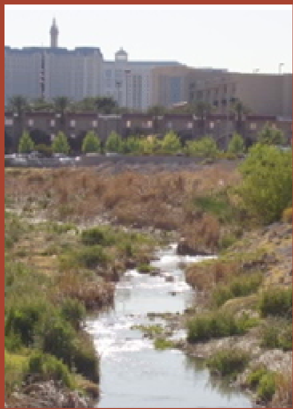

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A Comparison of Water Quality Improvements from Three Different Wetland Types in the Las Vegas Valley Watershed

May 2010

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Las Vegas Wash Coordination Committee

A Comparison of Water Quality Improvements from Three Different Wetland Types in the Las Vegas Valley Watershed

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ABSTRACT

Increased runoff associated with rapid growth in the Las Vegas Valley has led to creation of unique wetlands systems in Southern Nevada with abundance of biological diversity. Constructed and naturally created wetlands in the Las Vegas Valley watershed were studied to characterize and understand their potential role for pollutant removal from the system. Metals and nutrient dynamics study of the local plants, i.e., cattails and bulrushes were conducted to characterize their function in the local environment in four wetlands located in the Las Vegas Wash, Flamingo Wash, Demonstration Wetland at the City of Henderson Water Reclamation Facility and Pittman Wash Pilot Wetlands. The results suggest that nutrient uptake by plant tissue was dependent on the ambient nutrient concentrations in both the water column as well as sediments of specific wetlands, irrespective of the type of plants present. Nutrients in above and below ground plant tissues showed that removal of the root systems would be necessary for maximum phosphorus removal, whereas for nitrogen above-ground harvest would be sufficient. As for metalloids, bulrush species seem particularly more efficient, especially for arsenic and selenium, compared to cattails. Similar to phosphorus, below-ground plants had more metals per unit weight than above-ground parts for both species in our study. These findings have important implications for improving our ability to engineer ecological solutions to problems associated with nutrient-rich wastewater and to implement sustainable wetland management plans.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Wetlands have a higher rate of biological activity than most ecosystems; they can transform many of the common pollutants that occur in conventional wastewater into harmless byproducts or essential nutrients that can be used for additional biological productivity (Kadlec, 1998). Wetlands with a variety of hydrologic, vegetation, and soil conditions can occur naturally or be constructed in many landscape positions (Kadlec and Wallace, 2009). Wetlands are often highly productive systems where numerous biological transformations are taking place, driven by the natural energies of the sun, soil, wind, and by microorganisms, plants, and animals (Thullen et al., 2005 and the references therein). These biological transformations can sometimes provide an effective means to convert, release to the atmosphere, or sequester unwanted and excess chemicals from the system. The use of constructed wetlands for wastewater treatment has been tested widely in recent years, especially to reduce nitrogen and phosphorus loads (Vymazal, 2007). It has been found that the performance efficiencies of constructed or natural wetlands depend on several variables, such as the quality and quantity of effluent to be treated, and biological, physical, and chemical activities in that particular wetlands system (Greenway and Woolley, 2001; Greenway, 2003).

Until recently, nitrogen and phosphorus used to be the main nutrients of concern in wetland systems, with their concentrations varying depending on the source of wastewater (Vymazal, 2006; Toet et al., 2003) and the extent of nonpoint source pollution in the region. However, recently other pollutants, such as heavy metals, radioactive chemicals, and pharmaceutical and industrial organic chemicals have also emerged as pollutants of concern. Wetland plants play a wide range of roles in constructed wetlands for wastewater treatment. Roles include the physical effects of the plants themselves in affecting sedimentation, erosion control and providing surface area for microbial growth (biofilms) thus increasing microbial assisted processes including nitrification and denitrification. Aquatic plants also have a metabolic role in wastewater treatment with the potential to release oxygen into the rhizosphere aiding in nitrification and by the direct uptake of nutrients (Brix, 1997; Greenway and Woolley, 2001). Plants are the dominant structural component of most wetland treatment systems. Therefore, availability of nutrients affects plant growth responses and resource allocation as well as possibly influencing removal efficiency in wetlands (Tanner, 2001; Zhang et al., 2007). A basic understanding of the growth requirements and characteristics of these wetland plants is essential for successful treatment wetlands design and operation.

Emergent aquatic plant species such as cattails (*Typha* spp.), bulrushes (*Schoenoplectus* spp.), and common reed (*Phragmites australis*) have been widely used in the U.S. and elsewhere around the world for nutrient removal in constructed wetlands. Researchers argue that nutrient removal can be optimized by selecting suitable species with higher capacity for inorganic nitrogen and phosphorus absorption and conversion into plant biomass (Greenway, 2003; Vymazal, 2007; Mitsch and Gosselink, 2000). However, in the case of trace metals and radioactive and industrial organic chemicals, there is very little information available. The limited research that is available suggests that trace amounts of metals have been reported in plants growing in natural and constructed wetlands for wastewater treatment (Lesage et al., 2007; Vymazal and Krása, 2005; Vymazal et al., 2007). Also, a few others report that the bioaccumulation process is found to be effective in reducing some metals such as arsenic and selenium into insoluble forms in some constructed wetlands (Zhang and Moore, 1997; Zhang and Frankenberge, 2003; Lin and Terry, 2003).

Wetlands in arid and semi-arid regions often experience a lack of water due to water shortages and higher evaporation. Rapid population growth and economic development have caused deterioration or total destruction of many wetlands in these regions. In the semi-arid regions of the U.S., wetlands and riparian areas constitute less than 2% of the surface area, but provide partial habitat for 80% of the wildlife species (McKinstry et al., 2004). The Las Vegas Valley (Valley) watershed located in Southern Nevada, also an arid region of the U.S., supports many ecologically significant wetlands often regarded as an oasis in the desert (SNWA, 2004). The Las Vegas Wash (Wash), a primary drainage channel for the 1,600 square-miles of the Valley watershed, supports a substantial riparian area (Eckberg and Shanahan, 2009). In the early 1970s, the Wash provided an excellent wetland habitat as the desert soil was transformed into wet marshy wetland soils. However recently, the Wash has experienced considerable change as a result of rapid urban development in the valley (last 50 years). The wetland areas have decreased significantly, from about 2,000 acres in 1975 to about 300 acres in 1999 (LVWCC, 2000). Excessive erosion along the channel has resulted in loss of wetlands and wildlife habitat, loss of property, damage to infrastructure, excessive sediment transport and water quality concerns in Lake Mead (LVWCC, 2000). As a restoration initiative, many erosion controls structures are being built to stabilize the channel, lands that are adjacent to these structures are being revegetated with plants that are native to Mojave Desert riparian ecosystems. As of March 2008, 181 acres of land have been revegetated in the Wash. Also, construction of the 2,900 acre Clark County Wetlands Park has been initiated (Cizdziel and Zhou, 2005).

There are several other wetlands in the area, either naturally formed as a result of flood control structures, or purposely constructed to improve ecosystem services. Like wetlands in many other rapidly growing urban centers, the wetlands in Las Vegas receive relatively high amounts of nutrients from wastewater discharge and potential pollutants from nonpoint sources. Most of the wetlands in the valley are of free water surface (FWS) type, which have areas of open water and are similar in appearance to natural marshes. As the wastewater flows through the wetlands, it is treated by the process of sedimentation, filtration, oxidation, reduction, adsorption and precipitation. Since the FWS wetlands closely mimic natural wetlands, they attract a wide variety of wildlife (Kadlec and Wallace, 2009). Besides FWS types, a few pilot scale demonstration ponds have also been constructed. The details of individual wetlands are provided in the next section (site description). Since the Valley also has problems of naturally occurring trace metals such as selenium and arsenic in higher concentrations in some places, the wetlands in the Valley have the potential to function as natural filters by improving water quality from wastewater discharge and urban runoff. However, performance of these wetlands has not been cumulatively assessed. To understand the functions and services that these wetlands provide, it is important to develop assessment methods based on weather, geomorphology, plant types, and other water quality parameters. Not only will this allow the maximization of ecosystem services, but more broadly, lessons learned from these wetlands can be applied to similar wetlands in other arid and semi-arid systems.

The goal of this research was to compare and contrast the key characteristics of various types of wetlands in the Valley and to assess their capability to remove nutrients and metalloids as has been documented for other wetland systems in the literature. We investigated changes in the concentration of nutrients (nitrogen and phosphorus) and metalloids (selenium and arsenic) in the water column and sediments at wetland inlets and outlets in systems with established populations of two widespread wetlands plants (one species of cattail and three species of bulrush). A variety of above-ground and below-ground plant tissues were analyzed for nutrient and metalloid concentrations and values were compared across wetland sites to quantify the allocation and storage of these compounds with respect to ambient concentrations in the water column and sediments. This study confirms that the created and natural wetlands of the arid Las Vegas Valley are providing many of the ecosystem services predicted by the literature for wetlands in more temperate regions. This work also provides guidance for future research in refining the operation and maintenance of these wetland systems to maximize water quality improvements.

2.0 MATERIALS AND METHODS

2.1 Site Description

The study was carried out in four wetlands types in the Valley (Figure 1; Table 1) including: (1) a constructed wastewater effluent treatment wetland, Demonstration Wetlands at the City of Henderson Water Reclamation Facility (HD); (2) a constructed urban runoff treatment wetlands, Pitman Wash Pilot Wetland (PW); (3) a naturally occurring in-situ urban runoff treatment wetlands, Flamingo Wash (FW); and, (4) a wetlands created by backwater behind the Pabco Road Weir in the mainstream Las Vegas Wash (LVW).

LVW: The Wash is the major drainage for the Valley which drains into Las Vegas Bay in Lake Mead. The Wash currently discharges, at >290 cubic feet per second (cfs; http://waterdata.usgs.gov/nwis/annual) providing nearly 2% of the inflow to the reservoir (Leising, 2003; SNWA, 2004). The Wash also conveys untreated urban runoff, resurfacing groundwater, and stormwater runoff (SNWA, 2004). The LVW wetlands site, fed mostly by treated wastewater effluent from the three municipal facilities, is located in the main channel of the Wash and was created from the backwater pool behind Pabco Road Weir (Figure 2). It has a well established, dense population of vegetation (>100 feet wide at many places) and provides habitat to many aquatic and avian species. There is also a large amount of standing water in this wetland potentially forming very rich sediment deposits. The wetland vegetation in this area is dominated by cattails (*T. domingensis*) and common reeds (*P. australis*).

FW: These wetlands are located in the Flamingo Wash, a tributary to the Wash, and are fed by urban runoff (Figure 3). The Flamingo Wash stretches for several miles but the wetlands are somewhat patchy and sparsely located. Dense vegetation of annual weeds mixed with cattails exists throughout the channel and provides habitat to many aquatic and avian species. FW has an average discharge of ~5 cfs.

PW: The Pittman Wash is a demonstration-type pilot wetland created to study water quality from urban runoff before it enters the Wash (Figure 4). The PW wetlands are experimental wetlands (20 m x 20 m) and have both surface and sub-surface flow components. The main plants in the PW wetlands are three species of bulrushes (*S. acutus, S. americanus,* and *S. californicus*).

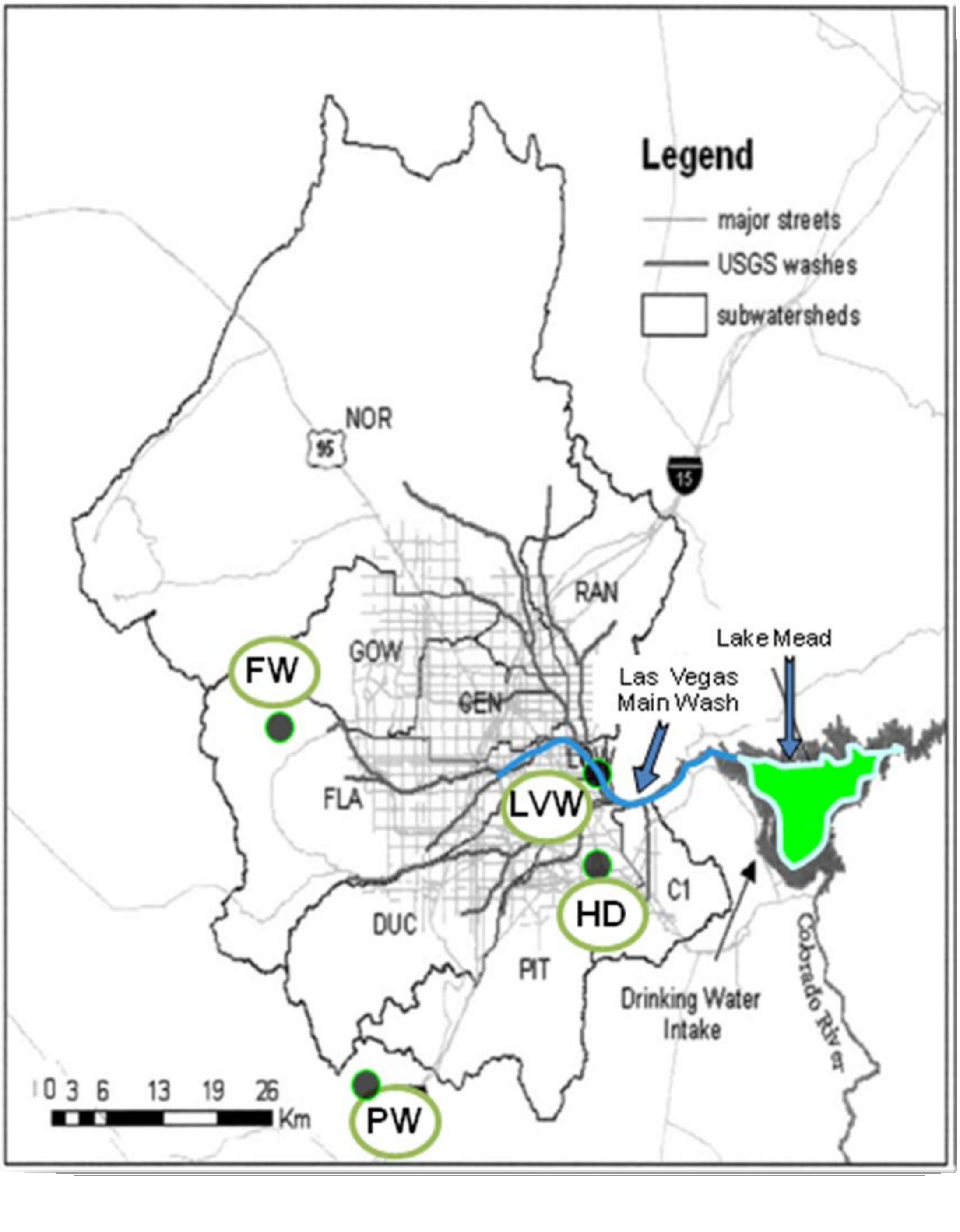

Figure 1: Map showing different wetlands sites located within the Valley - FW: Flamingo Wash, PW: Pitman Wash Pilot Wetlands, HD: Demonstration Wetland at the City of Henderson Water Reclamation Facility, and LVW: Las Vegas Wash (adapted from Reginato and Piechota, 2004).

Project Sites	LAT (N)	LON (W)
Las Vegas Wash (LVW)	36.088061	114.986333
Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD)	36.075497	115.001964
Pittman Wash Pilot Wetlands (PW)	36.046747	115.053628
Flamingo Wash (FW)	36.113675	115.148103

Table 1: Locations of the four wetland sites in the Valley.

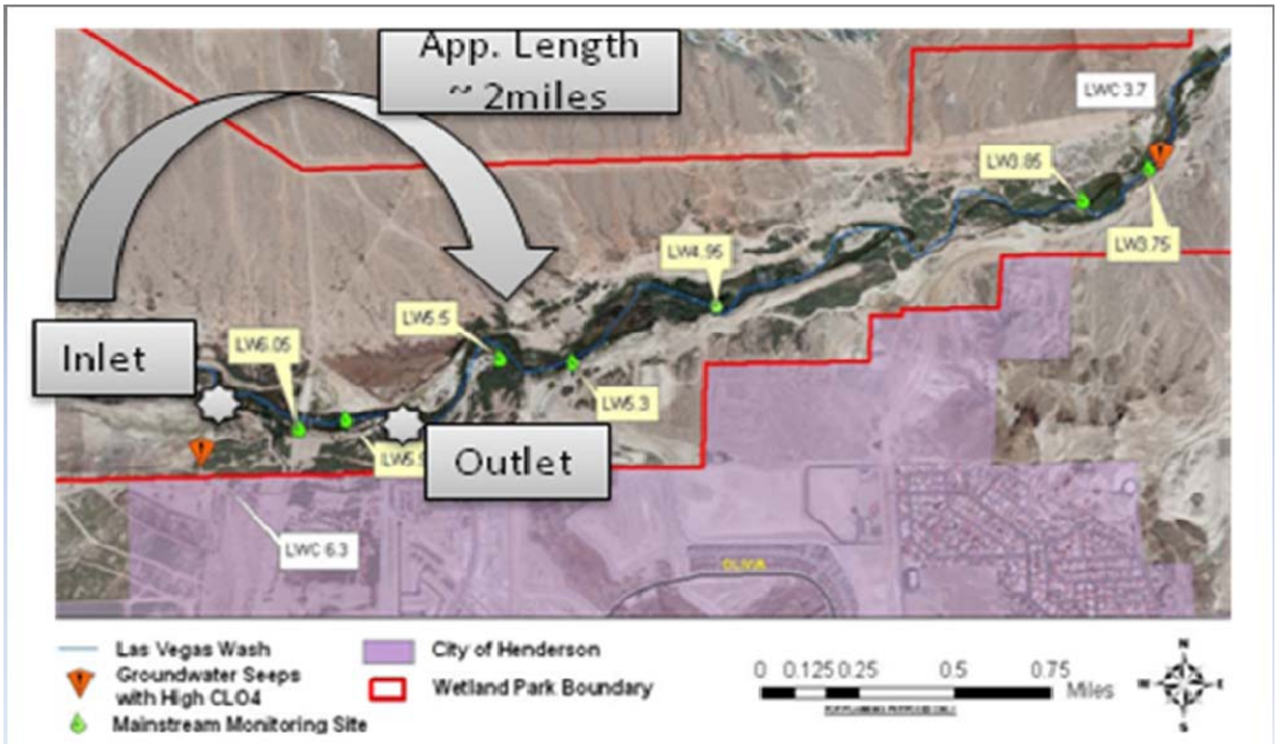

Figure 2: LVW showing inlet and outlet sampling locations for sediment and water sampling.

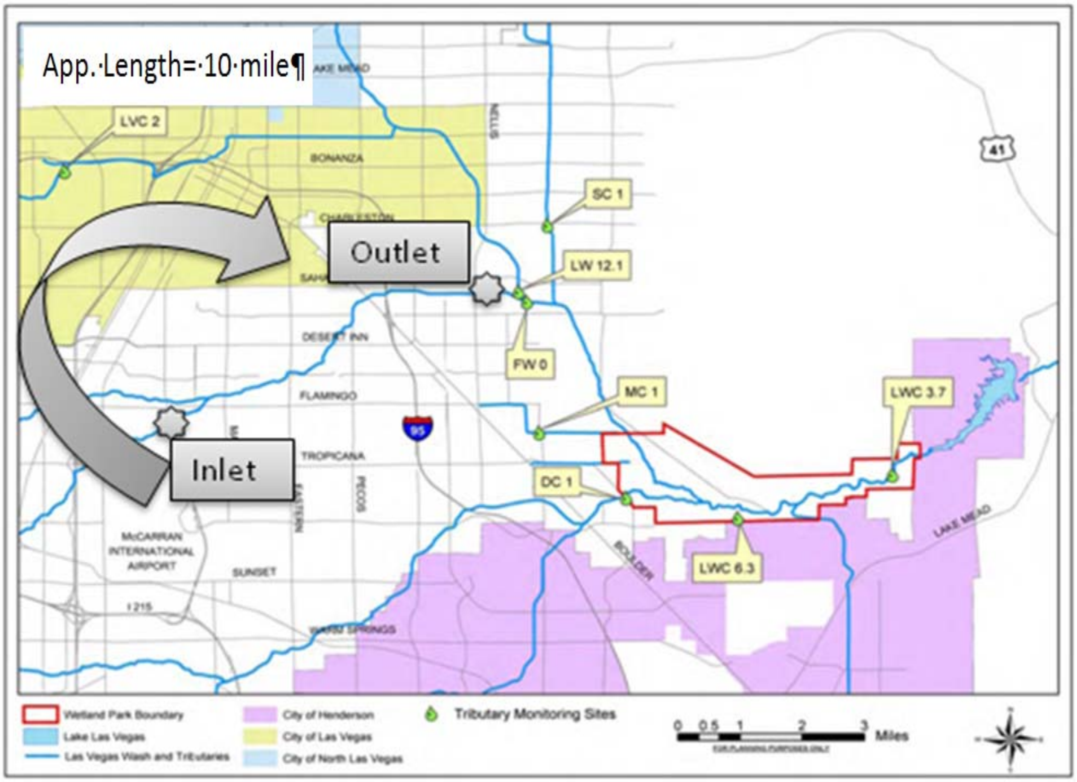

Figure 3: FW showing inlet and outlet sampling locations for sediment and water sampling (Zhou et al., 2009).

