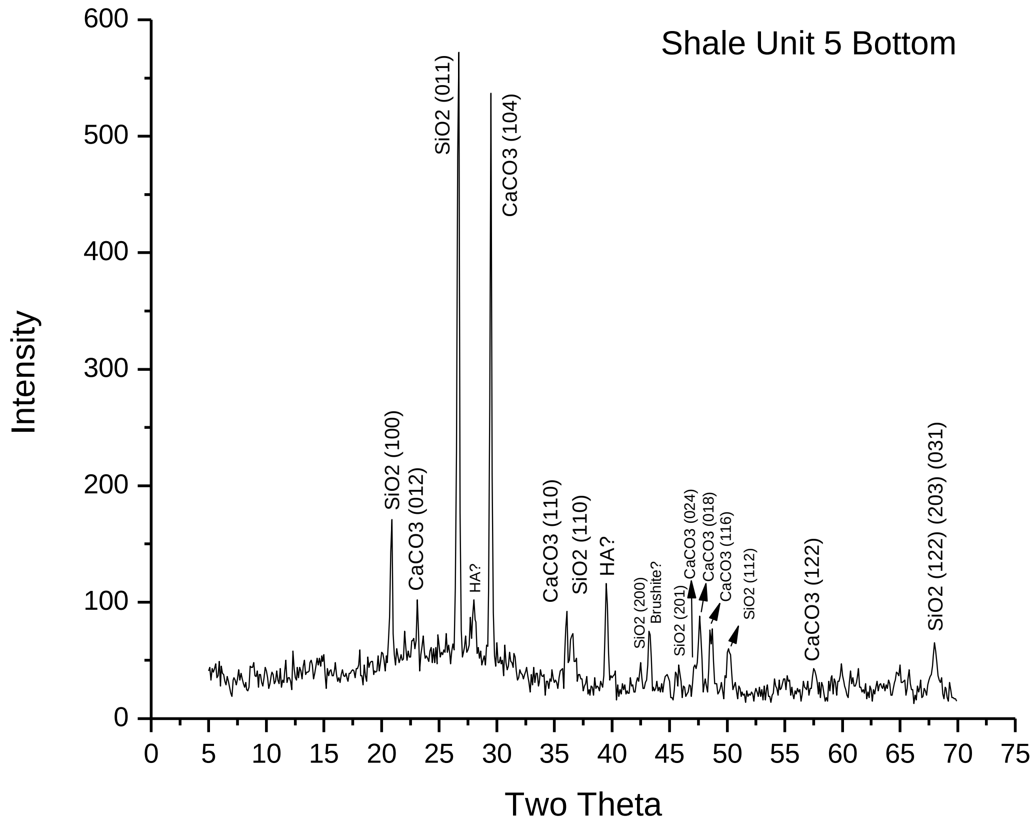

Figure 31. XRD patterns of expanded shale from WET5 Bottom.

CONCLUSIONS

1. All of the wetland treatment systems were effective in removing TSS and $CBOD_{5.}$

2. Passive aeration units (WET3 and WET5) generally had enhanced nitrification and the intermittent loading unit (WET3) was most effective in nitrifying ammonia-nitrogen to nitrate-nitrogen.

3. All of the newly constructed wetlands had good PO_4-P removal, and the intermittently loaded unit produced the lowest dissolved phosphorus levels (mean 1.4 mg l^{-1}).

4. The X-ray diffraction analyses suggest that the formation of calcium carbonate promotes the growth of the calcium phosphates on the surfaces of the of the expanded shale media, resulting in long-term, irreversible sequestration of phosphorus.

5. The intermittent loading design was the most effective overall treatment system and deserves further investigation.

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APPENDIX A

RAW DATA

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
12/18/07	RAW	21.5		0.35	8.19	487	77.1	
12/18/07	BWRP	16.0		0.28	7.31	488	98.4	DO probe and conductivity
12/18/07	SEPC	14.5		0.12	7.66	438	51.7	probe not working properly
12/18/07	WETBIG	15.6		0.36	7.24	495	71.2	Values in red omitted from analyses
12/18/07	WET1	15.9		1.3	8.31	185	7.0	
12/18/07	WET2	15.6		1.52	8.32	183	1.9	
12/18/07	WET3	16.6		1.11	8.25	185	7.0	
12/18/07	WET4	16.3		1.01	8.12	187	8.4	
12/18/07	WET5	14.5		1.22	8.3	188	9.5	
12/18/07	EFF	20.5		2.82	8.22	375	2.1	
12/27/07	RAW	18.4	8.9	0.83	7.24	953	83.2	
12/27/07	BWRP	13.6	26.5	2.60	7.12	1003	158.0	
12/27/07	SEPC	6.9	34.6	4.18	7.41	1053	50.8	
12/27/07	WETBIG	10.5	24.0	2.68	7.15	1079	108.0	
12/27/07	WET1	9.8	75.2	8.55	8.05	1133	15.3	
12/27/07	WET2	5.3	36.0	4.79	7.88	1118	12.9	
12/27/07	WET3	6.6	30.6	4.18	7.87	1151	16.6	
12/27/07	WET4	5.8	34.4	4.83	7.32	1126	18.6	
12/27/07	WET5	6.2	38.4	4.59	7.88	1152	10.2	
12/27/07	EFF	17.9	87.9	8.31	7.07	835	0.5	
1/3/08	RAW	13.9	2.8	0.29	7.05	1046	120	
1/3/08	BWRP	14.3	1.4	0.14	7.16	1064	145	
1/3/08	SEPC	11.5	31.4	3.41	7.30	1043	110	
1/3/08	WETBIG	10.9	25.6	2.65	8.01	1042	125	
1/3/08	WET1	10.8	67.9	7.51	8.01	1007	11.2	
1/3/08	WET2	11.0	68.3	7.49	7.99	1043	9.75	
1/3/08	WET3	11.8	56.4	6.08	7.96	1054	12.1	
1/3/08	WET4	11.3	63.5	6.94	7.44	1039	13.2	
1/3/08	WET5	11.6	60.8	6.59	7.93	1067	13.4	
1/3/08	EFF	12.5	102.2	10.88	7.19	898	1.73	
1/7/08	RAW	20.9	8.7	0.78	7.1	352.3	122	Values in red omitted from analyses
1/7/08	BWRP	19.9	8.8	0.87	7.14	360.5	194	Wrong conductivity probe used
1/7/08	SEPC	12.1	11.3	1.05	7.34	337	41.6	
1/7/08	WETBIG	14.9	16.4	1.65	6.97	350.6	117	
1/7/08	WET1	16.7	6.6	0.65	7.68	364	12.4	
1/7/08	WET2	18.1	7.9	0.62	7.82	371.2	10.9	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
1/7/08	WET3	17.11	7.7	0.73	7.68	369	15.2	first sample from wetbig (grab) had
1/7/08	WET4	17.01	6.1	0.4	7.27	358.6	13.8	black floc from standpipe
1/7/08	WET5	17.48	17.2	1.58	7.86	368.8	10	2nd bigwet sample no black floc
1/7/08	EFF	20.06	88.5	7.8	6.943	328.4	1.29	
1/7/08	WETBIG dupe	19.33	20.5	1.63	6.81	1080	8.98	
1/7/08	trip blank (DI)	20.22	94	8.57	6.25	2	NS	
1/14/08	RAW	20.18	35.8	3.24	6.89	1040	114	all are grab samples
1/14/08	BWRP	16.13	54.7	5.01	7.14	965	311	due to freezing temps
1/14/08	SEPC	13.59	42.9	4.40	7.25	1067	129	
1/14/08	WETBIG	13.52	61.5	6.88	7.09	1103	41.9	
1/14/08	WET1	13.57	62.5	6.70	8.01	1046	16.0	
1/14/08	WET2	13.83	56.3	5.79	7.97	1029	8.9	