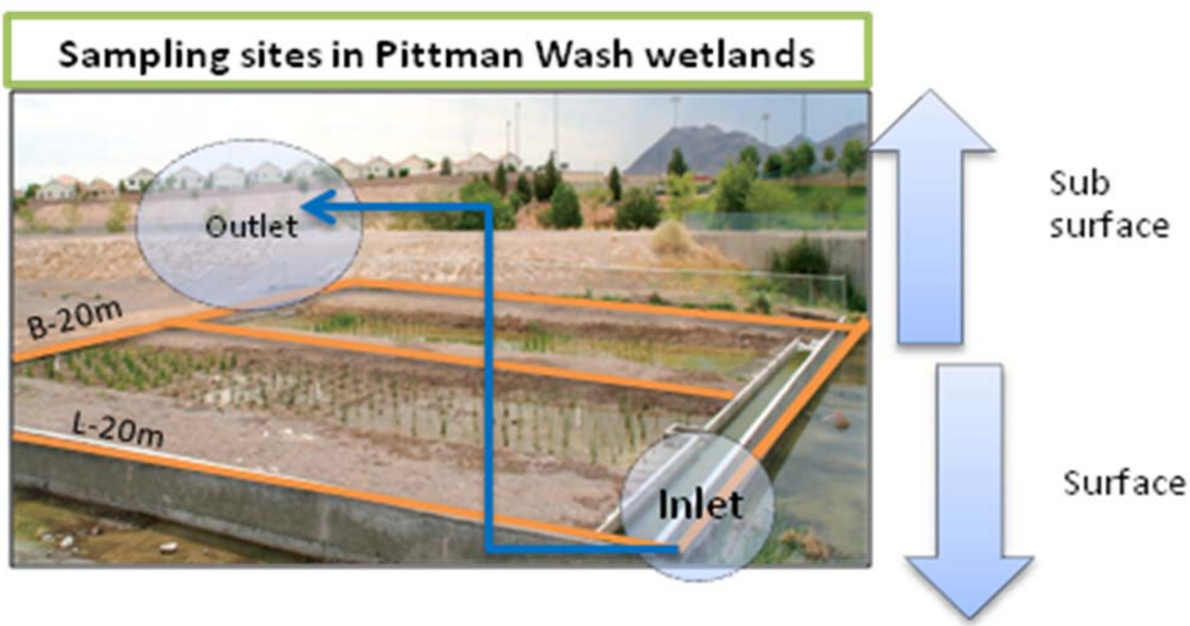

Figure 4: PW showing inlet and outlet sampling locations for sediment and water sampling (LVWCC, 2009).

HD: This is another demonstration-type wetlands located at the City of Henderson Water Reclamation Facility (Figure 5). These wetlands were constructed to test partially treated effluent discharge. The vegetation types here are mostly three species of bulrushes (*S. acutus*, *S. americanus,* and *S. californicus*) that exist in specially designed vegetation hummocks. The standing water in HD wetlands not only provides an opportunity for treatment but is also a popular destination for birds and other animals.

Based on distribution and dominance, cattails at FW and LVW and the three species of bulrush (*S. acutus*, *S. americanus,* and *S. californicus*) at PW and HD were selected for our study.

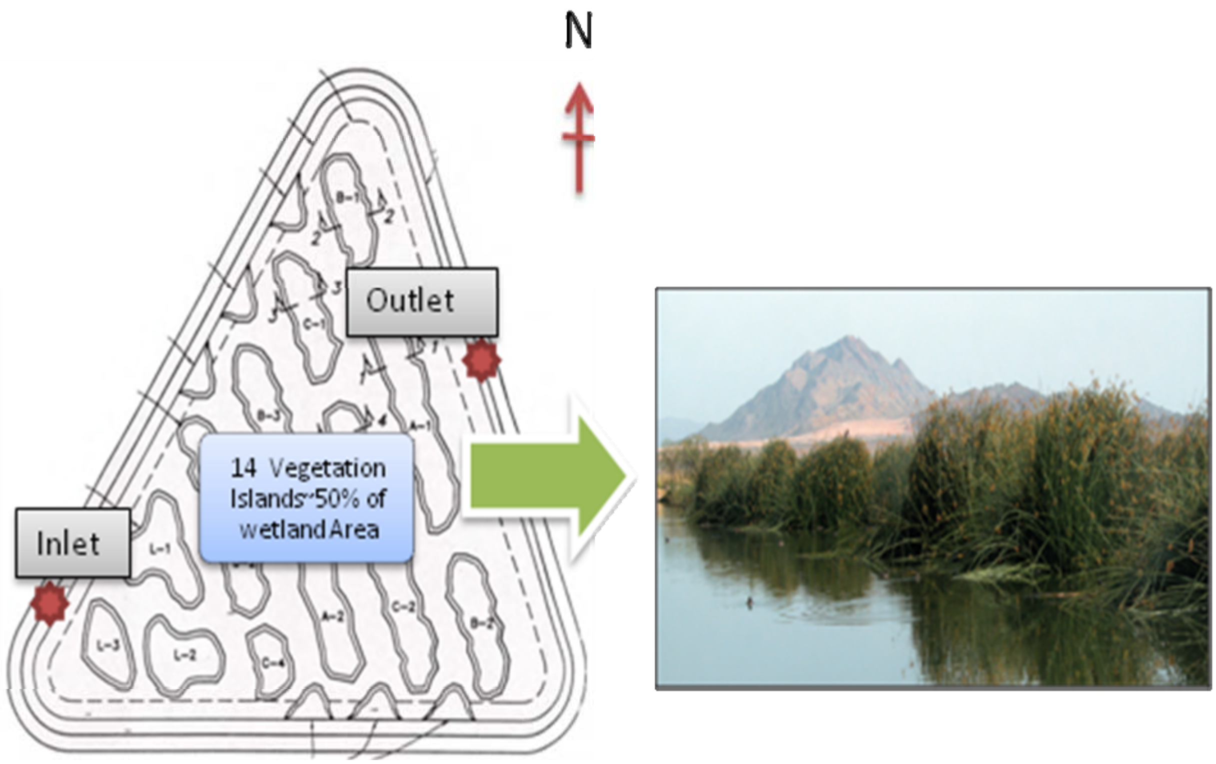

Figure 5: HD showing inlet and outlet locations for sediment and water sampling (Zhou and Van Dooremolen, 2007).

2.2 Sampling and Analysis

2.2.1 Water

Water samples were collected monthly from all four sites beginning in July 2008 and ending in June 2009. PW was only sampled through January 2009 because of storm damage. Various parameters were measured including total dissolved nitrogen (TN, measured as NO_3+NO_2+NH_4) and total phosphorus (TP, measured as orthophosphate) and physical parameters such as dissolved oxygen (DO), pH, specific conductivity, and temperature. Nalgene sample bottles (1 liter) used during sampling were acid rinsed prior to the sampling. Samples were collected from the inlet and outlet locations for all four wetland sites. Water samples were then immediately stored on ice. TP content was determined using the colorimetric analysis after persulfate digestion (APHA, 2005). TN was analyzed using an automated colorimetric method using a Lachat QC8000. Water sampling was conducted in conjunction with Southern Nevada Water

Authority (SNWA) regular water quality monitoring. Sites not covered under SNWA monitoring locations were sampled separately by Desert Research Institute (DRI) crews.

2.2.2 Sediment

Sediment samples were collected from the same inlet and outlet locations as the water samples at all four wetlands in four seasons (Fall 2008, Winter 2008, Spring 2009 and Summer 2009). Vertically mixed sediment samples were collected using a plastic scoop with a depth of up to ~10 cm and transferred into 100 ml glass bottles with polyvinyl caps. Samples were kept in the refrigerator until analysis. Samples were then dried in a convection oven at 70^oC until they were completely dry. Subsamples of dry sediment (~1 g) from each sample were processed for metal digestion following USEPA Method 3050B at the DRI Ecological Engineering Laboratory. Only samples collected in Winter 2008 and Spring and Summer 2009 were analyzed for metals. Sediment samples were digested with repeated addition of 70% HNO_3 and 3% H_2O_2. A low temperature thermostat (Lauda Ecoline, U.S. version) was used to provide uniform heating of 95oC. The resultant digest was diluted to 100 ml, centrifuged, and stored at 4oC until analysis. Samples were analyzed for trace metals using inductively coupled plasma mass spectroscopy (ICP-MS) at the Goldwater Environmental Laboratory at Arizona State University. Sediment TP content was analyzed for 1g dry subsamples using the colorimetric method mentioned above (APHA, 2005). Sediment TN content was analyzed on a dry subsample (~1 g) using a PerkinElmer 2400 CHN analyzer.

2.2.3 Plant

Plant samples were collected at the center of all four wetlands in four seasons using 50 cm x 50 cm quadrants. However, in some cases there were not enough live plants available, e.g., FW wetlands in winter and PW wetlands in summer of 2009. Analysis of seasonal variation in wetland vegetation is based on the plant sampling made in Fall 2008, Winter 2008, Spring 2009 and Summer 2009. Quadrant locations were chosen randomly to represent the whole wetlands. There were a total of 14 quadrants, 5 in LVW and 3 each in the three remaining wetlands. All plant materials (above- and below-ground) in each quadrant was harvested and processed for biomass, nutrients (TN and TP), and metals (29 trace metals) for all seasons. Plant biomass was calculated using methods developed by APHA (2005) for dry plant weight by storing for 72 hours at 70^oC or until a consistent dry weight was obtained. Dry plant samples were separated into rhizomes, roots, stems, and leaves prior to sub-sampling for nutrients and metals analysis. A Cyclone Sample Mill (UDY Corporation, Fort Collins, Colorado) was used to grind plant samples (homogenized samples were < 1 mm) for nutrients and metals analysis. Plant TP and TN contents were determined using the methods used for sediment analysis explained above. For metals, 200 mg ground plant samples were digested following USEPA Method 3050B. Digested samples were processed using ICP-MS, similar to the sediment samples.

2.3 Statistical Analysis

Statistical analyses were carried out using JMP software (SAS Institute, Cary, North Carolina). One-way analysis of variance (ANOVA) was used to study the effect of wetland type and plant species on the nutrient and metal concentrations in plants. Two-way ANOVA was also used to study the interactions of wetlands type and species distribution with TP, TN, and metals concentrations, for both the seasonal and annual means. Differences detected in ANOVAs from the wetland sites were compared using the Tukey pair-wise comparison test. For all of the tests, p-values < 0.05 (95% confidence interval) were considered significant. Plant, water and sediment nutrients and metals were regressed between sites to see correlations between them, which would then allow us to determine if plant uptake was regulated by water and sediment concentrations.

3.0 RESULTS

3.1 Plant Biomass

Biomass production values can be used as an indicator to estimate the nutrient uptake capacity of a species (Tanner, 1996: Greenway and Wolley, 2001). The majority of the plants in the LVW and FW wetlands were monospecific stands of cattails whereas the HD and PW wetlands were inhabited by three species of bulrushes. The total dry weight of cattails and bulrushes varied significantly among the four wetlands sites (Table 2). Cattails in the LVW wetlands had a higher total average biomass production (9.7 kg/m^2) compared to the FW wetlands (2.6 kg/m^2). Similarly, the total average biomass of bulrush species was found to be higher in HD wetlands than in PW wetlands. All three bulrush species had higher biomass in HD than in PW wetlands (*S. americanus* and *S. californicus* ~11 kg/m^2 vs. 4.0 kg/m^2 and *S. acutus* 4.0 vs. 2.2 kg/m^2). Overall, total biomass harvested per quadrant was highest in HD wetlands compared to the other three wetlands.

Site	**Plants**	**Culm per Quadrant**	**Biomass per Culm**	**Biomass**	**TN Storage**	**TP Storage**
		(number)	**(kg)**	**(kg/m^2)**	**(g/m^2)**	**(g/m^2)**
LVW	*T. domingensis*	14 ± 5	0.27±0.05	9.69±0.21	135.7±12	6.6±0.6
HD	*S. americanus*	17 ± 6	0.26±0.04	11.37±0.17	152.4±9.3	16.0±1.0
	S. californicus	13 ± 5	0.35±0.07	11.20±0.29	170.2±17.8	13.4±1.4
	S. acutus	15 ± 6	0.11±0.04	4.09±0.15	48.3±6.9	4.7±0.7
PW	*S. americanus*	11 ± 4	0.16±0.05	4.61±0.19	44.7±7.2	2.2±0.4
	S. californicus	14 ± 9	0.16±0.03	3.79±0.13	37.5±5.4	1.5±0.2
	S. acutus	14 ± 9	0.11±0.03	2.26±0.11	15.8±3.0	0.5±0.1
FW	*T. domingensis*	11 ± 3	0.08±0.03	2.62±0.12	28.6±5.2	1.5±0.3

Table 2: Average biomass and nutrient storage of individual plants (*Typha domingensis* and *Schoenoplectus* spp.) at the four wetland sites. Two digits after ± sign indicate standard errors.

3.2 Nutrients

Plant, sediment and water column nutrient data measured at the various wetlands differed in concentrations (ANOVA, $p<0.05$). Nutrient (nitrogen and phosphorus) concentrations in plant tissues were averaged annually over seasons and compared with the inlet and outlet nutrient concentrations from the sediment and water column for each wetlands site. Further, nutrients and metals concentration in plant tissues were also regressed with the ambient sediment and water column concentrations in the four wetlands sites to see their correlations using annual average values.

3.2.1 Phosphorus (P)

Plant tissue analyses indicate that TP concentration varied significantly among the four wetlands ($p<0.05$). Pair-wise comparison tests (Tukey LSD) showed that TP was significantly different among the HD ($p = 0.001$), PW ($p = 0.001$), and FW ($p = 0.05$) wetlands for both cattail and bulrush plants. TP concentration in the LVW ($p = 0.55$) wetlands; however, was similar to that in FW (Figure 6A). Based on the results for mean %TP in plant tissue and mean plant biomass, HD wetlands accumulate the highest amount of TP among the four wetlands. Below-ground plant parts in both species were more efficient for TP uptake than were above-ground plant parts (Tukey LSD, $p<0.05$; Figure 7). Plant tissue %TP generally followed the trend of the ambient sediment and water column concentrations for the wetland sites rather than for the individual species. HD wetlands had the highest average sediment TP concentration (0.08%), followed by the LVW (~0.045%; PW (~0.043%), and FW (~0.03%) wetlands. The pair-wise comparison showed that sediment TP concentration in HD wetlands was significantly different than LVW and FW wetlands ($p = 0.001$; Figure 6B). All four wetlands had significant drops in sediment TP concentrations at the outlets ($p = 0.005$; Figure 8). A relatively lower reduction of 16% was measured at LVW, whereas the reduction was nearly 60% at the FW, 30% at the PW, and 26% at the HD wetlands.

Unlike plants and sediments, phosphorus concentration in the water column was not significantly different between the PW, FW, and LVW wetlands. However, HD wetlands had a significantly higher TP concentration, ~ 2.0 mg/L, in the water column (Tukey LSD, $p = 0.01$; Figure: 6C). The other three wetlands did not show any uncharacteristically high TP concentrations. Overall, the annual mean TP concentrations were ~ 0.145 mg/L at the LVW, ~ 0.01 mg/L at FW, and ~ 0.010 mg/L at PW wetlands.

3.2.2 Nitrogen (N)

Total nitrogen (TN) concentrations measured in the cattail and bulrush plant tissues were significantly ($p<0.05$) different among the four wetlands. Cattail plants in the LVW wetlands and bulrush in the HD wetlands appeared more efficient in N storage compared to the other two wetlands (Table 9A).

Both the HD (1.48±0.541) and LVW wetlands (1.48±0.048) had higher %TN in their plant tissues (Figure 9A), but average plant biomass was higher in the HD wetlands (Table 2). Above-comparison to below-ground parts ($p = 0.001$). Unlike TP, plant TN (%) did not follow the trend of the ambient water column and sediment concentrations. As for the sediment nitrogen, LVW and FW had the highest TN concentration (0.09%), followed by PW (0.06%), and HD (0.05%) (Figure 9B). Pair-wise comparisons showed that sediment TN in the HD and PW wetlands was significantly different from LVW and FW wetlands.

There was a significant drop in sediment %TN ($p = 0.007$) at the outlets (Figure 10). This reduction of TN in FW was 61%, followed by 23% for HD. The other two wetlands (PW and LVW) had a relatively smaller reduction. Nitrogen concentrations in the water columns were also significantly different among the four wetlands ($p = 0.001$; Figure 9C). Average TN concentrations in water measured at the inlet and outlet of the LVW wetlands did not show any major difference (~14 vs.13 mg/L). Overall, the mean TN concentration in water at the PW

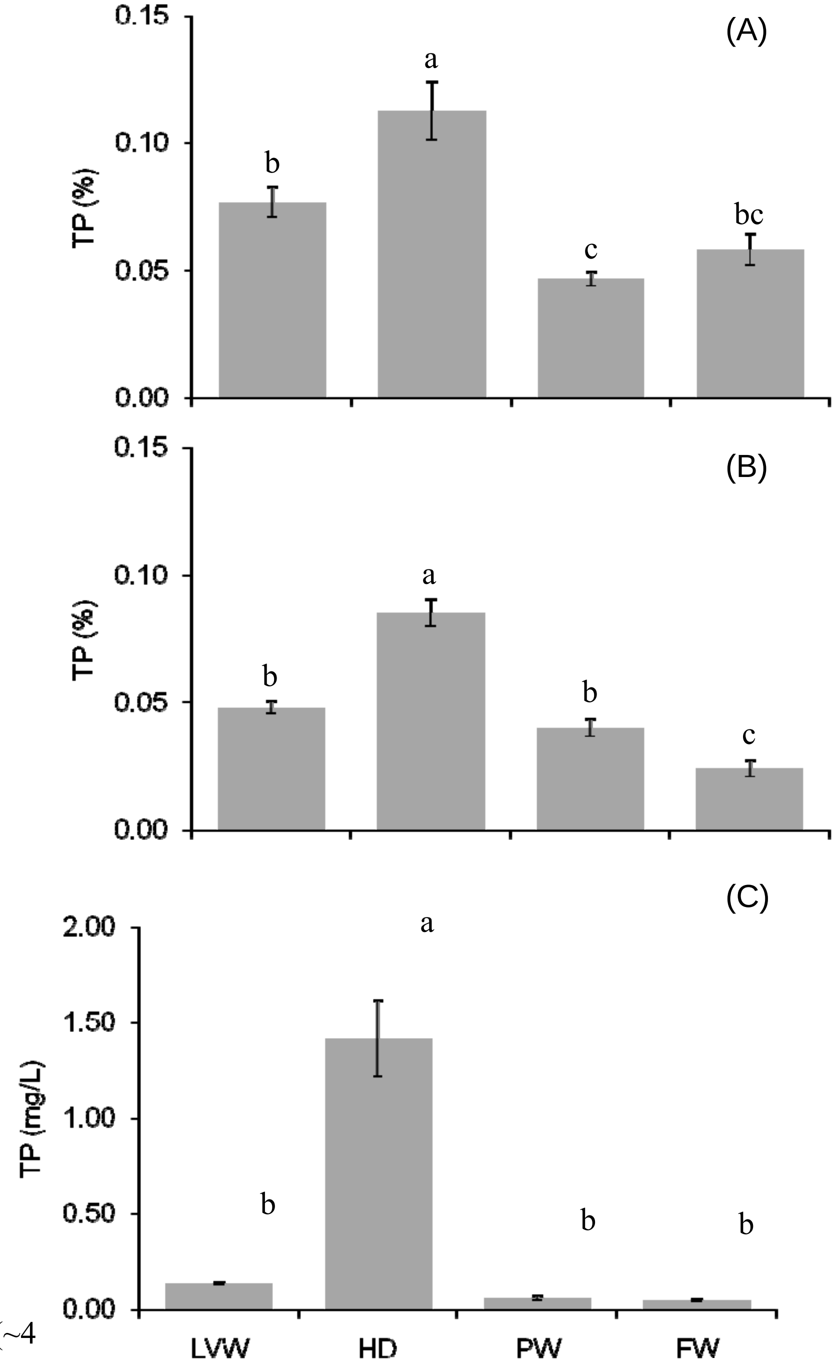

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Figure 6: Average annual total phosphorus concentrations in: (A) plants (*Typha domingensis* and *Schoenoplectus spp.*), (B) sediments, and (C) water at the four wetland sites. Error bars represent standard errors.