1/14/08	WET3	14.15	68.2	6.93	7.80	1058	10.7	
1/14/08	WET4	13.68	65.0	6.59	7.81	1022	11.0	
1/14/08	WET5	15.37	58.8	6.09	7.89	1032	9.42	
1/14/08	EFF	19.99	102.2	9.55	7.04	844	1.13	
1/14/08	trip blank (DI)	22.66	69.0	6.07		4		
1/21/08	RAW	16.48	0.4	0.04	6.787	947	78.8	
1/21/08	BWRP	13.25	0.1	0.01	6.912	964	191	
1/21/08	SEPC	8.72	0.8	0.09	6.902	1086	104	
1/21/08	WETBIG	7.79	0.3	0.04	7.159	1120	99.9	
1/21/08	WET1	7.78	0.1	0.09	7.712	1087	16.7	
1/21/08	WET2	7.57	0.6	0.08	7.751	1042	8.82	
1/21/08	WET3	7.46	0.3	0.03	7.548	1021	13	
1/21/08	WET4	7.48	0.3	0.04	7.093	1108	13.5	
1/21/08	WET5	7.34	0.2	0.02	7.159	1052	11.4	
1/21/08	EFF	18.52	0.7	0.07	7.145	842	0.884	
1/21/08	trip blank (DI)							
1/28/08	RAW	17.81	16.1	1.54	7.38	1014	132	
1/28/08	BWRP	14.16	19.6	2.02	7.81	1057	223	
1/28/08	SEPC	11.3	50.7	5.62	7.92	1205	87	
1/28/08	WETBIG	12.02	24.4	2.72	7.94	1178	90.9	
1/28/08	WET1	12.36	53.6	5.72	8.61	1205	23	
1/28/08	WET2	12.07	54.0	5.79	8.71	1220	23.8	
1/28/08	WET3	12.03	51.1	5.52	8.53	1213	13	
1/28/08	WET4	11.21	57.1	6.28	8.11	1176	14.8	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
1/28/08	WET5	11.2	42.6	4.59	8.58	1198	18.1	
1/28/08	EFF	18.82	88.3	8.02	7.2	885	1.1	
1/28/08	trip blank (DI)	21.9	83.5	6.49	7.68	6		
2/1/08	RAW	14.7	1	0.09	6.9	1038	94.7	
2/1/08	BWRP	15.96	5.3	0.55	6.8	1052	206	
2/1/08	SEPC	14.62	0.8	0.08	6.56	1140	129	
2/1/08	WETBIG	11.54	6.3	0.67	6.55	1144	82	
2/1/08	WET1	7.39	31.9	3.6	6.65	1183	64.9	
2/1/08	WET2	6.3	67.9	7.66	6.63	1184	14.9	
2/1/08	WET3	10.24	41.4	4.65	6.75	1158	10.2	
2/1/08	WET4	7.19	35.4	4.03	6.42	1140	12.6	
2/1/08	WET5	8.15	48.1	5.82	6.6	1216	14.4	no Sp Cond or Turb for intermed.
2/1/08	EFF	16.46	102.2	9.96	6.56	929	0.682	
2/1/08	WETBIG12.5	15.4	0.16	1.6	6.82			intermediate samples
2/1/08	WETBIG25	16.13	0.18	1.2	6.82			intermediate samples
2/1/08	WETBIG37.5	15.88	0.48	4.8	6.88			intermediate samples
2/1/08	WET1 f	12.58	31.4	3.23	7.29			intermediate samples
2/1/08	WET1 b	17.3	11.2	1.07	7.64			intermediate samples
2/1/08	WET2 f	12.34	6.9	0.73	7.55			intermediate samples
2/1/08	WET2 b	12.64	12.3	1.29	7.66			intermediate samples
2/1/08	WET4 f	12.45	19.6	1.81	7.09			intermediate samples
2/1/08	WET4 b	12.74	14	1.65	7.11			intermediate samples
2/1/08	WET5 f	12.38	6.6	0.88	7.28			intermediate samples
2/1/08	WET5 m	12.89	11	1.22	7.72			intermediate samples
2/1/08	WET5 b	12.7	24.3	2.65	7.83			intermediate samples
2/1/08	trip blank (DI)	18.54	48.3	4.56	8.58	4	0.222	
2/8/08	RAW	12.82	16.6	1.75	8.23	1058	262	
2/8/08	BWRP							pump down
2/8/08	SEPC	13.12	21.1	2.19	8.21	1198	295	
2/8/08	WETBIG	17.17	83.8	8.02	7.59	1091	99	
2/8/08	WET1	10.71	71	7.87	8.84	1072	28	
2/8/08	WET2	10.55	62.2	6.89	8.94	1088	9	
2/8/08	WET3	10.35	62.1	6.90	8.85	1063	947	
2/8/08	WET4	10.12	66.2	7.34	8.38	1023	10	
2/8/08	WET5	11.42	68.5	7.39	8.81	1091	11	
2/8/08	EFF	17.36	92.5	8.82	7.56	1071	1	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
2/8/08	trip blank (DI)	12.67	96.3	10.19	8.24	9	0	
2/15/08	RAW	21.68	29.2	2.55	7.55	1173	193	
2/15/08	BWRP	17.47	18.6	1.77	8.13	1123	295	
2/15/08	SEPC	18.55	16.6	1.55	7.73	1190	114	
2/15/08	WETBIG	14.42	32	3.26	7.97	1161	118	
2/15/08	WET1	13.55	12	1.23	9.06	1183	15.2	
2/15/08	WET2	14.00	10.5	1.09	9.02	1193	28.6	
2/15/08	WET3	11.97	86.3	9.29	9.29	1184	11.7	
2/15/08	WET4	13.73	14.9	1.54	8.27	1124	16.3	
2/15/08	WET5	11.64	13.5	1.48	9.22	1181	28.4	
2/15/08	EFF	21.01	93.2	8.29	7.75	952	1.04	
2/15/08	trip blank (DI)	16.78	9.7	100	7.93	3	0.999	
2/22/08	RAW	11.82	49.5	5.33	7.7	1039	174	
2/22/08	BWRP	12.49	22.4	2.31	7.82	1086	266	
2/22/08	SEPC	11.27	27.3	2.95	7.72	1121	139	
2/22/08	WETBIG	12.91	43.2	4.47	7.58	1073	22.2	
2/22/08	WET1	12.33	70.9	7.53	8.49	1094	5.9	
2/22/08	WET2	11.41	42.8	4.67	8.44	1027	29.2	
2/22/08	WET3	11.46	37.3	4.08	8.29	1082	7.23	
2/22/08	WET4	11.73	39.2	7.19	7.68	992	8.76	
2/22/08	WET5	12.01	43.1	4.58	8.22	1024	5.83	
2/22/08	EFF	15.79	96.4	9.49	7.46	891	0.924	
2/22/08	trip blank (DI)	11.95	103.6	9.7	7.82	25	0.073	
2/29/08	RAW	20.07	10.8	0.98	6.83	837	139	
2/29/08	BWRP	17.85	8.2	0.77	7.27	941	365	
2/29/08	SEPC	18.14	60	5.66	7.37	1006	155	
2/29/08	WETBIG	17.03	64.5	6.16	7.58	990	108	
2/29/08	WET1	16.67	79	7.64	8.06	984	27.8	
2/29/08	WET2	16.16	112.6	11.0	8.16	981	24.2	
2/29/08	WET3	16.78	118	11.4	8.15	981	9.47	
2/29/08	WET4	16.77	35.9	3.46	7.43	949	22.2	
2/29/08	WET5	17.41	114.4	10.89	8.01	945	6.3	
2/29/08	EFF	20.17	115.8	10.46	7.14	781	0.901	
2/29/08	trip blank (DI)							
3/7/08	RAW	14.31	27	2.75	7.59	736	57	
3/7/08	BWRP	13.66	35.7	3.71	7.95	763	229	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
3/7/08	SEPC	12.21	24.6	2.64	7.61	978	121	
3/7/08	WETBIG	6.11	11.4	1.42	8.77	941	54.3	
3/7/08	WET1	7.97	32.9	3.88	8.52	929	52.5	
3/7/08	WET2	8.35	63.4	7.27	8.62	946	8	
3/7/08	WET3	9.24	71.8	8.18	8.96	924	6.32	
3/7/08	WET4	11.46	36	3.85	8	877	121	
3/7/08	WET5	9.89	63.1	7.09	9.2	925	10.2	
3/7/08	EFF	14.4	86.9	8.98	7.54	628	1.48	
3/7/08	trip blank (DI)	12.09	92.2	9.96	8.4	3		trip blank burst in freezer
3/14/08	RAW	12.84	15.8	1.63	7.33	915	122	
3/14/08	BWRP	17.29	28.7	2.77	7.31	869	211	
3/14/08	SEPC	11.87	29.9	3.13	7.8	505	195	
3/14/08	WETBIG	11.21	9.9	1.05	7.6	987	39	
3/14/08	WET1	15.63	38.5	3.77	7.92	988	27.1	
3/14/08	WET2	15.58	39.4	3.88	8.02	1006	12.4	
3/14/08	WET3	14.84	62.4	6.2	8.17	980	4.84	
3/14/08	WET4	15.82	29.1	2.72	7.42	929	14.2	
3/14/08	WET5	15.64	63.1	6.23	8.08	984	14.16	
3/14/08	EFF	18.82	90.4	8.38	7.12	819	1.45	
3/14/08	trip blank (DI)	17.55	92.3	8.78	8.64	2		
3/28/08	RAW	15.03	8.3	0.83	7.98	881	217	did not sample 3/21 due to Easter
3/28/08	BWRP	19.38			8.41	905	235	
3/28/08	SEPC	18.77	7.8	0.74	8.00	948	134	
3/28/08	WETBIG	16.74	8.5	0.84	7.71	895	35.5	
3/28/08	WET1	19.59	19.53	1.58	8.1	899	7.99	
3/28/08	WET2	19.48	25.3	2.34	8.11	888	5.47	
3/28/08	WET3	19.37	27.2	2.53	8.17	903	4.92	
3/28/08	WET4	19.84	33.3	3.07	7.74	875	10.4	
3/28/08	WET5	19.69	38.5	3.55	8.25	880	2.12	
3/28/08	EFF	21.13	79.5	7.04	7.53	756	1.25	
3/28/08	trip blank (DI)	20.82	112.8	10.09	8.83	28	0.474	
4/4/08	RAW	14.26	76.3	7.91	8.14	933	156	
4/4/08	BWRP	19.59	3.6	0.33	8.01	997	218	
4/4/08	SEPC	18.5	10.4	0.95	7.95	1062	142	
4/4/08	WETBIG	19.4	31.7	2.92	7.99	1010	116	
4/4/08	WET1	17.35	28.6	2.76	8.13	1001	8.18	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
4/4/08	WET2	17.71	38.1	3.64	8.16	986	6.26	
4/4/08	WET3	17.39	48.8	4.69	8.44	1001	3.83	
4/4/08	WET4	17.38	36.3	3.48	7.91	763	20	
4/4/08	WET5	17.68	48.0	4.57	8.57	974	2.89	
4/4/08	EFF	20.52	102.3	9.22	7.84	842	1.14	
4/4/08	trip blank (DI)	18.86	82.0	7.57	10.02	16		
4/11/08	RAW	12.98	72.5	7.65	8.48	983	136	
4/11/08	BWRP	16.76	1.3	0.13	8.55	933	250	
4/11/08	SEPC	16.65	18.7	1.82	8.57	1104	266	
4/11/08	WETBIG	11.75	9.7	1.04	8.30	1089	61	
4/11/08	WET1	16.79	21.2	2.06	8.55	1015	18.5	
4/11/08	WET2	16.58	44.0	4.29	8.46	1044	5.54	
4/11/08	WET3	15.71	72.9	7.22	8.30	1061	3.94	
4/11/08	WET4	16.4	38.6	3.78	7.76	970	10.1	
4/11/08	WET5	17.45	44.0	4.22	8.13	1031	3.31	