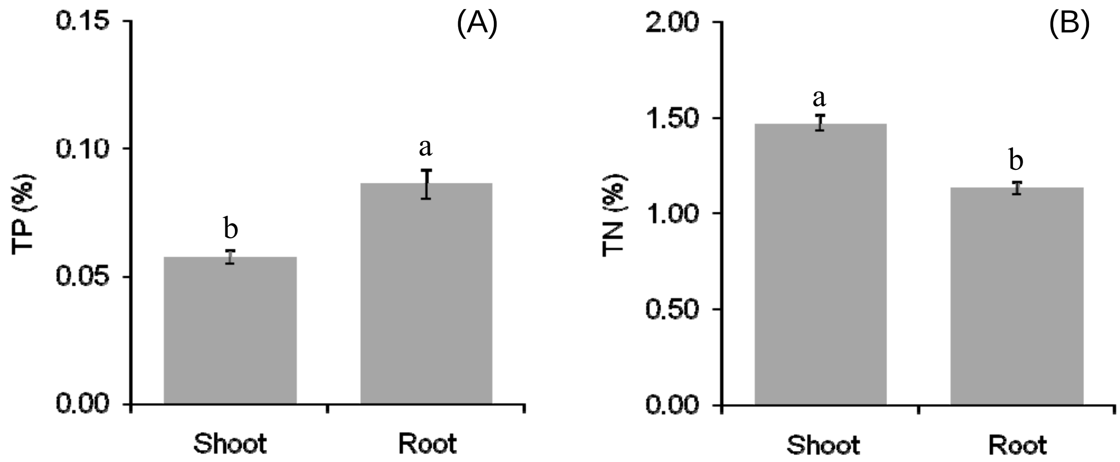

Figure 7: Average annual (A) total phosphorus, and (B) total nitrogen concentrations in shoot and root parts of plant tissues (*Typha domingensis* and *Schoenoplectus spp.*) at the four wetland sites. Error bars represent standard errors.

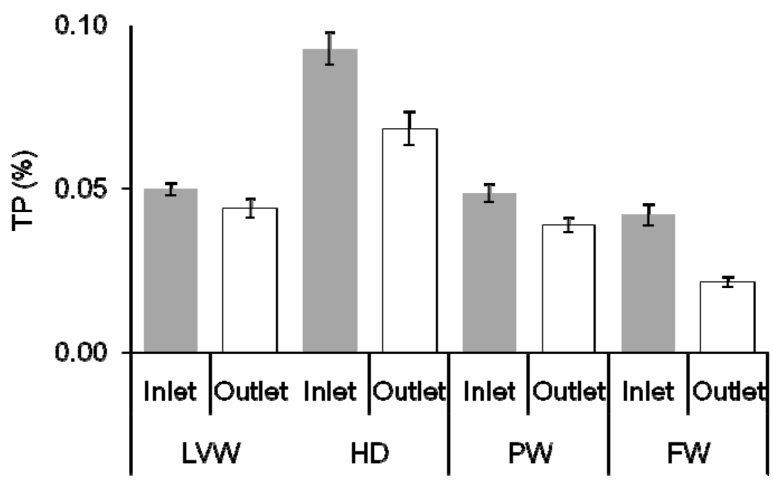

Figure 8: Average annual total phosphorus concentration in sediments at inlets and outlets of the four wetland sites. Error bars represent standard errors.

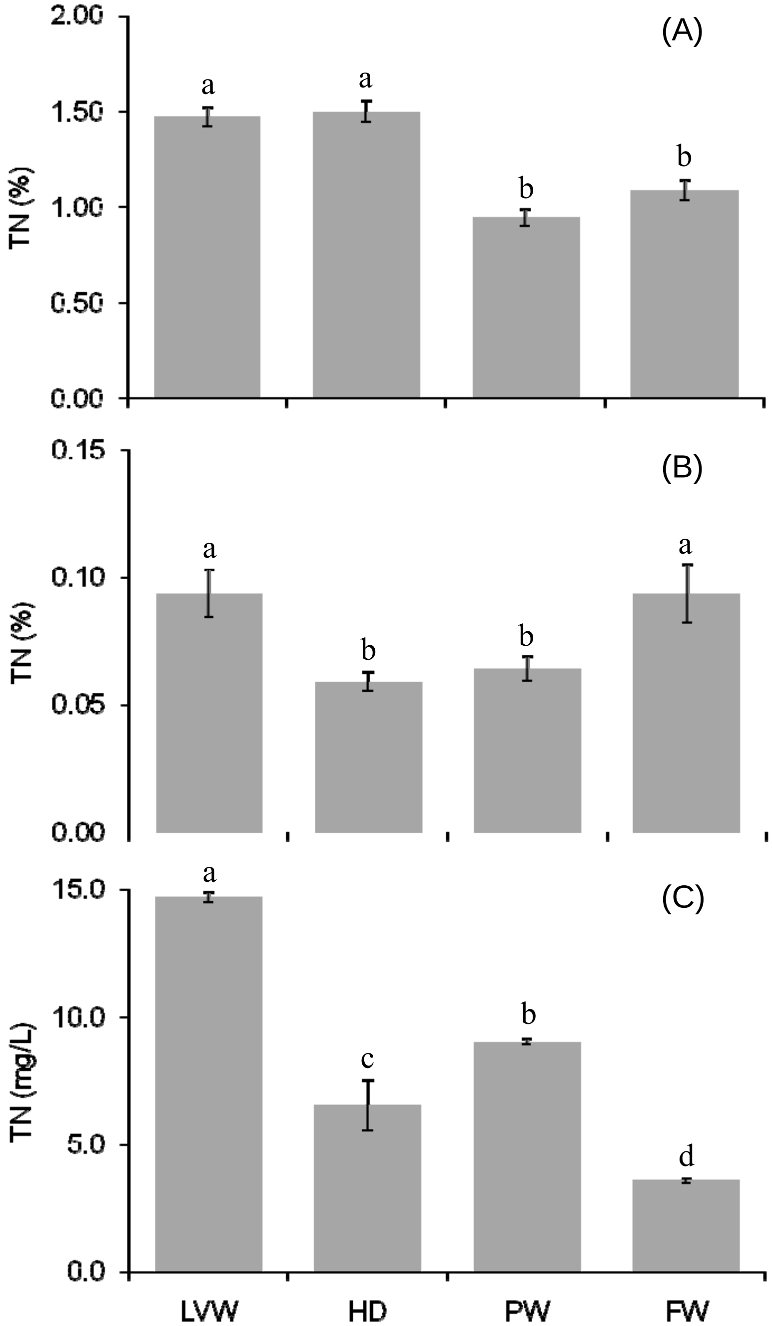

Figure 9: Average annual total nitrogen concentrations in: (A) plants (*Typha domingensis* and *Schoenoplectus spp.*), (B) sediments, and (C) water at the four wetland sites. Error bars represent standard errors.

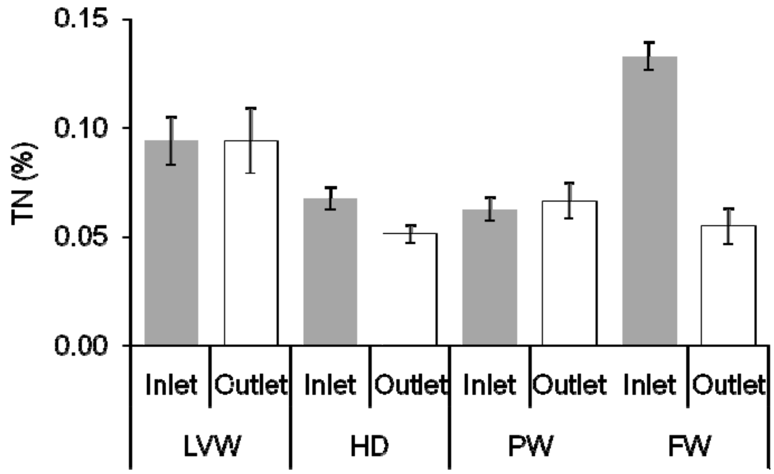

Figure 10: Annual average total nitrogen concentrations of sediment at inlets and outlets of the four wetland sites. Error bars represent standard errors.

wetlands was lower than at the LVW wetlands (~9 mg/L), followed by the FW wetlands the HD wetlands had a lower mean TN (~ 5 mg/L) than the LVW and PW wetlands. This might be due to the City of Henderson's efforts to denitrify discharged water since March 2008. That is perhaps the reason why the concentration in the water is so low and also may explain, at least in part, why the plant tissues have higher concentrations than the water and sediment. The plants have been growing in the HD for several years and were thus growing when N concentrations in the water and sediment were much higher than when this study was ongoing.

3.2.3 Metals

Twenty-nine trace metals were analyzed for the plant, sediment, and water samples. Not all the metals were detected but the ones that were detected in the sediments are As, Cd, Co, Cr, Cu, Hg, Fe, Li, Ni, Pb, Se and Zn and in plant tissues are As, Hg, Pb, Zn, Cd, Mo, Li, Cr, Cu, Se and Fe (Table 3 and 4). Among the detected metals, selenium and arsenic were paid special attention in this study because of their higher concentrations and known presence in the valley and potential adverse impact on water quality and aquatic wildlife. They have not been listed in the table below but analyzed separately (Figures 11-15). Metal concentrations in plant tissues were compared with the inlet and outlet sediment and water column concentrations for each of the four wetlands sites. The plant tissue concentrations were also compared with the ambient sediment and water column data measured at the various wetlands and no significant relationships were found ($p>0.05$).

Arsenic: Comparing above-ground and below-ground concentrations, As concentrations were significantly higher in the below-ground parts of either species than in the above-ground parts, at all sites ($p = 0.01$; Figure 11A). Among the four wetlands, PW wetlands had the highest average As concentrations in plants, sediments, and water. PW plants (bulrushes) had ~6.0 µg/g As, which was significantly higher than the As levels in the other wetland sites ($p = 0.001$; Figure 12A). LVW plants (cattails) had the second highest As concentration (~3.5 µg/g). Concentrations of As were lower in FW and HD wetland plants.

Trace Metals in Sediment (µg/g)	Wetland Sites			
	LVW	HD	PW	FW
Cd	0.12±0.03	0.23±0.15	0.12±0.03	0.06±0.04
Co	2.43±0.54	3.72±0.85	3.9±0.79	1.4±0.36
Cr	7.71±1.66	9.10±4.12	5.89±1.98	5.11±1.35
Cu	10.66±3.11	11.42±3.76	11.39±2.99	12.88±8.11
Fe	1208.53±140.83	911.74±183.16	509.50±122.72	821.05±129.53
Hg	0.36±0.10	1.60±0.71	2.15±0.65	0.49±0.11
Mo	144.10±59.60	120.53±52.10	86.75±31.61	44.51±18.65
Ni	10.09±7.75	18.39±3.08	21.26±10.26	14.79±12.13
Pb	5.51±1.28	11.40±3.67	8.83±1.70	8.89±4.49
Zn	68.58±16.01	32.29±6.68	45.29±9.04	88.57±57.20

Table 3: Average annual trace metal concentrations in sediments at the four wetland sites. Two digits after ± sign indicate standard errors.

Trace Metals in Plant tissue (µg/g)	Wetland Sites			
	LVW	HD	PW	FW
Cd	DL	DL	0.4±0.1	0.6±0.3
Co	15.4±3.9	15.8±5.1	3.4±1.4	1.0±0.5
Cr	5.9±0.7	4.05±0.3	7.2±0.7	2.5±0.15
Cu	287.1±53	83.9±18.5	47.2±22.5	14.7±7.3
Fe	1233.9±270	449.5±83.1	570.4±150.2	1032.3±672
Hg	0.3±0.2	0.4±0.1	2.1±0.63	3.1±0.89
Li	3.6±0.7	2.1±0.4	2.7±0.3	1.97±1.73
Mn	255.6±59.5	279.2±53.4	303.9±90.2	498.1±10.7
Mo	9.6±4.4	5.5±1.3	4.6±1.3	10.0±3.5
Ni	4.27±0.6	3.7±0.4	5.1±1.5	5.0±1.5
Pb	3.3±0.9	4.3±0.7	5.4±2.3	6.8±2.16
Zn	57.7±5.3	118.7±19.5	212.9±45.2	150.6±59.03

Table 4: Average annual trace metal concentrations in individual plants (*Typha domingensis* and *Schoenoplectus spp*.) at the four wetland sites. Two digits after ± sign indicate standard errors. DL = Less than detection limit. Detection limits for each element are based on DL of ICP-MS manufacturers.

Similarly, annual mean sediment As concentrations were different in different wetlands ($p = 0.001$; Figure 12B) but consistent with plant tissue concentrations. As with the plants, the PW wetlands had the highest concentration (~6.06 µg/g) followed by LVW (~4.71 µg/g), FW (~3.65 µg/g), and HD (~3.36 µg/g). As with the plants and sediments, the water column As concentrations differed between sites ($p = 0.01$), but the trend was not always consistent with the plant and sediment concentrations (Figure 12C). There was no significant decrease in As concentrations in sediment from inlet to outlet in any of the wetland sites ($p<0.05$, Figure 13). The PW wetlands had the highest concentration of As (~13.12 µg/L) in the water, followed by

LVW (~7.1 µg/L), FW (~4.47 µg/L), and HD (~3.42 µg/L). Generally, As concentrations at the outflow sites were similar to those at the inflow sites and did not show any significant reduction.

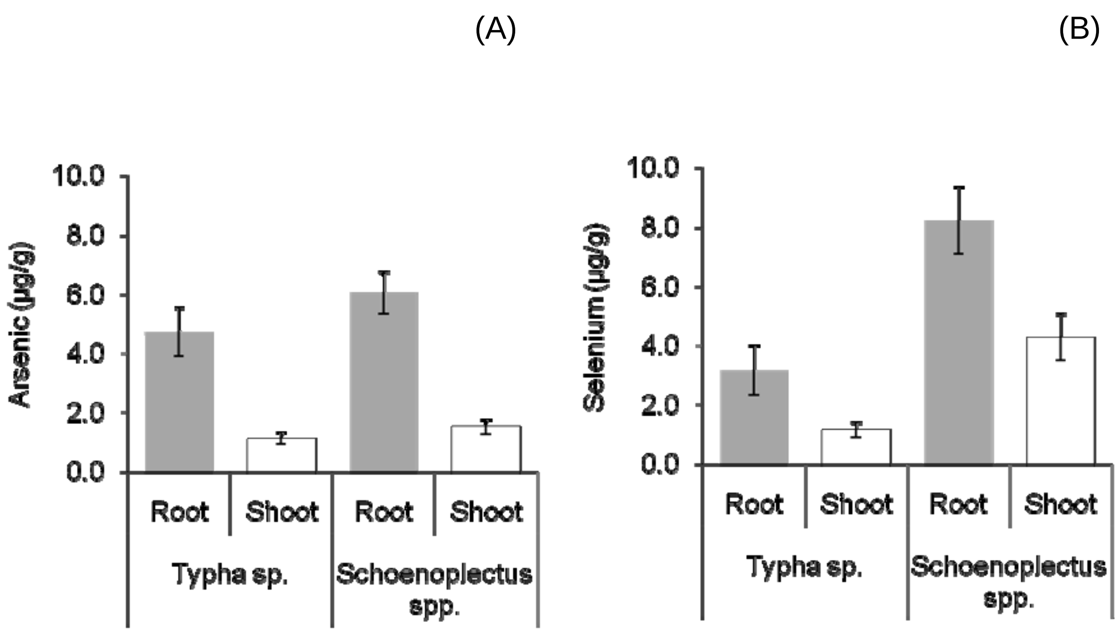

Figure 11: Average annual (A) Arsenic and (B) Selenium concentrations in plants (*Typha domingensis* and *Schoenoplectus spp.*) at the four wetland sites. Error bars represent standard errors.

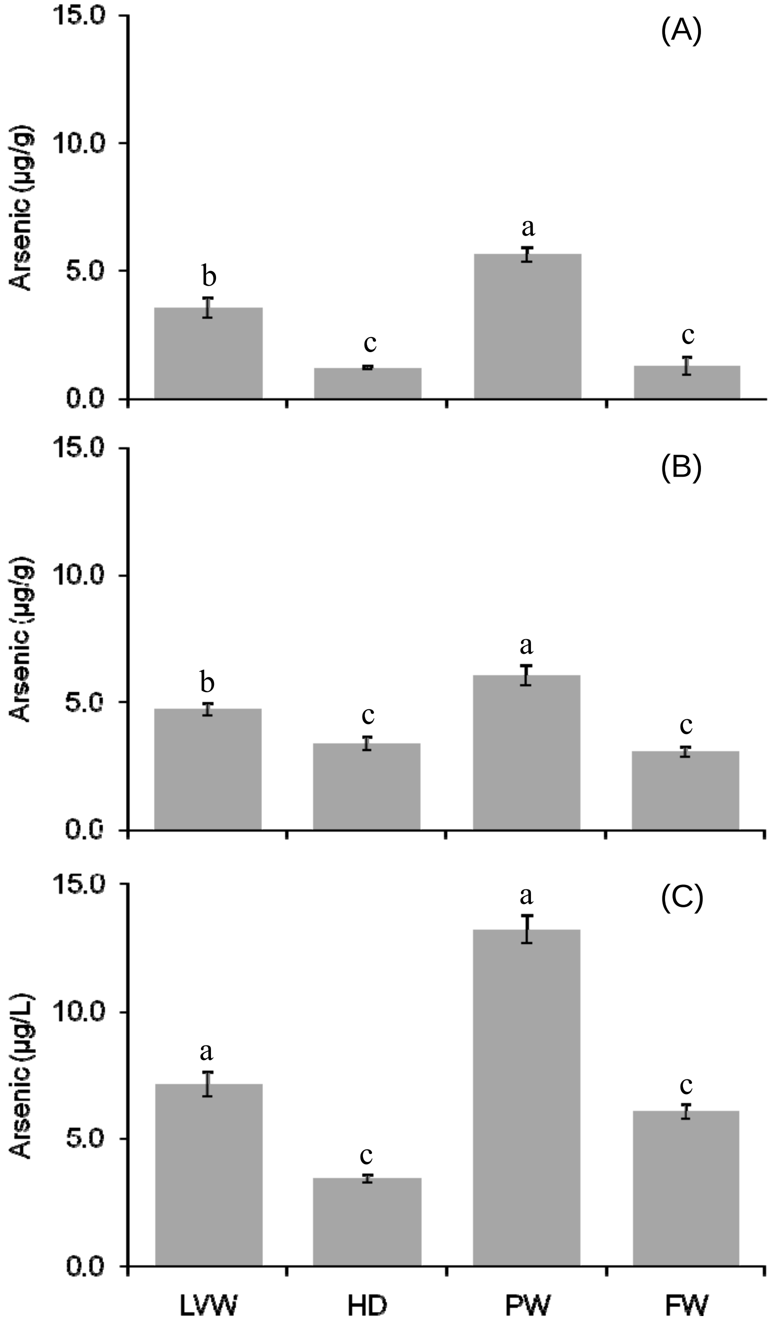

Figure 12: Average annual arsenic concentrations in: (A) plants (*Typha domingensis* and *Schoenoplectus spp.*), (B) sediments, and (C) water at the four wetland sites. Error bars represent standard errors.

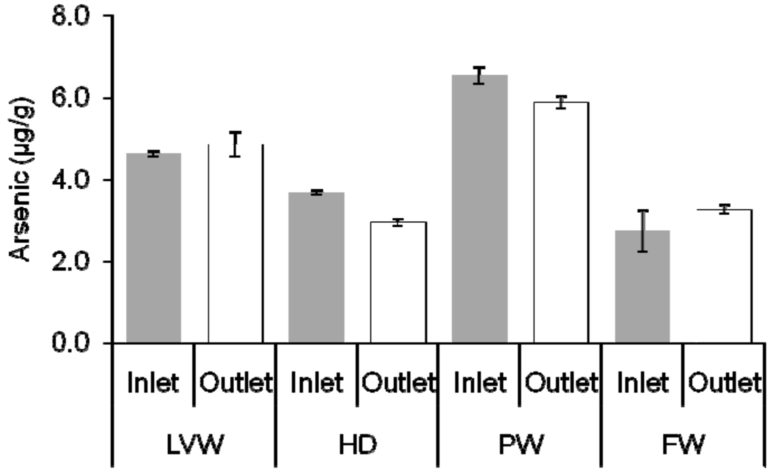

Figure 13: Average annual sediment arsenic concentrations at the inlets and outlets of the four wetland sites. Error bars represent standard errors.

Selenium: As with the As concentrations, Se concentrations were also higher in the below-ground parts for both species (Figure 11B) in all the wetlands. There was a remarkably high Se concentration (~9.80 µg/L) detected in the bulrush plant tissues in the PW wetlands. The rest of the wetlands each had about one fourth of the concentration of Se as in the PW wetlands. Cattails appeared to have lower Se concentrations at both the LVW (~2.32 µg/L) and FW wetlands (~1.29 µg/L), compared to the bulrushes of the HD and PW wetlands (Figure 14A). The LVW and FW wetlands sediments measured higher concentrations than the HD and PW wetlands ($p = 0.001$; Figure 14B). The annual mean sediment Se concentrations in FW and LVW were about 1.27 µg/g, followed by PW (~0.77 µg/g), and HD (~0.55 µg/g). Annual average Se concentrations in the water column were significantly different among the four wetlands sites ($p = 0.001$). The PW and FW wetlands were significantly higher than the LVW and HD wetlands (Figure 14C). Se concentration in the sediments did not show any significant differences between the inlets and the outlets ($p = 0.001$; Figure 15). The PW wetlands had the highest concentration of Se in the water (~10.68 µg/L), followed by FW (~8.2 µg/L), LVW (~3.2 µg/L), and HD (~1.91 µg/L).