4/11/08	EFF	21.6	81.3	7.17	7.54	782	1.51	
4/11/08	trip blank (DI)	18.62	74.1	6.9	6.17	59	0.061	
4/18/08	RAW	18.8	26.1	2.42	6.79	799	123	
4/18/08	BWRP	17.89	1.1	0.1	7.35	998	267	
4/18/08	SEPC	15.97	13.8	1.36	7.66	1137	67.8	
4/18/08	WETBIG	14.32	46.9	4.8	7.57	1114	82.3	
4/18/08	WET1	15.38	50.8	5.08	7.66	1073	34.7	
4/18/08	WET2	15.5	37.3	3.73	7.74	1046	4.66	
4/18/08	WET3	15.72	40.3	4.02	7.63	1083	2.54	
4/18/08	WET4	15.61	35.77	3.55	7.26	938	9.37	
4/18/08	WET5	15.75	65.6	6.53	7.65	1030	3.22	
4/18/08	EFF	20.75	84.4	7.57	6.94	868	0.946	
4/18/08	trip blank (DI)		0.024		8.37		0.601	
4/25/2008	RAW	20.06	11.2	1.04	7.37	1086	179	
4/25/2008	BWRP	20.31	4.9	0.42	7.4	1163	312	
4/25/2008	SEPC	20.12	12.2	1.11	7.39	1324	61.8	
4/25/2008	WETBIG	18.72	67.6	6.33	7.48	1283	239	
4/25/2008	WET1	18.64	37.9	3.54	7.51	1284	28.95	
4/25/2008	WET2	18.41	66.3	6.22	7.65	1264	9.91	
4/25/2008	WET3	18.06	96.9	9.18	7.84	1282	5.74	
4/25/2008	WET4	18.85	75.1	6.99	7.24	1177	8.99	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
4/25/2008	WET5	18.75	75	6.99	7.08	1059	5.55	
4/25/2008	EFF	18.9	88.7	7.74	7.11	956	2.05	
4/25/2008	trip blank (DI)	20.86	63.2	5.66	7.6	66	0.019	
5/3/2008	RAW	12.74	10.6	1.12	7.35	1050	152	
5/3/2008	BWRP	19.9	0.7	0.06	7.25	1060	275	
5/3/2008	SEPC	20.44	12.9	1.16	7.48	1106	107	
5/3/2008	WETBIG	15	25.9	2.61	7.22	1031	257	
5/3/2008	WET1	16.32	28.1	2.75	7.43	1047	29.4	
5/3/2008	WET2	16.75	53.5	5.2	7.61	1044	8.66	
5/3/2008	WET3	17.04	46.7	4.52	7.57	1019	2.84	
5/3/2008	WET4	17.05	41.6	4.02	7.13	1001	14.9	
5/3/2008	WET5	18.01	46.6	4.41	7.42	1082	1.95	
5/3/2008	EFF	22.85	85	7.32	7.06	1594	1.53	
5/3/2008	trip blank (DI)	19.16	79.1	7.34	7.65	72		
5/9/2008	RAW	14.89	32.3	3.27	7.28	1941	207	
5/9/2008	BWRP	21.36	0.8	0.07	7.3	1989	241	
5/9/2008	SEPC	21.59	72	1.06	7.45	2074	53.3	
5/9/2008	WETBIG	14.48	34.5	3.52	7.35	1953	59.3	
5/9/2008	WET1	17.62	25.8	2.46	7.44	1787	18.3	
5/9/2008	WET2	17.29	40.8	3.92	7.6	1948	5.35	
5/9/2008	WET3	17.54	47.7	4.56	7.51	1908	2.89	
5/9/2008	WET4	18.36	46.4	4.37	7.13	1858	8.56	
5/9/2008	WET5	18.51	51.2	4.8	7.39	1908	1.47	
5/9/2008	EFF	21.41	88.3	7.74	7.13	1733	1.701	
5/9/2008	trip blank (DI)				6.61	67	0.09	
5/15/2008	RAW	19.72	8.8	0.79	6.88	1646	42.6	
5/15/2008	BWRP	20.38	1.3	0.11	6.93	1641	134	
5/15/2008	SEPC	20.79	15.7	1.42	7.39	2155	29.3	
5/15/2008	WETBIG	17.01	41.2	3.99	7.39	1432	11.7	
5/15/2008	WET1	18.48	33.7	3.16	7.44	1450	21.2	
5/15/2008	WET2	20.25	29.8	2.7	7.52	1839	2.61	
5/15/2008	WET3	18.19	39	3.68	7.6	1574	15.3	
5/15/2008	WET4	18.91	30.9	2.88	7.21	2567	21.6	
5/15/2008	WET5	19.03	44.4	4.12	7.32	2592	2.09	
5/15/2008	EFF	21.77	86.9	7.62	7.15	2438	0.85	
5/15/2008	trip blank (DI)							

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
5/23/2008	RAW	22.95	7.4	0.62	7	1015	140	
5/23/2008	BWRP	23.57	3.7	0.29	7.33	1020	191	
5/23/2008	SEPC	24.44	7.1	0.59	7.45	1045	25.3	
5/23/2008	WETBIG	19.98	26.2	2.38	7.3	1031	47.4	
5/23/2008	WET1	24.74	11.7	0.96	7.25	1029	20.1	
5/23/2008	WET2	25.02	15.8	1.31	7.44	1010	6.14	
5/23/2008	WET3	24.54	24.54	1.55	7.39	1040	7.19	
5/23/2008	WET4	24.92	22.6	1.86	6.96	974	5.79	
5/23/2008	WET5	24.85	24.3	2.02	7.13	956	3.59	
5/23/2008	EFF	25.05	79.7	6.58	7.29	914	3.54	
5/23/2008	trip blank (DI)	25.38	65.8	5.38	8.08	51	0.9	
5/30/2008	RAW	24.37	3.5	0.28	7.34	939	153	
5/30/2008	BWRP	24.11	1.1	0.09	7.51	1050	207	
5/30/2008	SEPC	21.28	8.3	0.72	7.54	1067	27.2	
5/30/2008	WETBIG	16.82	22.6	2.19	7.43	1115	11.2	
5/30/2008	WET1	21.59	45.3	3.99	7.47	1092	6.27	