3.2.4 Treatment Performance

Treatment performance of the wetlands can also be explained using linear regression analysis among different variables. The annual average nutrient and metal concentrations in sediment and water column were positively correlated with plant tissue concentrations among sites. Plant tissue TP concentration was highly correlated with sediment (R^2= 0.83; Figure16) and water column (R^2= 0.85; Figure 17) concentrations. However, this correlation was not seen in plant tissue TN with either sediment or water. Similarly, plant tissue arsenic concentration showed a strong positive correlation with water (R^2= 0.88; Figure 18) and sediment (R^2= 0.99; Figure 19). On the other hand, the selenium in plant tissues had weaker correlations with both water (R^2=.039; Figure 20) and sediment (R^2<0.1).

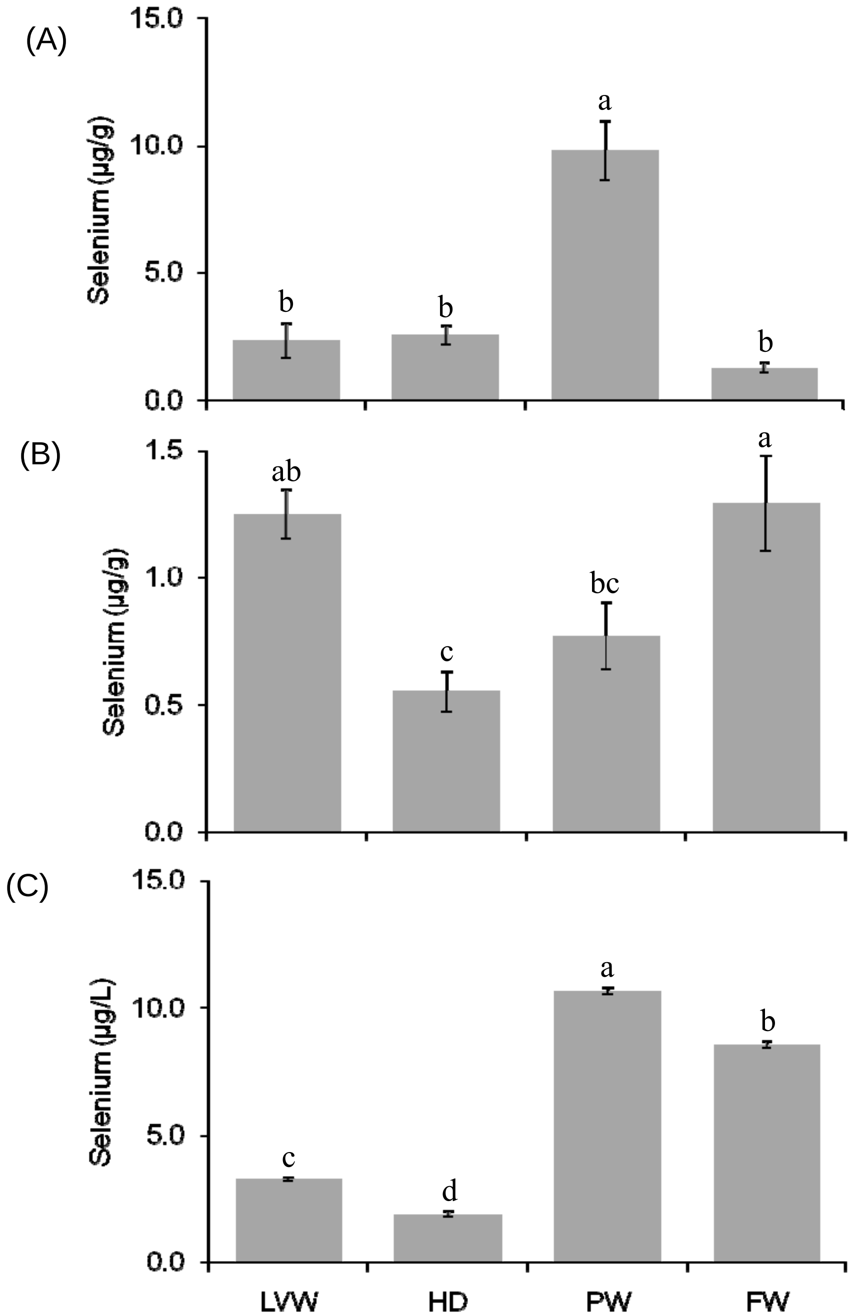

Figure 14: Average annual selenium concentrations in: (A) plants (*Typha domingensis* and *Schoenoplectus spp.*), (B) sediments, and (C) water at the four wetland sites. Error bars represent standard errors.

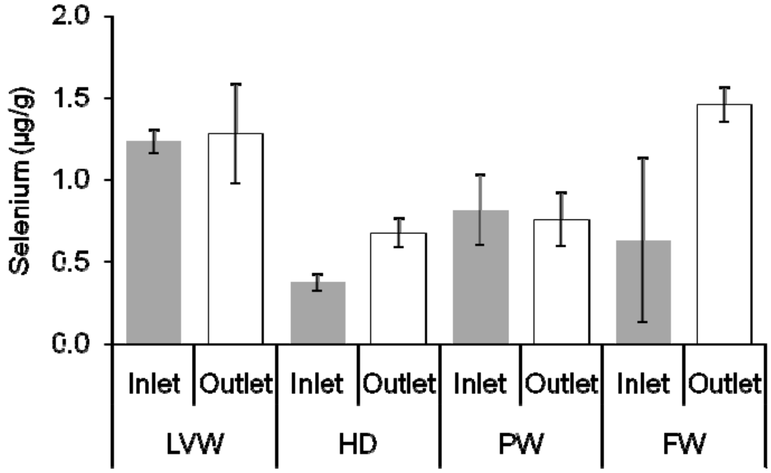

Figure 15: Annual average selenium concentrations of sediment at the inlets and outlets of the four wetland sites. Error bars represent standard errors.

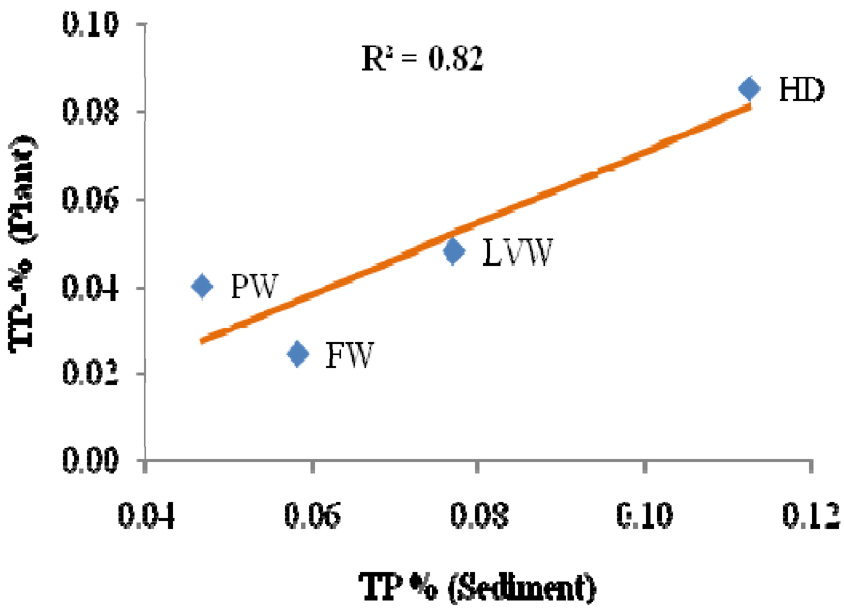

Figure 16: Overall correlations between annual average plant tissue and sediment total phosphorus concentrations (TP%) in the four wetland sites. The line shown is a least square linear regression.

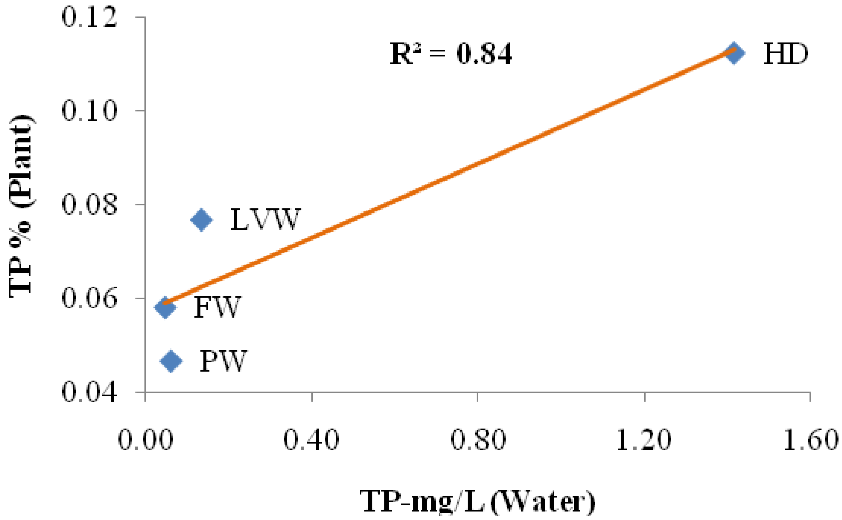

Figure 17: Overall correlations between annual average plant tissue (TP%) and water column(mg/L) total phosphorus concentrations in the four wetland sites. The line shown is a least square linear regression.

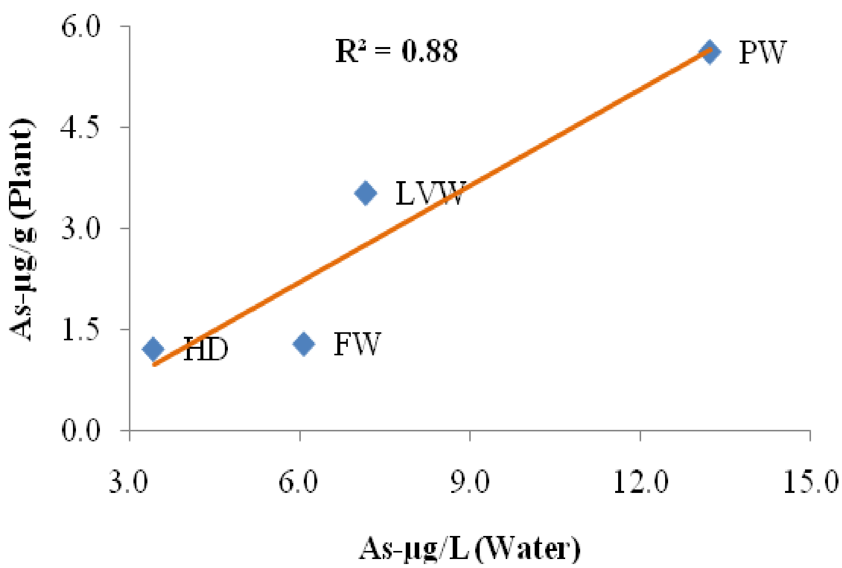

Figure 18: Overall correlations between annual average plant tissue (µg/g) and water column (µg/L) arsenic concentrations in the four wetland sites. The line shown is a least square linear regression.

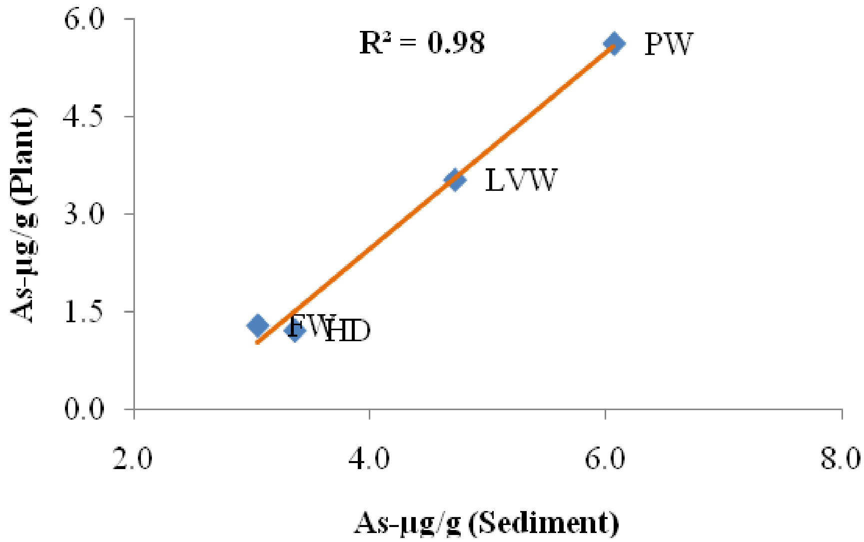

Figure 19: Overall correlations between annual average plant tissue and sediment arsenic concentrations (µg/g) in the four wetland sites. The line shown is a least square linear regression.

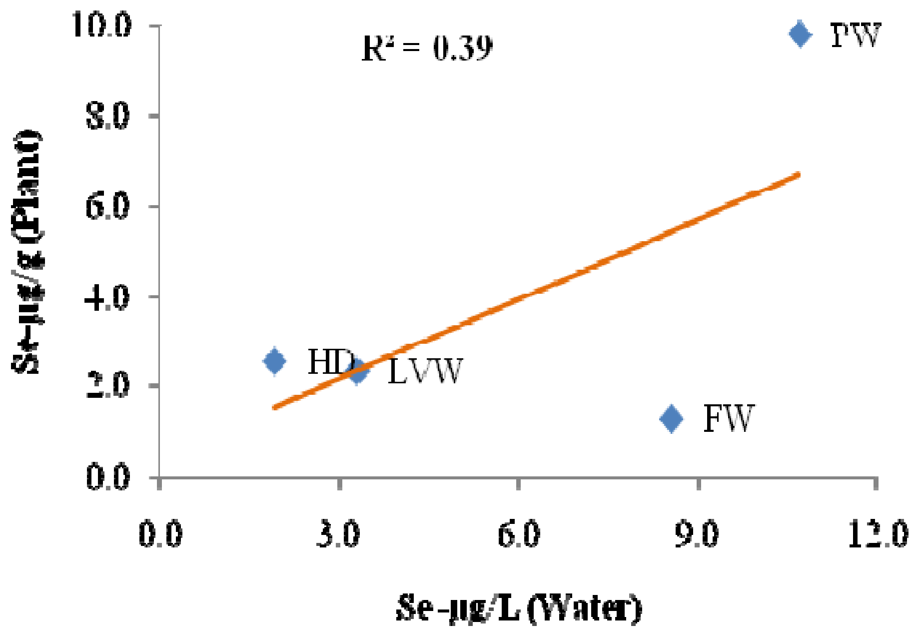

Figure 20: Overall correlations between annual average plant tissue (µg/g) and water column (µg/L) in the four wetland sites. The line shown is a least square linear regression.

3.3 Temporal Variation (Nutrients and Metals)

Seasonal average TP concentrations in the cattails were significantly higher in LVW for the summer season but there was no apparent difference between spring and winter. Similar trends were seen for seasonal distribution at HD and PW wetlands for TP% in bulrush plants with typically higher concentrations in summer followed by lower concentrations in spring and winter

(Figure 21). Our sampling locations in the FW wetlands did not have any live plants in the winter season therefore they were not included in the analysis. FW cattails also had higher concentrations in summer followed by spring. Seasonal mean TN% in cattail and bulrush plant tissues were similar to that of TP in all the wetlands (Figure 22).

Seasonal As concentrations (µg/g) in cattail plants at the LVW wetlands appeared generally higher in summer followed by spring and winter seasons but were not statistically significant (Figure 23); whereas bulrush plants As concentrations were generally consistent during winter, summer and spring. Unlike the HD wetlands, bulrush species had higher As concentrations in summer than winter season. Temporal data were not available for comparison in FW wetlands. Se concentrations (µg/g) in both cattails and bulrush were higher in winter at the LVW, HD and PW wetlands (Figure 24).

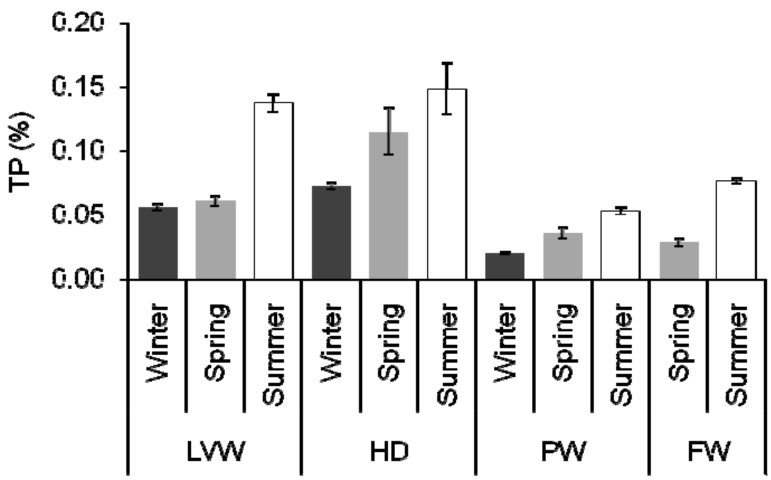

Figure 21: Average seasonal total phosphorus concentrations in plants (*Typha domingensis* and *Schoenoplectus spp.*) at the four wetland sites. Error bars represent standard errors.

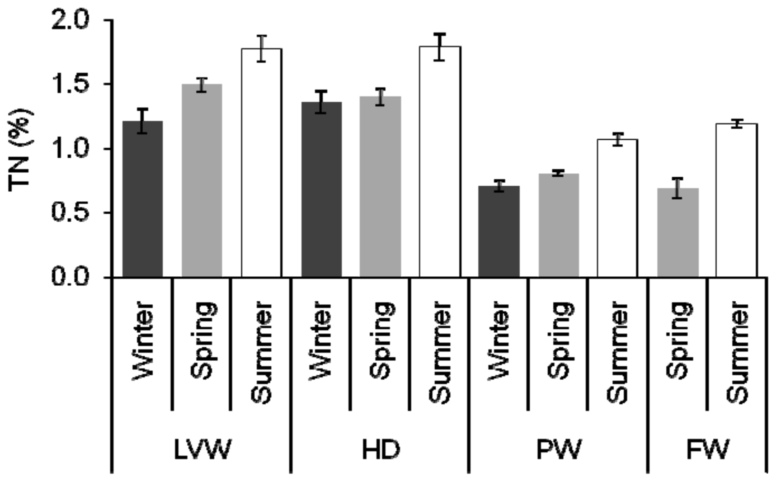

Figure 22: Average seasonal total nitrogen concentrations in plants (*Typha domingensis* and *Schoenoplectus spp*.) at the four wetland sites. Error bars represent standard errors.

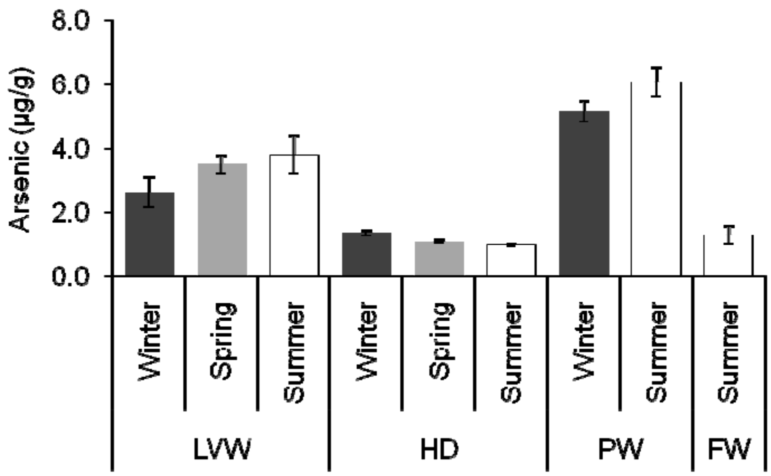

Figure 23: Average seasonal total arsenic concentrations in plants (*Typha domingensis* and *Schoenoplectus spp*.) at the four wetland sites. Error bars represent standard errors.

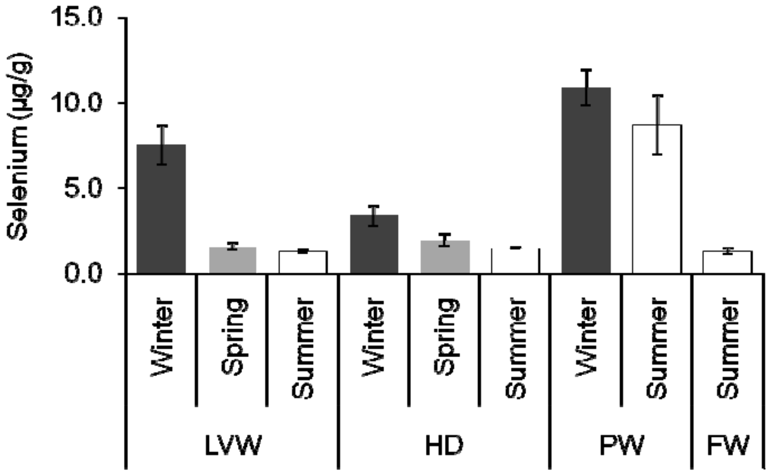

Figure 24: Average seasonal selenium concentrations in plants (*Typha domingensis* and *Schoenoplectus spp.*) at the four wetland sites. Error bars represent standard errors.