5/30/2008	WET2	22.14	40.7	3.54	7.78	1083	3.12	
5/30/2008	WET3	21.72	42.1	3.7	7.65	1082	2.19	
5/30/2008	WET4	21.37	40.3	3.57	7.33	1041	5.07	
5/30/2008	WET5	21.1	45.7	4.07	7.38	1110	1.32	
5/30/2008	EFF	24.83	87.8	7.27	7.39	858	0.798	
5/30/2008	trip blank (DI)	23.4	44.1	3.75	8.52	28	0.789	
6/6/2008	RAW	25.23	6.5	0.52	7.09	2174	151	
6/6/2008	BWRP	25.23	1.1	0.09	7.01	2182	142	
6/6/2008	SEPC	25.77	12.5	1.01	7.21	2131	33.9	
6/6/2008	WETBIG	24.43	40.2	3.36	6.97	2310	103	
6/6/2008	WET1	25.41	9.3	0.76	7	1113	17.5	
6/6/2008	WET2	23.5	47.4	4.03	7.28	1932	2.73	
6/6/2008	WET3	25.62	19.4	1.58	7.08	1078	1.33	
6/6/2008	WET4	25.26	20.1	1.65	6.89	1135	3.07	
6/6/2008	WET5	25.42	13.6	3.36	7.06	2453	5.39	
6/6/2008	EFF	25.79	89.1	7.25	7.14	2151	0.835	
6/6/2008	trip blank (DI)							
6/13/2008	RAW	25.02	7.1	0.57	7.29	980	202	
6/13/2008	BWRP	26.12	1.3	0.1	7.34	975	211	
6/13/2008	SEPC	26.2	4.9	0.38	7.59	1025	36.5	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
6/13/2008	WETBIG	19.24	55.4	5.12	7.22	1046	31.4	big wetland drained for 12 hours
6/13/2008	WET1	20.71	45.1	4.04	7.42	1087	7.33	to examine front clog
6/13/2008	WET2	20.65	52.7	4.73	7.83	989	3.59	
6/13/2008	WET3	21.39	51.5	4.56	7.51	1027	1.4	
6/13/2008	WET4	22.43	50.9	4.4	7.16	1090	2.97	
6/13/2008	WET5	23.25	51.2	4.4	7.22	1702	3.28	
6/13/2008	EFF	25.06	94.7	7.72	7.14	769	0.798	
6/13/2008	trip blank (DI)	21.01	107.6	8.78	8.23	57	0.214	
6/20/2008	RAW	21	4.4	0.38	7.05	1293	194	
6/20/2008	BWRP	21.7	1.5	0.12	7.39	1040	214	container burst
6/20/2008	SEPC	22.48	7.5	0.64	7.43	1041	49.8	
6/20/2008	WETBIG	18.34	52.6	4.98	7.17	1142	9.59	
6/20/2008	WET1	17.89	39	3.69	7.26	1076	8.87	
6/20/2008	WET2	18.44	41.7	3.92	7.69	1029	4.86	
6/20/2008	WET3	18.99	45.7	4.24	7.33	1028	2.87	
6/20/2008	WET4	19.48	45.3	4.19	6.95	1061	3.89	
6/20/2008	WET5	19.86	47.4	4.31	7.24	2927	4.39	
6/20/2008	EFF	23.97	84.6	7.12	7.17	889	1.04	
6/20/2008	trip blank (DI)							
6/27/08	RAW	23.34	4.59	0.38	6.69	1.059	72.6	
6/27/08	BWRP	23.54	1.8	0.15	7.3	1.048	203	
6/27/08	SEPC	23.68	2.3	0.18	7.18	1.18	142	
6/27/08	WETBIG	19.87	75.7	6.9	7.54	1.462	9.34	
6/27/08	WET1	20.82	54.5	4.87	7.21	1.263	6.44	
6/27/08	WET2	20.61	51.7	4.66	7.66	1.702	3.46	
6/27/08	WET3	21.73	50.7	4.46	7.23	1.254	4.3	
6/27/08	WET4	21.81	53	4.7	6.93	1.34	1.3	
6/27/08	WET5							no sample iin last cell
6/27/08	EFF	24.15	91.1	7.62	7.02	0.753	0.222	
6/27/08	trip blank (DI)	24.42	6.66					
7/4/08	RAW	22.9	6.4	0.55	7.16	1.061	193	
7/4/08	BWRP	22.77	1.1	0.09	7.22	1.057	131	
7/4/08	SEPC	15.56	20.9	2.08	7.38	1.031	111	
7/4/08	WETBIG	18.08	44.6	4.22	7.1	1.114	8.47	
7/4/08	WET1	17.68	115	11.03	7.17	1.155	4.05	
7/4/08	WET2	18.95	98.3	9.13	7.64	0.999	2.85	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
7/4/08	WET3	19.79	100	10.98	7.28	0.999	13.4	
7/4/08	WET4	19.93	61.7	5.49	6.79	1.800	1.27	
7/4/08	WET5							no water in last cell of Wet5
7/4/08	EFF	27.13	100	13.61	7.18	1.000	1.76	
7/4/08	trip blank (DI)	23.14	11.47		7.15	0.356	0.133	
7/11/08	RAW	23.45	10.8	0.91	7.21	0.909	345	
7/11/08	BWRP	23.1	2.3	0.2	7.3	0.95	205	
7/11/08	SEPC	15.34	59	5.92	7.89	1.021	128	
7/11/08	WETBIG	18.62	58.2	5.44	7.39	1.12	5.51	
7/11/08	WET1	18.07	43.6	4.12	7.33	1.037	3.47	
7/11/08	WET2	17.62	41.8	3.99	7.95	0.925	2.44	
7/11/08	WET3	18.19	51	4.81	7.27	1.194	1.21	
7/11/08	WET4	17.52	95.6	9.14	7.02	1.452	0.972	
7/11/08	WET5	17.2	92	8.97	7.02	1.257	0.871	
7/11/08	EFF	24.64	83.3	6.93	7.17	1.01		
7/11/08	trip blank (DI)							
7/18/08	RAW	21.58	7.5	0.65	7.36	0.878	287	
7/18/08	BWRP	20.18	1.9	0.16	7.47	0.958	200	
7/18/08	SEPC	15.75	49.5	4.92	7.72	0.99	83.3	
7/18/08	WETBIG	17.31	37.8	3.64	7.27	0.917	5.55	
7/18/08	WET1	18.5	16.2	1.52	7.04	1.158	3.1	
7/18/08	WET2	18.82	18.3	1.71	7.59	0.982	2.84	
7/18/08	WET3	17.96	22.1	2.09	7.34	1.032	1.24	
7/18/08	WET4	16.4	82.5	8.08	7.55	1.551	0.685	
7/18/08	WET5	18.3	11.6	1.1	7.34	4.078	3.46	Unit 5 -insufficient flow in last cell for
7/18/08	EFF	25.72	87	7.1	7.77	0.874	0.555	~ 1 month
7/18/08	trip blank (DI)				8.42	0.072	0.165	
7/25/08	RAW	23.22	6.1	0.5	7.00	1.329	222	
7/25/08	BWRP	21.54	2.4	0.2	7.02	1.437	271	
7/25/08	SEPC	16.07	38.4	3.8	7.05	1.533	104	
7/25/08	WETBIG	18.24	53.8	5.08	6.97	1.602	4.58	
7/25/08	WET1	18.27	20	1.88	6.92	1.455	3.26	
7/25/08	WET2	18.66	23.4	2.19	7.03	1.416	0.277	
7/25/08	WET3	19.39	25.7	2.36	6.82	1.407	0.987	
7/25/08	WET4	19	23.2	2.14	6.65	1.92	0.789	
7/25/08	WET5	18.23	100	9.49	7.28	5.034	6.33	double checked conductivity (re-calibrated)

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
7/25/08	EFF	27.14	97.8	7.73	6.64	0.966	1.02	
7/25/08	trip blank (DI)	23.05	78.4	6.72	7.24	0.31	0.222	
8/1/08	RAW	22.24	8.9	0.76	7.24	0.663	107	0.7 inches of rain overnight
8/1/08	BWRP	21.16	1.7	0.14	7.07	1.379	106	
8/1/08	SEPC	17.56	6.2	0.59	7.62	1.078	99.7	
8/1/08	WETBIG	19.94	47.6	4.34	7.37	1.207	4.64	
8/1/08	WET1	18.55	16.2	1.52	7.08	1.233	3.82	
8/1/08	WET2	18.25	13.4	1.26	7.54	1.03	2.51	
8/1/08	WET3	19.16	16.7	1.54	7.22	1.17	1.22	
8/1/08	WET4	18.37	18.7	1.76	6.72	2.633	0.626	
8/1/08	WET5	18.92	75.2	6.99	7.72	3.871	1.99	unit 5 not getting water to last cell
8/1/08	EFF	24.19	85.9	7.17	6.92	0.808	0.767	
8/1/08	trip blank (DI)				7.01	0.642	0.23	
8/8/08	RAW	25.85	8.8	0.7	7.26	0.974	171	
8/8/08	BWRP	25.84	1.9	0.14	7.31	1.115	129	
8/8/08	SEPC	25.99	21.8	1.76	7.47	1.286	49.9	
8/8/08	WETBIG	20.97	37.3	3.34	7.39	0.934	3.67	
8/8/08	WET1	25	23.9	1.96	7.03	1.057	1.77	
8/8/08	WET2	17.71	18	1.71	7.39	1.044	1.93	
8/8/08	WET3	17.3	26.1	2.5	7.23	0.934	1.17	
8/8/08	WET4	16.2	28.8	2.83	6.91	1.649	0.606	
8/8/08	WET5	16.35	92.9	9.15	8.28	3.266	1.15	
8/8/08	EFF	28.03	91.7	7.14	7	0.724	0.685	
8/8/08	trip blank (DI)	27.27	76.5	6.06	7.33	0.016	0.178	
8/15/08	RAW	25.41	8	0.6	6.96	0.967	138	
8/15/08	BWRP	24.52	0.7	0.06	7.18	1.162	279	
8/15/08	SEPC	24.85	8.1	0.63	7.4	1.124	10	
8/15/08	WETBIG	22.34	40	3.47	7.2	1.316	23	
8/15/08	WET1	18.59	70.1	6.57	7.31	1.305	5.55	
8/15/08	WET2	24.14	23.7	1.99	7.63	1.04	1.41	
8/15/08	WET3	23.7	29.2	2.46	7.09	1.292	1.11	
8/15/08	WET4	19.4	74.8	6.95	7.1	1.825	0.473	
8/15/08	WET5	19.64	23.6	2.17	7.32	5.101	1.8	
8/15/08	EFF	26.25	95.8	7.71	7.35	1.097	1.04	
8/15/08	TB	23.26	58.4	4.99	5.94	0.018	0.208	
9/5/08	RAW	22.24	9.7	0.78	6.97	0.548	64.4	no samples 8/23 or 8/30

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
9/5/08	BWRP	0.45	1.6	0.13	7.35	1.06	96.9	
9/5/08	SEPC	13.55	25.4	2.64	7.72	0.659	21	
9/5/08	WETBIG	13.99	68.1	7	7.51	1.282	10.8	
9/5/08	WET1	11.35	79.8	8.73	7.8	1.367	3.07	
9/5/08	WET2	12.63	75.1	7.98	7.85	1.074	2.87	
9/5/08	WET3	15.49	28.1	2.83	7.06	1.152	1.49	
9/5/08	WET4	23.87	33.6	2.83	6.79	1.803	31.8	
9/5/08	WET5	22.95	89.2	7.66	7.51	3	1.6	
9/5/08	EFF	26.33	93.8	7.57	7.22	0.955	0.914	
9/5/08	TB				7.97	0.144	0.16	
9/12/08	RAW	19.41	12.2	1.58	6.87	0.734	139	
9/12/08	BWRP	20.07	2.3	0.2	7.25	0.797	118	
9/12/08	SEPC	18.52	8.6	0.79	7.57	0.822	31.4	
9/12/08	WETBIG	19.4	69.8	6.42	7.22	0.845	13.4	
9/12/08	WET1	20.32	55.9	5.04	7	0.856	5.22	
9/12/08	WET2	18.81	52.5	4.89	7.6	0.746	1.58	