4.0 DISCUSSION

4.1 Plant Biomass

Plant composition in the LVW and FW wetlands was dominated by a high density of cattails. Cattails are common plants in naturally occurring surface runoff wetlands in the Southwestern U.S. (Seiler et al., 2003). Plant composition in the HD and PW wetlands is dominated by three species of bulrush. The HD and PW wetlands are constructed wetlands fed by partially treated wastewater effluent and urban runoff, respectively. Bulrush were chosen since these plants are native, fit a wide variety of niches in wetland ecosystems, planting stock is often available through commercial plant nurseries, and they spread through lateral rhizomes, which allow the relatively rapid development of an emergent plant canopy. Biomass is most frequently defined as the mass of all living tissue at the given time in a given unit of Earth's surface (Lieth and Whittaker, 1975). In our study, we measured the peak standing crops, also known as the single largest value of plant material present during a year's growth (Richardson and Vymazal, 2000).

Plant productivity and nutrient accumulation in plant biomass varied widely for cattail and bulrush species among the four different wetland sites (Table 2). This variation could be due to differences in environmental parameters such as incoming nutrients and hydrology in the wetlands systems. For example, bulrushes, especially *S. americanus*, showed a high density of stem growth in the HD wetlands, but relatively less density and biomass in the PW wetlands. Similarly, cattails in the LVW wetlands yielded higher plant density and biomass per quadrant compared to the FW wetlands. The LVW and HD wetlands receive high nutrient loads from wastewater treatment plants, whereas the PW and FW wetlands receive relatively lower nutrient loads as they are fed by urban runoff systems. In both of these cases, incoming nutrients might have played a major role. Aquatic plants take up large quantities of nutrients and assimilate them efficiently (Cronk and Fennessy, 2001). The present results show that the plants may be capable of growing better by taking up more nutrients (if available in the wetlands system) and producing more biomass. Similarly, plant nutrient concentrations in both cattails and bulrush were highest during the peak growing season of summer, followed by the early growing season of spring, and much lower during the winter season for both TN and TP in our study. Differences in biomass accumulation and tissue N and P concentrations between species are likely to reflect species and developmental stage differences in efficiency of nutrient uptake and use (Güsewell and Bollens, 2003; Tanner, 1996). Relatively low plant density was observed for cattail species in FW compared to LVW, as well as for bulrush species in PW compared to HD suggesting the roles nutrients, water availability, retention times, among other factors, might have played in shaping plant production in these different systems. However, the other three sites did not have the space limitation as HD (i.e., the hummocks) that might have also played a role in plant density. The biomass of cattail and bulrush species ranged from 2.2-11.3 $kg/m^2/yr$ in our study and are comparable with the constructed wetlands of highly productive ecosystems. Total plant productivity at the end of the vegetation cycle was estimated to be 13-20 $kg/m^2/yr$ for cattails and bulrush species in constructed ecosystems, but was only 3-5 $kg/m^2/yr$ in natural and less polluted areas (Vymazal, 1998; Mitsch and Gosselink, 2000; Reddy and De Busk, 1987). The biomass values measured in our study represent maximum seasonal biomass values and are higher than productivity estimates that include a carryover of biomass from the previous season. Since we did not know the exact age of the plant, some plants might represent two growing seasons in our random sampling; but plants representing two growing seasons do not necessarily carry maximum nutrient concentration (Reddy and De Busk, 1987).

4.2 Plant Nutrients

TN and TP contents of living biomass in different wetlands vary considerably among species, plant parts, and wetland sites. Wetland plants in constructed wetlands are often nutrient enriched and display higher values of tissue nutrient concentrations than natural wetlands (Boyd, 1978). It is known from growth experiments that both plant growth and tissue nutrient concentration (per unit dry weight) tend to be positively correlated with nutrient supply when all other resources are sufficiently available (Garnier, 1998). Our results support the hypothesis suggested by Reddy and De Busk (1987), regarding typical plant growth response to increased concentrations of nitrogen and phosphorus (Figure 25). Adding wastewater to wetlands generally increases the availability of water and nutrients and consequently results in the stimulation of gross and net primary productivity of these ecosystems. The maximum rate of plant growth is attained as nutrient levels are initially increased. However, at higher nutrient levels, plant growth levels off while luxury nutrient uptake continues, and at higher nutrient concentration toxic responses are observed.

Despite their differences in total biomass, nutrient concentrations in plant tissues were similar between cattail and bulrush species. Nutrient content per unit of biomass were generally more site-specific than species-specific. This is not unique to our system, for example, nutrient removal efficiency of a system depends on the plant type, growth rate, nutrient composition of the water, and physicochemical environment in the water-sediment system (Reddy et al., 1983). Our data suggest that nutrient concentration tended to be highest for *S. californicus* plants than in the other two bulrush species. Cattails were also found to have relatively higher nutrient concentrations. Cattail plants in our wetlands sites had high nutrient uptake compared with the similar constructed wetlands in different parts of the U.S. Similar to our study, in two free-water surface treatment cells at the Iron Bridge Wetland in Florida, *S. californicus,* and *T. latifolia* removed N and P to a similar extent (EPA, 2000). Nitrogen uptake by cattails and bulrushes was in the range of 100-300 g N/ m^2 at different constructed treatment wetlands in the U.S. (Kadlec

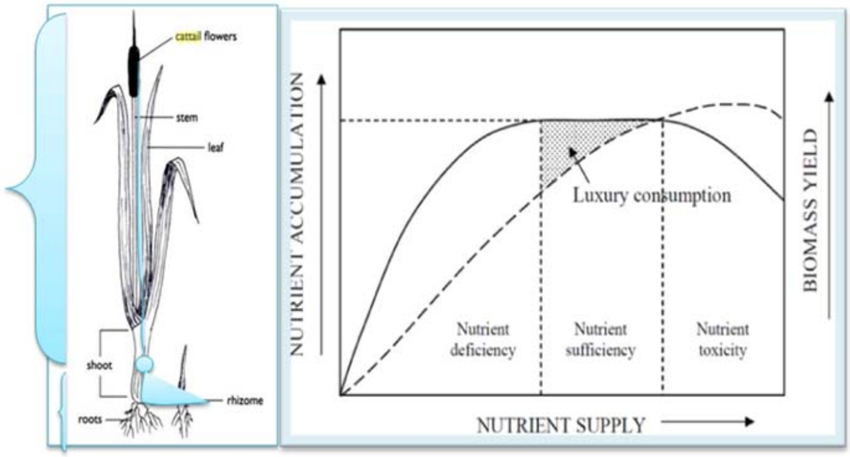

Figure 25: General relationships between plant biomass and nutrient concentrations in the water column and soil surface (Reddy and De Busk, 1987).

and Wallace, 2009), which was comparable to our results. However, the nutrient storage per m^2 in our study differs significantly because of the varying plant biomass values among the four wetlands (Table 2). High densities of bulrush species carried large amount of nutrients in the system, up to 170.2 g N/m^2 and 16.0 g P/m^2. Our results are on the high end compared to the findings of Vymazal (2006), who reported that the nitrogen standing stock for emergent species was in the range of 14 to 156 g N/m^2. Similarly, Tanner (2001) showed that bulrush plant tissues accumulated 8.8-13.4 g P/ m^2 and 48-69g N/ m^2 in total biomass (root and shoot). These data are within a close range of our wetland systems.

Also in our study, below-ground parts appear to be more efficient in phosphorus uptake compared to the above-ground plant parts (of both cattails and bulrushes). However, in contrast, above-ground plant parts had higher nitrogen concentrations compared to the below-ground parts for both species. Our results are in agreement with Greenway (2005), who compared nitrogen and phosphorus in root/rhizomes and leaf/stem tissues for a variety of native wetlands species from constructed wetlands of Queensland and found that the nitrogen content was highest in the above-ground parts and the phosphorus was highest in the below-ground parts. Similarly, our data suggest that the fibrous roots have higher TP concentrations for both cattails and bulrush species (0.11% for cattail and 0.13% for bulrush) than rhizome (0.07% for cattail and 0.10% for bulrush). Higher nutrient uptake by fibrous roots was also recognized by Yang et al. (2007) in their study of five different emergent plants. They found that removal efficiency was a function of the amount of fibrous roots present in the plant rather than the plant's total biomass.

4.3 Nutrient Uptake Among Wetland Types

Phosphorus: Constructed and natural wetlands are capable of absorbing new phosphorus loads, and in appropriate circumstances can provide a low cost alternative to chemical and biological treatment. Phosphorus interacts strongly with wetland sediment, water column and plant species, which provides both short term and sustainable long term storage of this nutrient (Kadlec, 1998). Our nutrient dynamics results suggest the efficiency of TP uptake was not specific to any particular species but was more dependent on the ambient concentration of nutrients in sediments of the specific wetland sites. Sites with higher ambient nutrients had generally higher nutrients in the plants. This is not completely unexpected because plants have higher plasticity for nutrients than other organisms. This has also been found in many algal nutrient studies, for example, algae grown in higher nutrient concentrations have higher algal N and P concentrations due to weaker homeostasis in plants compared to other organisms (Acharya, 2004; Sterner and Elser, 2002). Similarly, Zhang et al. (2008) investigated the concentration of nutrients (N and P) in wastewater fed wetlands and found results consistent with our findings.

Also, our data suggested that TP concentration in plant tissues had relatively higher correlation with the sediment concentration than water column (Figures 16, 17). This is not surprising due to higher P availability in the sediments than in the water columns. Correlations were particularly strong in the HD wetlands. This is perhaps expected considering that the HD wetland received partially treated effluent (primary treatment only) for a long period of time before water was denitrified. Furthermore, HD had the longest retention time of any wetland studied. Similarly, other previous studies suggest, for P removal, contact time may play a major role in the distribution within constructed wetlands (Drizo et al., 2000) and it has been suggested that the removal efficiency of P is positively correlated with retention time (Klomjek and Nitisoravut, 2005). In our study, among the four wetlands, HD is considered a terminal wetlands, whereas the other wetlands lack significant storage of water due to their regular flow. Nutrient contents of the water column can be quite unrelated to plant growth of emergent species having ready access to the abundant nutrient supply in the sediments (Wetzel, 2001). There was a noticeable reduction at the inlet and outlet sediment TP concentration for all the wetlands (Figure 8). However, reduction was less significant and highly variable for TP in the water column. Phosphorus removal in the water column is highly variable and depends on many factors such as settling of fine particles among others. This is also suggested in a study by Kadlec and Wallace (2009) that showed from 250 different free water surface wetlands that the reduction of phosphorus from inflow to outflow is unpredictable and variable.

Nitrogen: Wetland treatment systems consistently reduce nitrogen concentrations for many types of wastewater. The magnitude of these reductions depends on many factors including inflow concentrations, chemical form of nitrogen, water temperature, season, organic carbon and dissolved oxygen. Regardless of the complexity in nitrogen cycling, organic nitrogen compounds are a significant fraction of the wetland plants, sediment and water column (Vymazal, 2007; Kadlec and Wallace, 2009). In our study, nitrogen uptake by plants was not significantly correlated with ambient water and sediment concentrations as suggested by poor regression coefficients for both water column and sediment. However, there were significant differences among wetlands in plant nitrogen concentrations. Different hydrological regimes observed in our wetlands might have contributed to different N and P concentrations in the plants, sediments, and water columns. Despite less nitrogen input and lower water and sediment concentrations, TN recovery through plant assimilation was remarkably high in the HD wetlands compared to PW wetlands. Better performance of the HD wetlands might be due to better vegetation management practice of using hummocks. Despite less nitrogen input and lower water and sediment concentrations, TN recovery through plant assimilation was remarkably high in the HD wetlands compared to PW wetlands. As discussed before, it may be due to the denitrifying of pond water by Henderson Water Reclamation Facility in March 2008, just prior to our sampling date (pers. comm., Debbie Van Dooremolen). Also the plants have been growing in the HD wetlands for several years and were thus growing when N concentrations in the water and sediment were much higher than during our study period.

A study in the Southwestern U.S. by Thullen et al. (2005) concluded that properly configured hummocks in a constructed wastewater treatment wetlands can be used to maintain a proper balance of vegetation necessary to optimize treatment function. This may also be due to less favorable conditions for nitrogen loss via other processes, such as denitrification, which in general is a major sink of nitrogen in pond systems. In the HD wetlands, the high plant density may impair this denitrification process. This argument is also supported by the findings of Gebremarian and Beutel (2008) in their comparative study to understand the effectiveness of nitrate removal by cattail and bulrush species. They observed that bulrush plants enhanced the nitrification process by enhancing rhizosphere oxygenation, which limits the denitrification process. Total nitrogen measured in water and sediments were higher in the LVW wetlands than in other wetlands, in our study. The source of higher nitrogen input (~14 mg/L) is the effluent coming from the wastewater discharge (~250-350 cfs) in the LVW wetlands. Whereas, the FW wetlands, which is similar to and a tributary of the LVW wetlands (in terms of hydrology, and wetlands type), receives much smaller discharge (~ 5 cfs) and has much less nitrogen in the system but higher differences between the inlet and outlet (removal). Comparing inlet with outlet data, FW wetlands were more efficient at removing nutrients from the sediment surface. Higher volume of discharge in the LVW wetlands might be too much to overcome for the existing wetlands in LVW to noticeably increase removal of nitrogen from the system. Despite a loss in total nitrogen at the outlet of the FW wetlands, cattail plants in the FW wetlands generally had lower TN concentrations than in the LVW wetlands. This may be due to a seasonal fluctuation in FW surface runoff, which ultimately limits the regeneration capacity of wetland vegetation and gives it less space to flourish. Furthermore, nutrient inputs can directly modify or change biological communities. Fluctuations in hydrological conditions induce changes in nutrient inputs. Therefore, high dependence on hydrology is particularly important in semi-arid and arid areas, where surface water levels fluctuate seasonally (Mitsch and Gosselink, 1993).

4.4 Metals

Metal distribution in plant tissue: Metals are essential micronutrients for plant growth, but in wastewater they may be found in concentrations that are toxic to aquatic life. Biomagnification through the food chain occurs with a number of metals (e.g., Al, As, Se, Ag, Zn, Fe, Pb, Mn, Hg, Ni, Cr, and Cu) in treatment wetlands. The accumulation of metals in plants may be short lived since a portion of the metals are released back to the system upon senescence (Kadlec and Knight 1996). Among the 29 different trace elements analyzed, As and Se were detected at all wetlands sites and were studied in more detail due to their history in the Valley watershed. Several other trace metals (e.g., Hg, Pb, Zn, Cd, Fe, and Mo) were detected in the plant tissues as well, but all were under the maximum MCL (maximum contaminant level; USEPA, 2004). The concentrations of plant tissue Pb (3-8μg/g), Fe (0.7-2.3mg/g), Ni (3-7mg/g), and Cu (0.01-0.2 mg/g) measured in our wetland sites were found to be in a similar range as Mays and Edwards' (2001) natural and constructed wetlands data. There was no significant trend observed in plant tissue variation of trace metals besides As and Se for specific sites or species. As with nutrients, both cattail and bulrush species were effective bioaccumulators of these metalloid pollutants (As and Se) from the wetland systems.

Our study suggested that As and Se uptake capacity was significantly higher in bulrushes than in cattails. Among the three species of bulrush, *S. americanus* was the most effective at As and Se uptake, followed by *S. acutus* and *S. californicus*. However, both of these latter species are also known to acquire heavy metals in their root, rhizome, and leaf tissues, as found in different studies of wetlands ecosystems (Schwartz and Boyd, 1995; Cardwell et al., 2002). Similarly, below-ground plant tissues (root) had higher concentrations of both Se and As than above-ground (shoot) parts (Figure 11). Our results are comparable with the study by Vymazal et al. (2009) that found that concentrations decreased in the order of roots > rhizomes > leaf > stems for 19 different trace elements, including As and Se, for *Phragmites australis* plants growing in constructed wetlands with subsurface flow for treatment of municipal sewage in the Czech Republic.

Metal distribution in wetlands: A number of trace metals are essential micronutrients at low concentrations, but some trace metals may occur in wastewater at concentrations that are toxic to aquatic wildlife (Hamilton, 2004). Sediment metal concentration for trace metals such as Cd, Co, Cr, Cu, Hg, Fe, Li, Mg, Ni, Pb and Zn generally showed no significant differences between the samples taken at the inlets versus those taken at the outlets for any of our wetland sites. The levels of metals that may be tolerated by sensitive organisms have been promulgated in the form of guidelines for the protection of receiving waters and associated sediments. The values measured from different metal concentrations in our wetland sites were within the threshold levels provided by Wisconsin (WDNR, 2003; U.S.EPA, 2006) in guidelines for metal concentrations in sediments and water. Plant tissue in all wetlands sites also had significant concentrations of iron (Fe) ranging from 450-1233 µg/g. Our results are consistent with the range 200-2000 µg/g dry mass reported by (Vymazal, 1998) in Chez Republic. The wetlands vegetation in the wetlands in our study was found to be quite efficient on iron uptake from the system. However the plant senescence and leaching action of iron needed to be further investigated since some studies document wetlands are net sinks for iron in most of the seasons (Batty and Younger, 2002). Molybdenum (Mo) was measured in a reasonable amount in the sediments but was not in significant amount in the plant tissue in any of the four wetlands sites.

Hg and As in the PW wetlands sediment are near the probable effect concentration (PEC) and need a closer look. The concentrations are not yet under the threat level but appear close to PEC as defined by USEPA sediment quality benchmark (SQB) values (USDE, 1998). These values are being used to predict potential toxicity to sensitive ecological receptors. The water column concentrations for those elements were found to be slightly higher at the FW and PW wetlands. LVW had relatively smaller concentrations of these trace elements (Cizdziel and Zhou, 2005). Plant tissue concentrations in the four wetland sites were consistent with the ambient sediment and water column metal concentrations. Since the four wetlands sites are open to biota, they may be exposed to potentially higher levels of metals, primarily in the wetlands sediment. The removal of metals from the water column can result in storage in the sediments that is inimical to the subset of wetlands organisms that live or feed in those sediments.

As is of concern in aqueous environments because it is a known human carcinogen and is chronically toxic to aquatic organisms. As concentrations in plant tissues of the four wetlands were significantly consistent with the trend in ambient concentrations in the sediments and water columns. The regression analysis showed that the arsenic in plants is significantly correlated with sediment and water column (Figure 18, 19) concentrations. Overall, the highest measured As uptake in plants was in the PW wetlands, followed by the LVW wetlands. The HD and FW wetlands had the lowest plant As concentrations. Among the four wetland sites, the PW wetlands also had the highest sediment and water column As concentrations, followed by LVW wetlands. As concentration (13.12 µg/L) measured in the water column of the PW wetlands appears to exceed the drinking water standard (10 µg/L). It is thought that the As in PW is naturally occurring through the groundwater system rather than from anthropogenic sources (Cizdziel and Zhou, 2005). Sediment from the outlets of the PW and HD wetlands showed a small but significant drop in concentrations, which was not the case in the FW and LVW wetlands. The speciation of As in wetland sediment is complex because As forms a bond with organic and inorganic elements at diverse proportions (Keon et al., 2001; Fox and Doner, 2003). Se is a naturally occurring metalloid that is distributed widely in nature in most rocks and soils and usually combines with sulfide or with silver, copper, lead, and nickel minerals. Groundwater can leach Se from rocks and soil, and from agricultural and industrial waste. Some Se compounds will dissolve in water, and some will remain as solid particles (Zhang and Moore, 1997; Lin and Terry, 2003). Soluble forms of Se are very mobile and may accumulate up the food chain in vegetation and animal tissue. Constructed wetlands remove Se by reduction to insoluble forms which are deposited in the sediments, by accumulation into plant tissues, and by volatilization to the atmosphere (Lin and Terry, 2003). The metalloid Se presents a challenge for environmental regulatory managers because it demonstrates a narrow concentration range between essentiality and toxicity (Lemly, 1998; Sappington, 2002). In contrast to As, among the four wetlands, Se concentrations in plant tissues were relatively consistent with water column Se concentrations than sediment concentrations (Figure 20). The PW wetlands had the highest measured Se concentrations in plant tissues and water. In contrast with their relatively lower Se plant concentrations, the FW and LVW wetlands had higher Se sediment concentrations than found in the PW and HD wetlands. However, Se concentrations in the sediments of the four wetlands (<2.0 µg/g) were moderate and perhaps without any consequential impact on aquatic life. Se concentration less than 2 µg/g is considered below the toxicity threshold (USEPA, 2004).

Unlike concentrations in the sediments, Se concentration in the water column was relatively higher (10-15 µg/L) in both the FW and PW wetlands. Waterborne Se in both wetlands exceeded the EPA standard for chronic exposure (5 µg/L) and even came close to acute exposure (20 µg/L) (USEPA, 2004). It could pose an elevated risk of uptake of water soluble Se by fish and wildlife (Hamilton, 2004). Se concentrations analyzed in plant tissues from the LVW, FW, and HD wetlands (>3.0 µg/g) are similar to those found in the study by Seiler, et al. (2003) in the Western U.S. Our results for plant Se concentrations in the LVW, FW, and HD wetlands are similar to those of Pollard, et al. (2007) for bulrushes and cattails from the Clark County Wetlands Park Nature Preserve and Hansen, et al. (1998) for shoot and root tissues of wetland plants in the constructed wetlands of the San Francisco Bay. Seiler, et al. (2003) provided a typical background level for plant tissue Se (1.5 µg/g) and dietary effect levels in these tissues (~3 µg/g). Se concentration in plant tissues from LVW, HD, and FW were below these levels and only plant tissues in PW exceeded (~10 µg/g) this level. The PW wetlands' relatively high Se concentrations could pose an elevated risk for birds and wildlife of bioaccumulation and transfer to higher trophic levels in the food chain. Se concentration in the PW wetlands from bulrush plant tissue, sediment and water columns is similar to Se concentration in constructed wetlands from other parts of the world (Kadlec and Wallace, 2009). They compiled Se concentrations in vegetation in treatment wetlands exposed to Se which were typically in the range of 1-20 µg/g for plants and 1-10 µg/g for sediments.

4.5 Temporal variation (Nutrients and Metals)

The growth and senescence of wetland macrophytes commonly used for wastewater treatment all follow a seasonal pattern in different climates. New plant growth proceeds from small shoots that may be initiated as early as late summer of the preceding year for *Typha* species (Bernard, 1999), but remain tiny and dormant over the winter season. Above-ground biomass increases rapidly in spring in warm temperate climates. Then growth tapers off, causing above-ground biomass to peak in late summer. The size of the peak standing crop varies considerably with plant species and degree of nutrient availability (Tanner, 2001).

Plant growth changes proportions of stored phosphorus in various plant parts as each season progresses. Nutrient storage in plant tissue increases in growing seasons to a maximum and decrease to a minimum after senescence of plant (Tanner, 2001). Seasonal variation was analyzed based on the seasonal data on nutrient concentration of plant tissues taken from the four wetland sites. The annual mean seasonal data from cattail and bulrush tissue nutrient concentrations were not statistically significant among three different seasons. However, there were generally higher nutrient concentrations in summer followed by spring and winter seasons for both plant species among four wetland sites. Several studies have shown that nutrient concentrations in plant biomass generally decrease over the course of the growing season (Van der Linden, 1980; Ganzert & Pfadenhauer, 1986). Several studies have explored whether seasonal changes in nutrient concentrations are indicators of nutrient limitation and found that N: P ratio is more closely related to nutrient availability rather than N or P concentration only and was a better indicator of nutrient limitation (Güsewell and Koerselman, 2002).

Our data did not show any significant temporal variation in As concentrations. Other studies have found similar results (Jackson et al., 1991; Zayed et al., 1998; Mays and Edwards, 2001). They noticed the seasonal variation of As was less significant but was significantly associated with the substrate concentrations in which they are found. Also, Pollard et al. (2007) measured seasonal plant tissue Se concentration for five wetland plants (including cattails and bulrushes) in the Clark County Wetlands Park Nature Preserve. They found that the fall samples generally had higher concentrations in shoots compared to spring and summer seasons. Three of our wetlands sites (LVW, HD and PW) were somewhat similar in that winter samples (not particularly fall) generally had higher metal and nutrient concentrations in shoots for both plant types. This may be because of higher volatilization of Se in summer and spring season. It has been reported that the complexity in Se due to volatilization might cause differences in seasonal distribution and bioaccumulation in various plant tissues (Hansen et al., 1998; De Souza et al., 2000; Pollard et al., 2007).

4.6 Ecosystem Function of Wetlands

Comparison of annual average nutrient storage in standing biomass of cattail plants in the peak growing season showed that nutrient removal from the LVW wetlands was significantly higher than the FW wetlands. This can perhaps be attributed to a higher productivity by cattails in the LVW wetlands, and therefore more efficient nutrient removal. Total nutrient uptake potential by a particular species at particular wetlands site was not estimated because we do not have data on plant coverage on these wetlands (beyond the scope of this study), especially LVW and FW wetlands which cover a large area. However, based on our annual average nutrient storage in plants ($g/m^2/yr$) and approximate estimation of the coverage in the HD and PW wetlands, we calculated that the HD and PW wetlands plants stored ~44 and ~5 tons of nitrogen/yr, respectively. Similarly, the HD wetland plants sequestered ~4 tons of phosphorus/yr compared to ~0.2 tons/yr at the PW wetlands. Better ecosystem function of the HD wetlands is not only due to higher plant biomass and nutrient concentrations but also due to a larger surface area of the wetlands (11634 m^2 at HD vs. 40 m^2 at PW).

Metal uptake among the four wetland plants suggests that annual average metal storage by plant tissue measured as $g/m^2/yr$ was higher at the PW and FW wetlands compared to the HD and LVW wetlands. It appears that larger the surface area of wetlands vegetation the higher the metal accumulation and therefore higher flux suggesting that wetlands acreage is important as well. Similarly metals, especially As, Se, Fe, were efficiently taken up by plant species in all the wetland sites. Annual As and Se removal by the PW wetlands were less (<1 kg/yr) than the HD wetlands (~124 kg As/yr and 261.6 kg Se/yr) at the peak growing season.

5.0 CONCLUSION

Plant species selection and vegetation management may enhance nutrient and metal removal in both constructed and naturally created wetlands. However, there is a lack of knowledge on the relationships among plant growth, plant selection, and nutrient and metal uptake efficiencies in wetlands. This study helps us better understand how plant growth and resource allocations are influenced by nutrients and other pollutants in wastewater and urban runoff fed wetlands. Constructed and naturally created wetlands in the Valley watershed were studied to understand their potential for pollutant removal from the system. Metal and nutrient dynamics of cattail and bulrush plants were studied in four wetland sites to characterize their function in the local environment. Significant uptake of nutrients was found in the wetlands receiving high nutrient loads. Both plant species in the four wetlands sites were quite efficient in taking up large amount of nutrients and metals. It appears that high nutrient availability could stimulate growth and accumulation of nutrients in plant tissues if the environment is right. In all wetland sites, total plant biomass, thus acreage, was more responsible than species distribution for nutrient uptake and eventual removal. The nutrient uptake capacity of a wetland system was more dependent on individual plant biomass irrespective of plant type, i.e., size of individual or density rather than species.

Both cattails and bulrushes were found to be equally important for nutrient uptake in various environmental settings. Nutrient translocation in plant tissues showed that removal of the root system would be necessary for maximum phosphorus removal and an above-ground harvest would be sufficient for nitrogen removal from our wetlands systems. At the same time nutrient concentrations in the fibrous roots of both cattail and bulrush plants were higher than both above ground and rhizome biomass. We did not estimate the proportional biomass of fibrous vs. tap roots in these plants; therefore, we cannot conclude how much total nutrients were stored in each root type. Among the four wetlands studied, performance of the HD wetlands was more efficient for nutrient uptake, possibly due to better vegetation management using hummocks.

Plant nutrients in the four wetland sites correlated well with ambient nutrient concentrations in the sediment and water column, irrespective of the type of plants present. TP and TN in plant tissues showed consistent trends with ambient sediment and water column concentrations in all the wetlands sites. There was not a significant reduction in water column concentrations but there were significant decreases in sediment concentrations from the inlets to outlets at all four wetlands sites. Overall, this study suggests that different plant species have different capacities to take up nutrients mostly determined by ambient nutrient and hydrologic conditions. These findings have important implications for improving our ability to engineer ecological solutions to problems associated with nutrient-rich wastewater and to implement sustainable wetlands management plans.

Bioaccumulation of Se leading to toxicological impact and change in aquatic communities has been intensively investigated in the Wash in recent years. Investigation of Se in tributaries, urban runoff, and rain suggested that the source of the elevated Se is likely due to groundwater seeps located within a relatively narrow geographic band on the southeast side of the Valley (Cizdziel and Zhou, 2005). Constructed and naturally created wetlands in the Valley appear to be functioning quite efficiently to uptake metalloid pollutants from the wetlands system by means of plant tissues. Bulrush species seem particularly more efficient for metals such as As and Se, compared to cattails. Also, the belowground plants for both species seemed to store metals more efficiently than above ground parts. Harvesting plant roots might be necessary for maximum removal from the treatment wetlands. Higher metal accumulation in the PW wetland plants suggested that there is a potential for wildlife exposure and may become a problem in the future. Besides the PW wetlands, none of the metals were measured under elevated concentrations with possible toxic effects. Although As and Hg concentrations were moderate in the PW and FW wetlands, regular monitoring is needed to further explore their complex distribution in wetlands ecosystem.

Proper vegetation management could be utilized to enhance the bioremediation potential for Se using existing wetlands in the Wash. Better bioaccumulative property of bulrush species in the wetlands in this study might provide clues for Se removal using existing wetlands plants in these wetlands. Our data provide only a glimpse of what might be happening in the wetlands in the desert southwest using a few wetlands and a few species of plants. A more detailed and long-term (multi-year) study including many plant species will be necessary to understand the possible effect of metals and nutrients on trophic transfer in the food chain.

Based on the results from the interaction of plant tissues with the water column and sediment, we can somewhat quantify and characterize the ecological efficiency of the wetlands. Cattail plants in the LVW wetlands had high standing biomass and nutrient concentrations in comparison to the FW wetlands. Although the total nutrients removed by both wetlands were not estimated, the LVW wetlands were found to be functioning more efficiently than the FW wetlands for nutrient uptake. Similarly, nutrient uptake performance of the HD wetlands appeared better than the PW wetlands. Bulrush species in the HD plants had higher standing biomass and nutrient concentrations, resulting in better ecosystem functions than the PW wetlands. Metals uptake by plant tissues among the four wetlands were relatively less significant compared to nutrients. There was some seasonal variation with higher nutrient uptake in summer seasons for all wetlands but there was not any difference for nutrient distribution in spring and winter seasons in our study. This interpretation is only based on a single year study; a long term study in the future would be necessary to provide conclusive evidence of temporal variations.

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Appendix A

Photographs showing a) sample collection, processing and analysis and
b) plant types found at four wetlands

Appendix A (a): (1) Field sampling and laboratory processing of plants and sediments at the Ecological Engineering Laboratory, Desert Research Institute, Las Vegas.

Appendix A (b): Various plant species found at the Las Vegas Wash (LVW), Flamingo Wash (FW), Henderson Demonstration (HD) and Pittman Wash (PW) wetlands in the Valley.

Typha domingensis Pers. CN: Southern Cattail	*Schoenoplectus acutus* (Muhl. ex Bigelow) A. Löve & D. Löve CN: Hardstem Bulrush	*Schoenoplectus californicus* (C.A. Mey.) Palla CN: California Bulrush	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller CN: Chairmaker's Bulrush

Appendix B

Total phosphorus data from plant tissues, water columns and sediments at four wetland sites

Appendix B1 - Plant tissue total phosphorous (TP) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Plant Species	Sample ID	TP (%)		
				Shoot	Root	Total
LVW	Winter	Typha	P-1	0.043	0.082	0.063
LVW	Winter	Typha	P-2	0.052	0.061	0.057
LVW	Winter	Typha	P-3	0.045	0.065	0.055
LVW	Winter	Typha	P-4	0.049	0.054	0.052
LVW	Winter	Typha	P-5	0.061	0.081	0.071
LVW	Winter	Typha	P-6	0.051	0.071	0.061
LVW	Winter	Typha	P-7	0.032	0.049	0.041
LVW	Winter	Typha	P-8	0.046	0.052	0.049
LVW	Winter	Typha	P-9	0.053	0.067	0.060
LVW	Winter	Typha	P-10	0.042	0.045	0.044
LVW	Winter	Typha	P-11	0.053	0.061	0.057
LVW	Winter	Typha	P-12	0.053	0.078	0.066
LVW	Winter	Typha	P-13	0.046	0.049	0.048
LVW	Winter	Typha	P-14	0.042	0.083	0.063
LVW	Spring	Typha	P-1	0.070	0.068	0.069
LVW	Spring	Typha	P-2	0.074	0.072	0.073
LVW	Spring	Typha	P-3	0.047	0.053	0.050
LVW	Spring	Typha	P-4	0.042	0.059	0.051
LVW	Spring	Typha	P-5	0.023	0.057	0.040
LVW	Spring	Typha	P-6	0.056	0.054	0.055
LVW	Spring	Typha	P-7	0.070	0.098	0.084
LVW	Spring	Typha	P-8	0.058	0.067	0.063
LVW	Spring	Typha	P-9	0.033	0.088	0.061
LVW	Spring	Typha	P-10	0.046	0.071	0.059
LVW	Spring	Typha	P-11	0.036	0.073	0.055
LVW	Spring	Typha	P-12	0.042	0.052	0.047
LVW	Spring	Typha	P-13	0.034	0.133	0.084
LVW	Spring	Typha	P-14	0.039	0.136	0.088
LVW	Spring	Typha	P-15	0.048	0.065	0.057
LVW	Spring	Typha	P-16	0.028	0.056	0.042
LVW	Summer	Typha	P-1	0.084	0.139	0.112
LVW	Summer	Typha	P-2	0.089	0.157	0.123
LVW	Summer	Typha	P-3	0.116	0.170	0.143
LVW	Summer	Typha	P-4	0.103	0.148	0.126
LVW	Summer	Typha	P-6	0.073	0.145	0.109

Site	Season	Plant Species	Sample ID	TP (%)		
				Shoot	Root	Total
LVW	Summer	Sch-cal	P-7	0.082	0.224	0.153
LVW	Summer	Sch-cal	P-9	0.082	0.259	0.171
HD	Winter	Sch-ac	P-1	0.048	0.087	0.068
HD	Winter	Sch-ac	P-2	0.044	0.083	0.064
HD	Winter	Sch-am	P-3	0.049	0.084	0.067
HD	Winter	Sch-am	P-4	0.063	0.076	0.070
HD	Winter	Sch-cal	P-5	0.061	0.089	0.075
HD	Winter	Sch-cal	P-6	0.069	0.079	0.074
HD	Winter	Sch-cal	P-7	0.086	0.088	0.087
HD	Winter	Sch-cal	P-8	0.066	0.076	0.071
HD	Spring	Sch-ac	P-1	0.169	0.205	0.187
HD	Spring	Sch-ac	P-2	0.120	0.170	0.145
HD	Spring	Sch-am	P-3	0.068	0.077	0.073
HD	Spring	Sch-am	P-4	0.064	0.650	0.357
HD	Spring	Sch-cal	P-5	0.060	0.171	0.116
HD	Spring	Sch-cal	P-6	0.056	0.019	0.038
HD	Spring	Sch-cal	P-7	0.069	0.126	0.098
HD	Spring	Sch-cal	P-8	0.075	0.123	0.099
HD	Spring	Sch-cal	P-9	0.086	0.153	0.120
HD	Spring	Sch-cal	P-10	0.084	0.169	0.127
HD	Spring	Typha	P-11	0.070	0.094	0.082
HD	Spring	Typha	P-12	0.060	0.097	0.079
HD	Spring	Typha	P-13	0.064	0.101	0.083
HD	Spring	Typha	P-14	0.071	0.105	0.088
HD	Spring	Typha	P-15	0.056	0.093	0.075
HD	Spring	Typha	P-16	0.052	0.091	0.072
HD	Summer	Typha	P-1	0.067	0.118	0.093
HD	Summer	Typha	P-2	0.082	0.138	0.110
HD	Summer	Typha	P-3	0.057	0.113	0.085
HD	Summer	Typha	P-4	0.091	0.146	0.119
HD	Summer	Sch-cal	P-5	0.188	0.225	0.207
HD	Summer	Sch-cal	P-6	0.229	0.251	0.240
HD	Summer	Sch-cal	P-7	0.143	0.179	0.161
HD	Summer	Sch-cal	P-8	0.155	0.186	0.171
PW	Winter	Sch-ac	P-1	0.015	0.020	0.018
PW	Winter	Sch-ac	P-2	0.017	0.022	0.020
PW	Winter	Sch-am	P-4	0.015	0.030	0.023

Site	Season	Plant Species	Sample ID	TP (%)		
				Shoot	Root	Total
PW	Winter	Sch-am	P-6	0.013	0.016	0.015
PW	Winter	Sch-cal	P-7	0.022	0.024	0.023
PW	Winter	Sch-cal	P-8	0.018	0.020	0.019
PW	Spring	Sch-ac	P-1	0.024	0.030	0.027
PW	Spring	Sch-ac	P-2	0.019	0.028	0.024
PW	Spring	Sch-am	P-3	0.016	0.027	0.022
PW	Spring	Sch-am	P-4	0.029	0.030	0.030
PW	Spring	Sch-cal	P-5	0.039	0.048	0.044
PW	Spring	Sch-cal	P-6	0.056	0.058	0.057
PW	Spring	Sch-cal	P-7	0.031	0.048	0.040
PW	Spring	Sch-cal	P-8	0.038	0.047	0.043
PW	Summer	Sch-am	P-1	0.006	0.017	0.012
PW	Summer	Sch-am	P-2	0.009	0.030	0.020
PW	Summer	Sch-am	P-3	0.021	0.017	0.019
PW	Summer	Sch-am	P-4	0.018	0.024	0.021
PW	Summer	Sch-am	P-5	0.103	0.078	0.091
PW	Summer	Sch-am	P-6	0.078	0.082	0.080
PW	Summer	Sch-am	P-7	0.039	0.089	0.064
PW	Summer	Sch-am	P-8	0.043	0.063	0.053
PW	Summer	Sch-am	P-9	0.087	0.047	0.067
PW	Summer	Sch-am	P-10	0.091	0.061	0.076
PW	Summer	Sch-am	P-11	0.087	0.059	0.073
PW	Summer	Sch-am	P-12	0.091	0.064	0.078
PW	Summer	Sch-am	P-13	0.050	0.097	0.074
PW	Summer	Sch-am	P-14	0.035	0.069	0.052
PW	Summer	Sch-am	P-15	0.039	0.047	0.043
PW	Summer	Sch-am	P-16	0.041	0.059	0.050
PW	Summer	Sch-am	P-17	0.043	0.054	0.049
PW	Summer	Sch-am	P-18	0.095	0.032	0.064
PW	Summer	Sch-am	P-19	0.041	0.060	0.051
PW	Summer	Sch-am	P-20	0.047	0.049	0.048
PW	Summer	Sch-am	P-21	0.077	0.068	0.073
PW	Summer	Sch-am	P-22	0.076	0.082	0.079
PW	Summer	Sch-cal	P-23	0.029	0.048	0.039
PW	Summer	Sch-cal	P-24	0.046	0.048	0.047
PW	Summer	Sch-cal	P-25	0.021	0.038	0.030
PW	Summer	Sch-cal	P-29	0.049	0.051	0.05

Site	Season	Plant Species	Sample ID	TP (%)		
				Shoot	Root	Total
PW	Summer	Sch-cal	P-28	0.04	0.04	0.04
PW	Summer	Sch-cal	P-30	0.02	0.07	0.05
PW	Summer	Sch-cal	P-26	0.02	0.04	0.03
PW	Summer	Sch-cal	P-31	0.02	0.05	0.03
PW	Summer	Sch-cal	P-32	0.02	0.05	0.03
PW	Summer	Sch-cal	P-33	0.07	0.07	0.07
PW	Summer	Sch-cal	P-34	0.07	0.06	0.06
PW	Summer	Sch-cal	P-35	0.03	0.05	0.04
PW	Summer	Sch-cal	P-36	0.02	0.06	0.04
PW	Summer	Sch-cal	P-37	0.03	0.07	0.05
PW	Summer	Sch-cal	P-38	0.03	0.08	0.06
PW	Summer	Sch-cal	P-39	0.03	0.04	0.04
PW	Summer	Sch-cal	P-40	0.03	0.07	0.05
PW	Summer	Typha	P-41	0.06	0.07	0.07
PW	Summer	Typha	P-42	0.07	0.05	0.06
PW	Summer	Typha	P-43	0.08	0.07	0.08
PW	Summer	Typha	P-44	0.06	0.05	0.06
PW	Summer	Typha	P-45	0.05	0.04	0.04
FW	Spring	Typha	P-1	0.02	0.04	0.03
FW	Spring	Typha	P-2	0.02	0.04	0.03
FW	Spring	Typha	P-3	0.02	0.02	0.02
FW	Spring	Typha	P-4	0.02	0.01	0.02
FW	Spring	Typha	P-5	0.02	0.02	0.02
FW	Spring	Typha	P-6	0.02	0.03	0.02
FW	Summer	Typha	P-1	0.05	0.10	0.07
FW	Summer	Typha	P-2	0.05	0.10	0.07
FW	Summer	Typha	P-3	0.06	0.08	0.07
FW	Summer	Typha	P-4	0.04	0.08	0.06
FW	Summer	Typha	P-5	0.05	0.11	0.08
FW	Summer	Typha	P-6	0.05	0.10	0.07
FW	Summer	Typha	P-7	0.05	0.08	0.06
FW	Summer	Typha	P-8	0.04	0.09	0.06
FW	Summer	Typha	P-9	0.07	0.08	0.08
FW	Summer	Typha	P-10	0.08	0.08	0.08