9/12/08	WET3	18.61	40	3.74	7.08	0.874	2.4	
9/12/08	WET4	18.88	41.6	3.86	6.84	1.208	9.93	
9/12/08	WET5	19.71	75.2	6.88	7.53	2.872	3.34	
9/12/08	EFF	21.83	86	7.55	7.25	0.658	1.13	
9/12/08	TB	23.15	41.5	3.55	9.6	0.091		
9/19/08	RAW	22.96	6.6	0.55	6.91	0.582	134	
9/19/08	BWRP	22.93	2.3	0.19	7.14	1.067	158	
9/19/08	SEPC	23.27	12.4	1.05	7.25	1.146	20.3	
9/19/08	WETBIG	21	77.1	6.9	7.01	1.124	12.3	
9/19/08	WET1	21.01	76.3	6.78	7.02	1.124	7.17	
9/19/08	WET2	20.34	71.9	6.52	7.61	1.076	4.04	
9/19/08	WET3	20.21	84.3	7.67	7.13	1.107	1.13	
9/19/08	WET4	19.83	80.9	7.38	7.03	1.494	1.67	
9/19/08	WET5	19.94	73.8	6.64	7.28	2.652	0.957	
9/19/08	EFF	25.26	91.9	7.68	7.13	0.98	1.32	
9/19/08	TB							
9/26/08	RAW	23.35	7.7	0.65	7.1	1.13	113	first sample with new UNIT2-UNIT3 in series
9/26/08	BWRP	21.33	1.4	0.12	7.14	1.078	178	
9/26/08	SEPC	11.98	20.9	2.23	7.4	7.081	90.9	
9/26/08	WETBIG	12.73	35.9	3.7	7.03	1.128	10.2	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
9/26/08	WET1	21.6	59.6	5.32	6.93	1.92	4.41	
9/26/08	WET2	19.76	50.9	5.8	7.5	1.075	1.92	
9/26/08	WET3	14.65	80.8	8.21	7.19	1.5	0.855	
9/26/08	WET4	16.79	64.5	6.29	6.85	2.923	0.988	
9/26/08	WET5	9.91	73.5	7.92	7.15	2.485	0.676	
9/26/08	EFF	26.61	99.9	8.11	6.81	0.87	0.771	
9/26/08	TB	21.7			8.81	0.037	0.258	
10/3/08	RAW	22.17	8.2	0.69	7.12	1.031	121	
10/3/08	BWRP	19.74	2.3	0.19	7.39	0.788	161	
10/3/08	SEPC	10.39	18.9	2.10	7.65	0.866	22.2	
10/3/08	WETBIG	9.02	35.8	4.11	7.8	0.894	11.8	
10/3/08	WET1	9.37	34.6	3.96	7.35	1.135	2.26	
10/3/08	WET2	6.89	31.8	3.87	7.75	0.875	5.79	
10/3/08	WET3	6.72	33.2	4.02	7.52	0.955	1.68	
10/3/08	WET4	7.22	32.6	3.93	7.37	1.356	1.18	
10/3/08	WET5	9.45	35.6	4.04	7.58	2.274	1.24	
10/3/08	EFF	24.88	49.7	4.14	7.5	0.652	0.722	
10/3/08	TB	18.96	37.6	3.48	9.96	0.148	0.143	
10/10/08	RAW	19.73	7.2	0.65	7.31	1.065	112	
10/10/08	BWRP	19.86	2.2	0.19	7.41	1.008	72.4	
10/10/08	SEPC	12.24	20.4	2.18	7.4	1.086	88.7	
10/10/08	WETBIG	14.55	40.9	4.17	7.32	1.219	11.5	
10/10/08	WET1	13.65	34.4	3.57	7.24	1.47	1.05	
10/10/08	WET2	13.79	32.1	3.33	7.84	1.143	1.69	
10/10/08	WET3	14.24	97.7	10.03	7.87	1.2	6.19	
10/10/08	WET4	12.24	31.1	3.34	7.14	1.851	1.08	
10/10/08	WET5	12.3	75.2	8.07	7.3	3.227	5.99	
10/10/08	EFF	22.13	78.4	6.85	7.42	0.894	0.971	
10/10/08	TB	17.98	74.4	7.06	10.11	0.521	0.438	
10/17/08	RAW	22.01	5.4	0.46	7.43	1.031	159	
10/17/08	BWRP	17.41	1	0.08	7.24	1.083	133	
10/17/08	SEPC	17.97	7.5	0.69	7.27	1.126	114	
10/17/08	WETBIG	13.84	33.9	3.5	7.17	1.164	16.3	
10/17/08	WET1	11.04	32.8	3.62	7.23	1.16	2.35	
10/17/08	WET2	10.4	24.7	2.77	7.42	1.191	10.9	
10/17/08	WET3	10.93	34.1	3.78	7.26	1.19	6.52	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
10/17/08	WET4	11.97	31	3.36	7.08	1.428	1.37	
10/17/08	WET5	13.04	79.3	8.37	7.09	3.321	2.83	
10/17/08	EFF	22.8	81.7	7.01	7.21	0.885	1.09	
10/17/08	TB	16.95	61.7	5.97	10.21	0.244	0.361	
10/24/08	RAW	17.82	8.7	0.82	7.22	1.06	150	
10/24/08	BWRP	15	5	0.49	7.34	1.126	141	
10/24/08	SEPC	12.76	42	4.5	7.37	1.14	136	
10/24/08	WETBIG	16.68	48.6	4.73	7.17	1.125	20.2	
10/24/08	WET1	16.55	49	4.77	7.07	1.389	4.34	
10/24/08	WET2	15.22	43.5	4.37	7.48	1.072	5.32	
10/24/08	WET3	15.38	47.4	4.74	7.36	1.071	5.06	
10/24/08	WET4	15.32	53.4	5.35	7.09	2.005	3.01	
10/24/08	WET5	15.59	95.6	9.56	7.42	3.531	3.2	
10/24/08	EFF	21.19	80.8	7.16	7.02	0.925	1.36	
10/24/08	TB	13.77	83	8.65	8.1	0.199	0.191	
10/31/08	RAW	17.51	6.8	0.64	7.34	0.821	142	
10/31/08	BWRP	12.66	6.1	0.6	7.4	0.67	121	