Note: Sch-cal: *Schoenoplectus californicus*, Sch-am: *Schoenoplectus americanus*, Sch-ac: *Schoenoplectus acutus* and Typha: *Typha domingensis*

Appendix B2- Water column total phosphorus (mg/L) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	**Location**	**SNWA Location**	**Sampling Date**	**TP (mg/L)**
				Water Column
LVW	Inlet	LW 6.85	Oct-07	0.160
LVW	Inlet	LW 6.85	Nov-07	0.120
LVW	Inlet	LW 6.85	Dec-07	0.120
LVW	Inlet	LW 6.85	Jan-07	0.094
LVW	Inlet	LW 6.85	Feb-07	0.130
LVW	Inlet	LW 6.85	Mar-07	0.093
LVW	Inlet	LW 6.85	Apr-07	0.160
LVW	Inlet	LW 6.85	Feb-08	0.084
LVW	Inlet	LW 6.85	Mar-08	0.080
LVW	Inlet	LW 6.85	Apr-08	0.130
LVW	Outlet	LW 5.9	Feb-07	0.100
LVW	Outlet	LW 5.9	Mar-07	0.150
LVW	Outlet	LW 5.9	Apr-07	0.130
LVW	Outlet	LW 5.9	Feb-08	0.140
LVW	Outlet	LW 5.9	Mar-08	0.140
LVW	Inlet	LW 5.9	May-07	0.150
LVW	Inlet	LW 5.9	Jun-07	0.130
LVW	Inlet	LW 5.9	Jul-07	0.120
LVW	Inlet	LW 5.9	Aug-07	0.110
LVW	Outlet	LW 5.9	May-07	0.150
LVW	Outlet	LW 5.9	Jun-07	0.140
LVW	Outlet	LW 5.9	Jul-07	0.130
LVW	Outlet	LW 5.9	Aug-07	0.120
HD	Inlet	HD1	Nov-08	1.610
HD	Inlet	HD1	Dec-08	0.840
HD	Inlet	HD1	Nov-07	0.600
HD	Inlet	HD1	Dec-07	0.920
HD	Outlet	HD4	Nov-08	1.120
HD	Outlet	HD4	Dec-08	0.810
HD	Outlet	HD4	Nov-07	0.950
HD	Outlet	HD4	Dec-07	0.850
HD	Inlet	HD1	Jan-07	1.020
HD	Inlet	HD1	Feb-07	2.010
HD	Inlet	HD1	Mar-07	0.940
HD	Inlet	HD1	Apr-07	0.560

Site	Location	SNWA Location	Sampling Date	TP (mg/L) Water Column
HD	Outlet	HD4	Jan-07	1.830
HD	Outlet	HD4	Feb-07	3.450
HD	Outlet	HD4	Mar-07	4.130
HD	Inlet	HD1	May-07	1.120
HD	Inlet	HD1	Jun-07	0.370
HD	Inlet	HD1	Jul-07	1.220
HD	Inlet	HD1	Aug-07	0.510
HD	Outlet	HD4	May-07	2.540
HD	Outlet	HD4	Jun-07	1.290
HD	Outlet	HD4	Jul-07	0.860
HD	Outlet	HD4	Aug-07	2.620
PW	Inlet	PW-Inlet	Nov-07	0.038
PW	Inlet	PW-Inlet	Dec-07	0.045
PW	Outlet	PW-Outlet	Nov-07	0.033
PW	Outlet	PW-Outlet	Dec-07	0.033
PW	Inlet	PW-Inlet	Jan-07	0.160
PW	Inlet	PW-Inlet	Feb-07	0.096
PW	Inlet	PW-Inlet	Mar-07	0.034
PW	Inlet	PW-Inlet	Jan-08	0.110
PW	Outlet	PW-Outlet	Jan-07	0.025
PW	Outlet	PW-Outlet	Feb-07	0.040
PW	Outlet	PW-Outlet	Mar-07	0.072
PW	Inlet	PW-Inlet	May-07	0.041
PW	Inlet	PW-Inlet	Jun-07	0.110
PW	Outlet	PW-Outlet	May-07	0.030
PW	Outlet	PW-Outlet	Jun-07	0.030
FW	Inlet	TW-DRI	Jan-07	0.070
FW	Inlet	TW-DRI	Feb-07	0.020
FW	Inlet	TW-DRI	Mar-07	0.030
FW	Inlet	TW-DRI	Jan-08	0.010
FW	Outlet	FW-0	Jan-07	0.020
FW	Outlet	FW-0	Feb-07	0.060
FW	Outlet	FW-0	Mar-07	0.030
FW	Outlet	FW-0	Jan-08	0.020
FW	Inlet	TW-DRI	May-07	0.130
FW	Inlet	TW-DRI	Jun-07	0.110
FW	Inlet	TW-DRI	Jul-07	0.080
FW	Inlet	TW-DRI	Aug-07	0.050

Site	Location	SNWA Location	Sampling Date	TP (mg/L)
				Water Column
FW	Outlet	FW-0	May-07	0.010
FW	Outlet	FW-0	Jun-07	0.020
FW	Outlet	FW-0	Jul-07	0.030
FW	Outlet	FW-0	Aug-07	0.050
FW	Inlet	TW-DRI	Nov-07	0.050
FW	Inlet	TW-DRI	Dec-07	0.060

Appendix B3 - Sediment total phosphorus (TP) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Location	TP (%)
			Sediment
LVW	Winter 08	Inlet	0.048
LVW	Winter 08	Inlet	0.045
LVW	Winter 08	Inlet	0.044
LVW	Winter 08	Inlet	0.042
LVW	Spring 09	Outlet	0.036
LVW	Spring 09	Outlet	0.038
LVW	Spring 09	Outlet	0.058
LVW	Spring 09	Outlet	0.056
LVW	Summer 09	Outlet	0.049
LVW	Summer 09	Outlet	0.047
LVW	Summer 09	Outlet	0.056
LVW	Summer 09	Inlet	0.057
HD	Winter 08	Inlet	1.610
HD	Winter 08	Inlet	0.840
HD	Winter 08	Inlet	0.600
HD	Winter 08	Inlet	0.920
HD	Winter 08	Inlet	1.120
HD	Winter 08	Inlet	0.810
HD	Winter 08	Outlet	0.950
HD	Winter 08	Outlet	0.850
HD	Spring 09	Outlet	1.020
HD	Spring 09	Outlet	2.010
HD	Spring 09	Outlet	0.940
HD	Spring 09	Inlet	0.560
HD	Spring 09	Inlet	1.830
HD	Spring 09	Inlet	3.450
HD	Spring 09	Inlet	4.130
HD	Spring 09	Outlet	1.800
HD	Summer 09	Outlet	1.120
HD	Summer 09	Outlet	0.370
HD	Summer 09	Inlet	1.290
HD	Summer 09	Outlet	1.220
HD	Summer 09	Inlet	0.510
HD	Summer 09	Inlet	0.860
HD	Summer 09	Outlet	2.620
PW	Winter 08	Outlet	0.030

Site	Season	Location	TP (%)
			Sediment
PW	Winter 08	Outlet	0.025
PW	Winter 08	Outlet	0.031
PW	Winter 08	Inlet	0.026
PW	Spring 09	Inlet	0.041
PW	Spring 09	Inlet	0.042
PW	Spring 09	Inlet	0.037
PW	Spring 09	Outlet	0.034
PW	Summer 09	Outlet	0.054
PW	Summer 09	Outlet	0.057
PW	Summer 09	Outlet	0.052
PW	Summer 09	Inlet	0.051
FW	Spring 09	Inlet	0.041
FW	Spring 09	Inlet	0.044
FW	Spring 09	Inlet	0.019
FW	Spring 09	Outlet	0.016
FW	Summer 09	Outlet	0.021
FW	Summer 09	Outlet	0.034
FW	Summer 09	Outlet	0.020
FW	Summer 09	Inlet	0.013
FW	Winter 08	Inlet	0.021
FW	Winter 08	Inlet	0.027
FW	Winter 08	Inlet	0.021
FW	Winter 08	Outlet	0.014

Appendix C

Total nitrogen data from plant tissues, water column and sediment at four wetland sites

Appendix C1 - Plant tissue total nitrogen (TN) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Plant	Plant ID	TN (%)		
				Shoot	Root	Total
LVW	Spring	Typha	P-1	1.77	1.20	1.48
LVW	Spring	Typha	P-1	1.68	1.25	1.46
LVW	Spring	Typha	P-2	1.81	1.12	1.46
LVW	Spring	Typha	P-2	1.71	1.60	1.65
LVW	Spring	Typha	P-3	1.40	1.12	1.26
LVW	Spring	Typha	P-3	1.40	1.05	1.22
LVW	Spring	Typha	P-3	0.94	0.84	0.89
LVW	Spring	Typha	P-3	0.86	0.73	0.79
LVW	Spring	Typha	P-5	1.90	1.30	1.60
LVW	Spring	Typha	P-5	1.88	1.35	1.61
LVW	Spring	Typha	P-5	1.88	1.14	1.51
LVW	Spring	Typha	P-6	1.69	1.21	1.45
LVW	Spring	Typha	P-6	1.69	1.24	1.46
LVW	Spring	Typha	P-6	0.89	0.51	0.70
LVW	Spring	Typha	P-6	0.96	1.15	1.05
LVW	Spring	Typha	P-7	1.56	1.95	1.75
LVW	Spring	Typha	P-8	1.83	1.44	1.63
LVW	Spring	Typha	P-8	2.74	1.03	1.88
LVW	Spring	Typha	P-8	2.68	1.04	1.86
LVW	Spring	Typha	P-9	2.05	1.26	1.65
LVW	Spring	Typha	P-10	1.56	1.42	1.49
LVW	Spring	Typha	P-11	0.83	1.69	1.26
LVW	Spring	Typha	P-11	0.92	2.12	1.52
LVW	Spring	Typha	P-11	1.34	1.00	1.17
LVW	Spring	Typha	P-11	2.91	1.52	2.21
LVW	Spring	Typha	P-12	1.68	1.03	1.35
LVW	Spring	Typha	P-12	1.18	0.86	1.02
LVW	Spring	Typha	P-12	1.95	0.89	1.42
LVW	Spring	Typha	P13	1.76	0.94	1.35
LVW	Spring	Typha	P-14	2.32	1.46	1.89
LVW	Spring	Typha	P-14	1.90	1.07	1.48
LVW	Spring	Sch-cal	P-15	1.86	1.64	1.75
LVW	Spring	Sch-cal	P-15	1.84	1.50	1.67
LVW	Spring	Sch-cal	P-16	2.10	1.20	1.65
LVW	Spring	Sch-cal	P-18	2.57	1.42	1.99

Site	Season	Plant	Plant ID	TN (%)		
				Shoot	Root	Total
LVW	Spring	Sch-cal	P-19	2.62	1.34	1.98
LVW	Winter	Typha	P-1	1.58	1.10	1.34
LVW	Winter	Typha	P-2	1.18	0.82	1.00
LVW	Winter	Typha	P-3	0.94	0.84	0.89
LVW	Winter	Typha	P-3	0.86	0.79	0.82
LVW	Winter	Typha	P-3	1.39	1.46	1.42
LVW	Winter	Typha	P-4	0.95	0.78	0.86
LVW	Winter	Typha	P-5	2.32	1.07	1.69
LVW	Winter	Typha	P-6	0.97	0.78	0.88
LVW	Winter	Typha	P-7	1.05	1.29	1.17
LVW	Winter	Typha	P-8	1.36	0.86	1.11
LVW	Winter	Typha	P-8	1.92	1.12	1.52
LVW	Winter	Typha	P-8	2.32	1.26	1.79
LVW	Summer	Typha	P-1	2.23	1.55	1.89
LVW	Summer	Typha	P-2	1.96	1.48	1.72
LVW	Summer	Typha	P-3	1.79	1.04	1.41
LVW	Summer	Typha	P-4	2.17	1.01	1.59
LVW	Summer	Typha	P-5	1.82	1.80	1.81
LVW	Summer	Typha	P-6	1.73	1.76	1.74
LVW	Summer	Sch-cal	P-7	2.41	2.13	2.27
LVW	Summer	Sch-cal	P-8	2.51	2.15	2.33
LVW	Summer	Sch-cal	P-9	1.53	1.21	1.37
LVW	Summer	Sch-cal	P-10	1.70	1.42	1.56
HD	Spring	Sch-ac	P-20	1.01	1.06	1.03
HD	Spring	Sch-ac	P-21	1.26	1.06	1.16
HD	Spring	Sch-am	P-22	1.37	1.19	1.28
HD	Spring	Sch-am	P-23	1.43	1.24	1.33
HD	Spring	Sch-cal	P-24	1.68	1.36	1.52
HD	Spring	Sch-cal	P-25	1.70	1.35	1.52
HD	Spring	Sch-cal	P-26	0.80	1.30	1.05
HD	Spring	Sch-cal	P-27	0.97	1.27	1.12
HD	Spring	Sch-cal	P-28	1.41	1.47	1.44
HD	Spring	Sch-cal	P-29	1.42	1.58	1.50
HD	Spring	Typha	P-30	1.89	1.44	1.66
HD	Spring	Typha	P-31	1.77	1.7	1.73
HD	Spring	Typha	P-32	1.36	1.81	1.58
HD	Spring	Typha	P-34	1.77	1.51	1.64

Site	Season	Plant	Plant ID	TN (%)		
				Shoot	Root	Total
HD	Spring	Typha	P-35	1.79	1.51	1.65
HD	Winter	Sch-ac	P-9	1.15	1.15	1.15
HD	Winter	Sch-ac	P-10	1.40	1.43	1.42
HD	Winter	Sch-am	P-11	2.41	0.71	1.56
HD	Winter	Sch-am	P-12	1.26	1.12	1.19
HD	Winter	Sch-cal	P-13	1.26	1.40	1.33
HD	Winter	Sch-cal	P-14	1.58	1.05	1.31
HD	Winter	Sch-cal	P-15	1.25	2.41	1.83
HD	Winter	Sch-cal	P-16	1.30	0.85	1.07
HD	Summer	Typha	P-11	2.10	1.85	1.97
HD	Summer	Typha	P-11	2.10	1.90	2.00
HD	Summer	Typha	P-12	1.54	1.21	1.37
HD	Summer	Typha	P-12	1.32	1.27	1.29
HD	Summer	Sch-cal	P-13	2.09	1.41	1.75
HD	Summer	Sch-cal	P-14	2.21	2.02	2.11
HD	Summer	Sch-cal	P-15	2.33	1.52	1.92
HD	Summer	Sch-cal	P-16	2.46	1.25	1.85
PW	Summer	Typha	P-17	1.17	0.77	0.97
PW	Summer	Typha	P-18	0.63	0.91	0.77
PW	Summer	Sch-cal	P-19	0.58	1.27	0.92
PW	Summer	Sch-cal	P-19	1.46	1.25	1.35
PW	Summer	Sch-cal	P-19	1.57	1.28	1.43
PW	Summer	Sch-cal	P-20	1.29	0.86	1.07
PW	Summer	Sch-cal	P-20	1.18	0.89	1.04
PW	Summer	Sch-cal	P-21	1.04	1.06	1.05
PW	Summer	Sch-cal	P-22	1.22	0.90	1.06
PW	Summer	Sch-cal	P-23	0.92	1.02	0.97
PW	Summer	Sch-cal	P-23	0.79	0.47	0.63
PW	Summer	Sch-am	P-24	1.25	1.16	1.21
PW	Summer	Sch-am	P-25	1.58	1.25	1.42
PW	Summer	Sch-am	P-26	1.13	1.23	1.18
PW	Summer	Sch-am	P-27	1.38	0.72	1.05
PW	Summer	Sch-am	P-28	0.96	0.54	0.75
PW	Summer	Sch-am	P-28	1.90	1.42	1.66
PW	Summer	Sch-am	P-29	0.89	0.81	0.85
PW	Summer	Sch-am	P-29	0.94	0.73	0.84
PW	Spring	Sch-ac	P-36	0.85	0.72	0.78

Site	Season	Plant	Plant ID	TN (%)		
				Shoot	Root	Total
PW	Spring	Sch-ac	P-37	0.76	0.71	0.73
PW	Spring	Sch-am	P-38	0.91	0.79	0.85
PW	Spring	Sch-am	P-39	0.79	0.65	0.72
PW	Spring	Sch-cal	P-40	0.86	0.76	0.81
PW	Spring	Sch-cal	P-41	0.92	0.82	0.87
PW	Spring	Sch-cal	P-42	0.91	0.78	0.84
PW	Winter	Sch-ac	P-17	0.80	0.53	0.66
PW	Winter	Sch-am	P-18	0.73	0.63	0.68
PW	Winter	Sch-am	P-19	0.91	0.82	0.86
PW	Winter	Sch-am	P-20	0.63	0.52	0.57
PW	Winter	Sch-cal	P-21	0.82	0.75	0.78
PW	Winter	Sch-ac	P-22	0.68	0.61	0.64
FW	Spring	Typha	P-43	1.20	0.49	0.84
FW	Spring	Typha	P-44	1.15	0.58	0.86
FW	Spring	Typha	P-45	0.85	0.54	0.69
FW	Spring	Typha	P-46	0.50	0.45	0.47
FW	Spring	Typha	P-47	0.75	0.40	0.57
FW	Summer	Typha	P-48	1.24	0.81	1.02
FW	Summer	Typha	P-49	1.34	1.17	1.25
FW	Summer	Typha	P-50	1.56	1.05	1.30
FW	Summer	Typha	P-50	1.60	1.07	1.33
FW	Summer	Typha	P-50	1.16	0.73	0.94
FW	Summer	Typha	P-50	1.18	1.38	1.27
FW	Summer	Typha	P-51	1.33	0.74	1.03
FW	Summer	Typha	P-51	1.34	0.74	1.03
FW	Summer	Typha	P-51	1.12	0.81	0.96
FW	Summer	Typha	P-52	1.07	0.79	0.92
FW	Summer	Typha	P-52	1.53	0.91	1.21
FW	Summer	Typha	P-52	1.52	0.90	1.20
FW	Summer	Typha	P-53	1.67	0.99	1.32
FW	Summer	Typha	P-53	1.70	1.00	1.34
FW	Summer	Typha	P-53	1.56	0.99	1.27
FW	Summer	Typha	P-53	1.83	1.03	1.42
FW	Summer	Typha	P-54	1.30	1.10	1.19
FW	Summer	Typha	P-55	1.50	0.91	1.20

Appendix C2 - Water column total nitrogen (TN) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands. (Ref: SNWA-database).