10/31/08	SEPC	11.77	21.2	2.3	7.56	0.909	105	
10/31/08	WETBIG	15.52	19.6	1.96	7.5	0.971	47.8	
10/31/08	WET1	11.3	21.5	2.36	7.15	0.946	1.04	
10/31/08	WET2	11.12	20.9	2.3	7.69	0.889	2.16	
10/31/08	WET3	12.12	20.8	2.24	7.65	0.715	3.77	
10/31/08	WET4	14.89	23.8	2.41	7.05	1.844	1.46	
10/31/08	WET5							
10/31/08	EFF	21.74	26.9	2.36	7.51	0.731	1.01	
10/31/08	TB	16.48	24.6	2.39	8.07	0.047	0.245	
11/7/08	RAW	18.3	7.9	0.72	7.15	1.083	1.62	
11/7/08	BWRP	16.17	5.3	0.49	7.23	1.145	145	
11/7/08	SEPC	16.3	9.3	0.9	7.37	1.187	74	
11/7/08	WETBIG	16.12	42.2	4.14	7.36	1.238	25.1	
11/7/08	WET1	11.2	37.9	4.17	7.02	1.592	1.25	
11/7/08	WET2	11.76	38.8	4.22	7.42	1.213	5.37	
11/7/08	WET3	14.75	54.7	5.54	7.22	1.162	2.91	
11/7/08	WET4	12.7	47.5	5.07	7.34	1.524	0.948	
11/7/08	WET5							
11/7/08	EFF	22.41	89.3	7.73	8.91	0.992	1.28	
11/7/08	TB	15.21	85.3	8.61	9.34	0.191	0.804	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
11/14/08	RAW	20.79	6.2	0.54	6.99	0.79	145	
11/14/08	BWRP	20.48	2.9	0.23	7.29	0.838	73.6	
11/14/08	SEPC	19.7	7.3	0.66	7.44	0.854	35.2	
11/14/08	WETBIG	18.63	29.6	2.78	7.16	0.896	18.6	
11/14/08	WET1	17.56	39.9	3.8	6.89	9.42	0.523	
11/14/08	WET2	18.32	27.8	2.62	7.39	0.826	3.38	
11/14/08	WET3	18.4	34.7	3.26	7.19	0.802	1.45	
11/14/08	WET4	17.71	37.7	3.58	6.82	1.004	0.968	
11/14/08	WET5	18.67	76.4	6.89	7.69	0.611	5.68	
11/14/08	EFF	22.74	58.2	5.03	7.29	0.698	1.75	
11/14/08	TB	18.27	53.4	4.99	8.28	0.118	0.486	
11/21/08	RAW	15.92	8.5	0.83	7.1	0.804	141	
11/21/08	BWRP	12.69	4.9	0.5	7.34	0.907	130	
11/21/08	SEPC	4.97	45.4	5.81	7.43	1.019	46.1	
11/21/08	WETBIG	7.13	48.8	5.92	7.34	1.151	7.87	
11/21/08	WET1							
11/21/08	WET2	7.71	34.7	4.08	7.36	0.931	4.69	
11/21/08	WET3	7.21	40.3	4.9	7.28	0.959	3.34	
11/21/08	WET4							
11/21/08	WET5	9.45	36.3	4.2	7.57	2.115	3.63	
11/21/08	EFF	17.92	83.5	7.86	7.66	0.677	4.46	
11/21/08	TB	12.25	70.3	7.52	8.48	0.08	0.503	
12/5/08	RAW	12.2	8.1	0.85	7.34	0.458	92.1	
12/5/08	BWRP	10.65	6.7	0.73	7.37	0.584	156	
12/5/08	SEPC	4.75	40.6	5.23	7.62	0.503	15.7	
12/5/08	WETBIG	5.92	33.4	4.22	7.42	0.498	11.3	
12/5/08	WET1	4.11	21.3	2.79	7.21	0.951	16.6	
12/5/08	WET2	5.52	19.9	2.51	7.33	0.534	5.12	
12/5/08	WET3	5.35	43.1	5.49	7.3	0.495	2.17	
12/5/08	WET4	5.29	40.4	5.15	7.29	1.02	22.3	
12/5/08	WET5	5.96	68.5	8.61	7.09	0.834	5.37	
12/5/08	EFF	16.09	82.3	8.08	7.42	0.527	0.947	
12/5/08	TB	8.15	63.8	7.6	7.86	0.036	0.186	
12/12/08	RAW	20.01	8.9	0.8	6.98	1.318	108	
12/12/08	BWRP	19.57	2.3	0.21	7.27	1.325	106	

Date	Unit	Temp C	DO (%)	DO (mg/l)	pH	Sp cond (us/cm)	Turbidity (NTU)	Comments
12/12/08	SEPC	17.83	8.9	0.83	7.32	1.41	194	
12/12/08	WETBIG	15.43	46.2	4.6	7.22	1.648	14.7	
12/12/08	WET1	13.98	30.8	3.18	7.09	1.415	34.9	
12/12/08	WET2	13.76	40.6	4.2	7.37	1.341	4.31	
12/12/08	WET3	12.46	80.2	8.56	7.24	1.396	2.83	
12/12/08	WET4	11.6	67.8	7.39	6.85	2.234	5.35	
12/12/08	WET5	12.43	15.5	1.68	7.11	1.398	15.7	
12/12/08	EFF	19.1	90.4	8.34	6.67	1.102	1.36	
12/12/08	TB	13.03	88.6	9.37	7.32	0.518	0.563	
12/18/08	RAW	22.77	6.1	0.52	6.82	1.134	98.6	
12/18/08	BWRP	21.89	1.6	0.13	7.08	1.128	365	
12/18/08	SEPC	18.49	8.4	0.78	7.32	1.168	179	
12/18/08	WETBIG	16.37	37	3.62	7.06	1.457	11.2	
12/18/08	WET1	14.51	34.7	3.54	7.08	1.241	14.9	
12/18/08	WET2	13.74	40	4.15	7.46	1.113	3.29	
12/18/08	WET3	13.45	40.6	4.24	7.37	1.093	1.52	
12/18/08	WET4	10.46	94.7	10.58	6.98	1.449	0.87	
12/18/08	WET5	10.24	25.4	2.86	7.27	1.14	26.7	
12/18/08	EFF	16.67	82.2	7.98	7.19	0.934	1.27	
12/18/08	TB	12.17	74.8	8.05	8.09	0.158	0.297	