Site	Location	SNWA Location	Sampling Date	TN (mg/L) Water Column
LVW	Inlet	LW 6.85	Jan-07	14
LVW	Inlet	LW 6.85	Feb-07	15
LVW	Inlet	LW 6.85	Mar-07	16
LVW	Inlet	LW 6.85	Apr-07	13
LVW	Inlet	LW 6.85	Jan-07	14
LVW	Inlet	LW 6.85	Feb-07	15
LVW	Outlet	LW 5.9	Jan-07	14
LVW	Outlet	LW 5.9	Feb-07	14
LVW	Outlet	LW 5.9	Mar-07	14
LVW	Outlet	LW 5.9	Apr-07	14
LVW	Outlet	LW 5.9	Jan-07	14
LVW	Outlet	LW 5.9	Feb-07	15
LVW	Inlet	LW 6.85	Sep-07	16
LVW	Inlet	LW 6.85	Oct-07	14
LVW	Inlet	LW 6.85	Nov-07	17
LVW	Inlet	LW 6.85	Dec-07	14
LVW	Inlet	LW 6.85	Sep-07	17
LVW	Inlet	LW 6.85	Oct-07	15
LVW	Inlet	LW 6.85	Nov-07	14
LVW	Inlet	LW 6.85	Dec-07	16
LVW	Inlet	LW 6.85	Oct-07	13
LVW	Outlet	LW 5.9	Sep-07	14
LVW	Outlet	LW 5.9	Oct-07	15
LVW	Outlet	LW 5.9	Nov-07	16
LVW	Outlet	LW 5.9	Dec-07	13
LVW	Outlet	LW 5.9	Sep-07	14
LVW	Outlet	LW 5.9	Oct-07	15
LVW	Outlet	LW 5.9	Nov-07	14
LVW	Outlet	LW 5.9	Dec-07	14
LVW	Outlet	LW 5.9	Oct-07	15
LVW	Outlet	LW 5.9	Nov-07	14
LVW	Outlet	LW 5.9	Dec-07	15
LVW	Inlet	LW 6.85	May-07	13
LVW	Inlet	LW 6.85	Jun-07	16
LVW	Inlet	LW 6.85	Jul-07	14

Site	Location	SNWA Location	Sampling Date	TN (mg/L) Water Column
LVW	Inlet	LW 6.85	Aug-07	14
LVW	Inlet	LW 6.85	Jun-07	15
LVW	Inlet	LW 6.85	Jul-07	13
LVW	Inlet	LW 6.85	Aug-07	16
LVW	Outlet	LW 5.9	May-07	16
LVW	Outlet	LW 5.9	Jun-07	17
LVW	Outlet	LW 5.9	Jul-07	14
LVW	Outlet	LW 5.9	Aug-07	14
LVW	Outlet	LW 5.9	May-07	16
LVW	Outlet	LW 5.9	Jun-07	17
LVW	Outlet	LW 5.9	Jul-07	11
LVW	Outlet	LW 5.9	Aug-07	14
HD	Inlet	HD1	Jan-07	17
HD	Inlet	HD1	Feb-07	13
HD	Inlet	HD1	Mar-07	13
HD	Outlet	HD4	Jan-07	2.43
HD	Outlet	HD4	Feb-07	17
HD	Outlet	HD4	Mar-07	2.44
HD	Outlet	HD4	Apr-07	18
HD	Inlet	HD1	Sep-07	1.45
HD	Inlet	HD1	Oct-07	4.32
HD	Inlet	HD1	Nov-07	5.60
HD	Inlet	HD1	Dec-07	1.67
HD	Inlet	HD1	Nov-07	3.83
HD	Outlet	HD4	Oct-07	3.65
HD	Outlet	HD4	Nov-07	1.01
HD	Outlet	HD4	Dec-07	1.86
HD	Inlet	HD1	May-07	13
HD	Inlet	HD1	Jun-07	6.63
HD	Inlet	HD1	Jul-07	6.50
HD	Inlet	HD1	Aug-07	12
HD	Inlet	HD1	Jul-07	2.28
HD	Inlet	HD1	Aug-07	1.08
HD	Outlet	HD4	May-07	11
HD	Outlet	HD4	Jun-07	2.83
HD	Outlet	HD4	Jul-07	1.13
HD	Outlet	HD4	Aug-07	12
HD	Outlet	HD4	Jul-07	2.04

Site	Location	SNWA Location	Sampling Date	TN (mg/L) Water Column
HD	Outlet	HD4	Aug-07	1.07
PW	Inlet	PW-Inlet	May-07	8.10
PW	Inlet	PW-Inlet	Jul-07	10
PW	Inlet	PW-Inlet	Aug-07	8.50
PW	Outlet	PW-Outlet	May-07	8.10
PW	Outlet	PW-Outlet	Jun-07	10
PW	Outlet	PW-Outlet	Jul-07	9.50
PW	Outlet	PW-Outlet	Aug-07	8.50
PW	Outlet	PW-Outlet	May-07	7.80
PW	Outlet	PW-Outlet	Jun-07	10
PW	Outlet	PW-Outlet	Jul-07	9.60
PW	Outlet	PW-Outlet	Aug-07	8.30
PW	Inlet	PW-Inlet	Jan-08	8.80
PW	Inlet	PW-Inlet	Feb-08	9.60
PW	Inlet	PW-Inlet	Mar-08	10
PW	Outlet	PW-Outlet	Jan-08	8.90
PW	Outlet	PW-Outlet	Feb-08	9.60
PW	Outlet	PW-Outlet	Mar-08	9.00
PW	Outlet	PW-Outlet	Feb-07	8.80
PW	Outlet	PW-Outlet	Mar-07	9.50
PW	Outlet	PW-Outlet	Apr-07	10
PW	Inlet	PW-Inlet	Feb-07	9.90
PW	Inlet	PW-Inlet	Mar-07	9.10
PW	Inlet	PW-Inlet	Apr-07	8.90
PW	Outlet	PW-Outlet	Feb-07	9.50
PW	Outlet	PW-Outlet	Mar-07	8.90
PW	Outlet	PW-Outlet	Apr-07	8.80
PW	Outlet	PW-Outlet	Jan-08	7.50
PW	Outlet	PW-Outlet	Feb-08	8.10
PW	Outlet	PW-Outlet	Mar-08	9.60
PW	Outlet	PW-Outlet	Jan-08	8.80
PW	Outlet	PW-Outlet	Feb-08	8.70
PW	Inlet	PW-Inlet	Sep-07	8.10
PW	Inlet	PW-Inlet	Oct-07	8.80
PW	Outlet	PW-Outlet	Sep-07	9.00
PW	Outlet	PW-Outlet	Oct-07	8.70
PW	Outlet	PW-Outlet	Sep-07	8.90
PW	Outlet	PW-Outlet	Oct-07	8.60

Site	Location	SNWA Location	Sampling Date	TN (mg/L) Water Column
PW	Inlet	PW-Inlet	Aug-07	9.40
PW	Outlet	PW-Outlet	Sep-07	9.10
FW	Outlet	FW-0	Jan-07	4.30
FW	Outlet	FW-0	Feb-07	4.83
FW	Outlet	FW-0	Mar-07	4.56
FW	Outlet	FW-0	Jan-08	4.26
FW	Inlet	TW-DRI	Jan-07	2.04
FW	Inlet	TW-DRI	Feb-07	5.34
FW	Inlet	TW-DRI	Mar-07	3.50
FW	Inlet	TW-DRI	Feb-08	4.33
FW	Inlet	TW-DRI	Mar-08	4.28
FW	Inlet	TW-DRI	Jan-08	3.93
FW	Inlet	TW-DRI	Jan-07	5.20
FW	Inlet	TW-DRI	Feb-07	3.41
FW	Inlet	TW-DRI	Mar-07	5.15
FW	Inlet	TW-DRI	Jan-08	4.31
FW	Inlet	TW-DRI	Jan-07	3.01
FW	Outlet	FW-0	May-07	4.57
FW	Outlet	FW-0	Jun-07	3.63
FW	Outlet	FW-0	Jul-07	3.85
FW	Outlet	FW-0	Aug-07	3.49
FW	Outlet	FW-0	May-08	3.39
FW	Outlet	FW-0	Jun-08	4.14
FW	Outlet	FW-0	Jul-08	3.36
FW	Outlet	FW-0	Aug-08	3.64
FW	Inlet	TW-DRI	Oct-07	3.56
FW	Inlet	TW-DRI	Nov-07	5.40
FW	Inlet	TW-DRI	Dec-07	2.86
FW	Outlet	FW-0	Nov-07	4.31
FW	Outlet	FW-0	Dec-07	4.78

Note: Nearby sites were sampled for nutrients and metals in water column whenever insufficient samples were found in one location.

Appendix C3- Sediment total nitrogen (TN) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Location	TN (%) Sediment
LVW	Spring 09	Inlet	0.09
LVW	Spring 09	Inlet	0.07
LVW	Spring 09	Outlet	0.06
LVW	Spring 09	Outlet	0.08
LVW	Winter 08	Inlet	0.11
LVW	Winter 08	Inlet	0.15
LVW	Winter 08	Inlet	0.11
LVW	Winter 08	Outlet	0.13
LVW	Winter 08	Outlet	0.16
LVW	Winter 08	Outlet	0.14
LVW	Summer 08	Inlet	0.05
LVW	Summer 08	Inlet	0.07
LVW	Summer 08	Inlet	0.10
LVW	Summer 08	Outlet	0.06
LVW	Summer 08	Outlet	0.06
LVW	Summer 08	Outlet	0.06
HD	Spring 09	Inlet	0.05
HD	Spring 09	Inlet	0.05
HD	Spring 09	Outlet	0.05
HD	Spring 09	Outlet	0.06
HD	Winter 08	Inlet	0.07
HD	Winter 08	Inlet	0.07
HD	Winter 08	Inlet	0.06
HD	Winter 08	Outlet	0.04
HD	Winter 08	Outlet	0.04
HD	Winter 08	Outlet	0.04
HD	Summer 08	Inlet	0.08
HD	Summer 08	Inlet	0.07
HD	Summer 08	Inlet	0.09
HD	Summer 08	Outlet	0.07
HD	Summer 08	Outlet	0.05
HD	Summer 08	Outlet	0.06
PW	Summer 08	Inlet	0.05
PW	Summer 08	Inlet	0.05
PW	Summer 08	Inlet	0.04
PW	Summer 08	Outlet	0.05

Site	Season	Location	TN (%)
			Sediment
PW	Summer 08	Outlet	0.05
PW	Spring 09	Inlet	0.07
PW	Spring 09	Inlet	0.07
PW	Spring 09	Outlet	0.10
PW	Spring 09	Outlet	0.10
PW	Winter 08	Inlet	0.08
PW	Winter 08	Inlet	0.08
PW	Winter 08	Outlet	0.07
PW	Winter 08	Outlet	0.06
PW	Winter 08	Outlet	0.06
PW	Winter 08	Inlet	0.06
FW	Spring 09	Outlet	0.02
FW	Spring 09	Outlet	0.03
FW	Spring 09	Inlet	0.15
FW	Spring 09	Inlet	0.11
FW	Summer 08	Inlet	0.11
FW	Summer 08	Inlet	0.16
FW	Summer 08	Inlet	0.12
FW	Summer 08	Outlet	0.08
FW	Summer 08	Outlet	0.08
FW	Summer 08	Outlet	0.08
FW	Winter 08	Inlet	0.14
FW	Winter 08	Inlet	0.13
FW	Winter 08	Inlet	0.14
FW	Winter 08	Outlet	0.05
FW	Winter 08	Outlet	0.05
FW	Winter 08	Outlet	0.05

Appendix D

Arsenic data from plant tissues, water column and sediment at four wetland sites

Appendix D1 - Arsenic concentrations (As) in plant tissues from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Plant	Sample ID	Arsenic (µg/g)		
				Shoot	Root	Total
LVW	Spring	Typha	P-1	5.21	1.32	3.26
LVW	Spring	Typha	P-1	4.23	2.12	3.17
LVW	Spring	Typha	P-2	5.31	2.86	4.08
LVW	Summer	Typha	P-3	10.10	1.39	5.74
LVW	Summer	Typha	P-3	9.86	1.16	5.51
LVW	Summer	Typha	P-4	9.16	1.12	5.14
LVW	Summer	Typha	P-4	3.60	1.53	2.56
LVW	Summer	Sch-cal	P-1	5.60	0.13	2.86
LVW	Summer	Sch-cal	P-2	3.02	1.44	2.23
LVW	Summer	Sch-cal	P-2	4.54	0.63	2.58
LVW	Winter	Typha	P-5	5.80	0.40	3.10
LVW	Winter	Typha	P-5	3.35	0.95	2.15
HD	Summer	Sch-cal	P-3	1.02	0.86	0.94
HD	Summer	Sch-cal	P-3	1.89	0.16	1.02
HD	Spring	Sch-ac	P-4	1.52	0.62	1.07
HD	Spring	Sch-cal	P-5	1.64	0.35	0.99
HD	Spring	Typha	P-6	2.06	0.25	1.19
HD	Winter	Sch-ac	P-6	2.05	0.84	1.44
HD	Winter	Sch-ac	P-6	2.00	0.70	1.35
HD	Winter	Sch-am	P-7	2.05	1.05	1.55
HD	Winter	Sch-am	P-8	2.56	0.4	1.48
HD	Winter	Sch-cal	P-9	2.51	0.25	1.37
HD	Winter	Sch-cal	P-9	1.72	0.35	1.02
PW	Winter	Sch-ac	P-10	8.05	1.60	4.80
PW	Winter	Sch-ac	P-11	6.24	1.51	3.87
PW	Winter	Sch-am	P-12	9.65	1.90	5.77
PW	Winter	Sch-am	P-13	8.41	2.60	5.50
PW	Winter	Sch-cal	P-14	10.2	1.25	5.72
PW	Summer	Sch-ac	P-15	10.21	3.90	7.05
PW	Summer	Sch-ac	P-16	8.34	2.30	5.32
PW	Summer	Sch-am	P-17	10.60	3.50	7.05
PW	Summer	Sch-am	P-17	9.41	4.88	7.14
PW	Summer	Sch-cal	P-18	13.91	0.20	7.05
PW	Summer	Sch-cal	P-18	12.28	0.35	6.31
PW	Summer	Sch-cal	P-19	5.85	1.20	3.52
PW	Summer	Sch-cal	P-19	6.85	3.54	5.19
PW	Winter	Sch-cal	P-20	12.21	0.96	6.58

Site	Season	Plant	Sample ID	Arsenic (µg/g)		
				Shoot	Root	Total
PW	Winter	Sch-cal	P-21	5.15	3.65	4.40
FW	Summer	Typha	P-7	3.50	0.6	2.05
FW	Summer	Typha	P-8	0.35	0.85	0.60
FW	Summer	Typha	P-9	2.21	0.56	1.38
FW	Summer	Typha	P-10	1.63	0.74	1.17

Appendix D2 - Arsenic concentrations (As) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands. (Ref: SNWA database)

Site	**Location**	**Sampling Date**	**Arsenic (µg/L)**
			Water Column
LVW	Inlet	Jan-07	5.9
LVW	Inlet	Feb-07	6.5
LVW	Inlet	Mar-07	7.2
LVW	Inlet	May-07	7.5
LVW	Inlet	Jun-07	6.2
LVW	Inlet	Jul-07	6.5
LVW	Inlet	Aug-07	5.7
LVW	Inlet	Sep-07	3.0
LVW	Inlet	Oct-07	1.8
LVW	Inlet	Nov-07	2.6
LVW	Inlet	Dec-07	5.1
LVW	Inlet	Sep-07	6.6
LVW	Inlet	Oct-07	6.6
LVW	Inlet	Nov-07	4.1
LVW	Inlet	Dec-07	7.3
LVW	Outlet	Jan-07	9.2
LVW	Outlet	Feb-07	9.8
LVW	Outlet	Mar-07	11
LVW	Outlet	May-07	9.4
LVW	Outlet	Jun-07	8.3
LVW	Outlet	Jul-07	8.4
LVW	Outlet	Aug-07	9.3
LVW	Outlet	Nov-07	8.9
LVW	Outlet	Dec-07	10
LVW	Outlet	Oct-07	9.7
LVW	Outlet	Nov-07	7.2
LVW	Outlet	Dec-07	9.7
HD	Inlet	Jul-07	3.3
HD	Inlet	Aug-07	3.8
HD	Inlet	Nov-07	4.8
HD	Outlet	Feb-07	3.2
HD	Outlet	May-07	3.0
HD	Outlet	Jun-07	3.0
HD	Outlet	Jul-07	3.1

Site	Location	Sampling Date	Arsenic (µg/L) Water Column
HD	Outlet	Aug-07	3.0
HD	Outlet	May-07	3.1
HD	Outlet	Jun-07	3.6
HD	Outlet	Jul-07	3.0
HD	Outlet	Aug-07	3.1
HD	Outlet	Sep-07	3.4
HD	Outlet	Nov-07	4.0
HD	Outlet	Dec-07	3.1
PW	Inlet	Feb-07	14
PW	Inlet	Mar-07	15
PW	Inlet	Apr-07	10
PW	Inlet	Feb-07	14
PW	Inlet	Mar-07	12
PW	Inlet	Apr-07	14
PW	Inlet	May-07	14
PW	Inlet	Jun-07	14
PW	Inlet	Jul-07	15
PW	Inlet	Aug-07	15
PW	Inlet	Sep-07	14
PW	Inlet	Oct-07	15
PW	Inlet	Nov-07	15
PW	Outlet	Feb-07	13
PW	Outlet	Mar-07	15
PW	Outlet	Apr-07	15
PW	Outlet	Feb-07	9.9
PW	Outlet	Mar-07	14
PW	Outlet	Apr-07	11
PW	Outlet	Feb-07	14
PW	Outlet	Mar-07	14
PW	Outlet	Apr-07	12
PW	Outlet	Feb-07	15
PW	Outlet	Mar-07	13
PW	Outlet	Apr-07	15
PW	Outlet	Feb-07	15
PW	Outlet	Mar-07	9.8
PW	Outlet	Jun-07	14
PW	Outlet	Jul-07	16
PW	Outlet	Aug-07	15

Site	Location	Sampling Date	Arsenic (µg/L)
			Water Column
PW	Outlet	May-07	14
PW	Outlet	Jun-07	14
PW	Outlet	Jul-07	15
PW	Outlet	Aug-07	15
PW	Outlet	Sep-07	15
PW	Outlet	Oct-07	15
PW	Outlet	Nov-07	15
FW	Outlet	Jan-01	6.4
FW	Outlet	Apr-01	7.5
FW	Outlet	Jan-02	8.1
FW	Outlet	Apr-02	7.2
FW	Outlet	Jan-03	5.2
FW	Outlet	Apr-03	4.8
FW	Outlet	Jan-04	7.4
FW	Outlet	Apr-04	5.4
FW	Outlet	Apr-05	7.0
FW	Outlet	Apr-06	5.2
FW	Outlet	Jan-07	4.1
FW	Outlet	Apr-07	4.9
FW	Outlet	Jan-08	4.5
FW	Outlet	Apr-08	4.5
FW	Outlet	Jul-01	6.2
FW	Outlet	Jul-02	9.2
FW	Outlet	Jul-03	5.8
FW	Outlet	Jul-04	5.1
FW	Outlet	Jul-05	8.5
FW	Outlet	Jul-06	5.5
FW	Outlet	Jul-07	5.5
FW	Outlet	Oct-02	6.7
FW	Outlet	Oct-03	4.9
FW	Outlet	Oct-04	6.8
FW	Outlet	Oct-05	4.4
FW	Outlet	Oct-06	5.8
FW	Outlet	Oct-01	8.8

Note: Water quality data in LVW, HD & PW were selected for year 2007/08, for FW years 2001-2008, due to less frequent sampling.

Appendix D3 – Arsenic concentrations (As) from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	**Location**	**Season**	**Arsenic (µg/g)**
			Sediment
LVW	Inlet	Spring 09	3.50
LVW	Inlet	Spring 09	3.69
LVW	Inlet	Summer 09	3.86
LVW	Inlet	Summer 09	4.72
LVW	Inlet	Summer 09	4.71
LVW	Inlet	Summer 09	5.49
LVW	Inlet	Winter 08	5.68
LVW	Inlet	Winter 08	5.33
LVW	Outlet	Summer 09	3.63
LVW	Outlet	Summer 09	4.12
LVW	Outlet	Summer 09	5.78
LVW	Outlet	Summer 09	5.27
LVW	Outlet	Winter 08	4.72
LVW	Outlet	Winter 08	5.56
HD	Inlet	Spring 09	3.53
HD	Inlet	Spring 09	3.46
HD	Inlet	Summer 09	5.94
HD	Inlet	Summer 09	3.23
HD	Inlet	Summer 09	2.53
HD	Inlet	Summer 09	2.57
HD	Inlet	Winter 08	4.32
HD	Inlet	Winter 08	3.85
HD	Outlet	Summer 09	2.74
HD	Outlet	Summer 09	3.05

Site	Location	Season	Arsenic (µg/g)
			Sediment
HD	Outlet	Summer 09	3.38
HD	Outlet	Summer 09	3.64
HD	Outlet	Winter 08	2.32
HD	Outlet	Winter 08	2.52
PW	Inlet	Summer 09	5.99
PW	Inlet	Summer 09	6.21
PW	Inlet	Winter 08	6.35
PW	Outlet	Spring 09	5.61
PW	Outlet	Spring 09	4.03
PW	Outlet	Summer 09	6.81
PW	Outlet	Summer 09	6.90
PW	Outlet	Summer 09	4.11
PW	Outlet	Summer 09	3.63
PW	Outlet	Summer 09	5.80
PW	Outlet	Summer 09	8.30
PW	Outlet	Winter 08	6.38
PW	Outlet	Winter 08	7.25
FW	Inlet	Summer 09	2.44
FW	Inlet	Summer 09	3.02
FW	Inlet	Summer 09	1.99
FW	Inlet	Summer 09	2.45
FW	Inlet	Winter 08	3.03
FW	Inlet	Winter 08	3.56
FW	Outlet	Spring 09	3.86
FW	Outlet	Spring 09	2.51
FW	Outlet	Spring 09	3.06
FW	Outlet	Summer	4.37

Site	Location	Season	Arsenic (µg/g)
			Sediment
		09	
FW	Outlet	Summer 09	3.89
FW	Outlet	Summer 09	2.38
FW	Outlet	Summer 09	2.53
FW	Outlet	Winter 08	3.61

Appendix E

Selenium data from plant tissues, water column and sediment at four wetland sites

Appendix E1 - Selenium concentrations (Se) in plant tissues from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Season	Plant	Sample ID	Selenium (µg/g)		
				Shoot	Root	Total
LVW	Spring	Typha	P-1	2.60	0.96	1.78
LVW	Spring	Typha	P-1	1.36	0.87	1.11
LVW	Spring	Typha	P-2	1.70	1.02	1.36
LVW	Spring	Typha	P-2	3.62	0.58	2.10
LVW	Summer	Typha	P-3	1.80	1.34	1.57
LVW	Summer	Typha	P-3	1.82	0.72	1.27
LVW	Summer	Typha	P-4	2.20	0.76	1.48
LVW	Summer	Typha	P-5	1.54	0.67	1.10
LVW	Summer	Sch-cal	P-1	1.58	0.58	1.08
LVW	Summer	Sch-cal	P-3	1.32	0.69	1.00
LVW	Winter	Typha	P-6	8.30	4.45	6.37
LVW	Winter	Typha	P-6	14.35	2.95	8.65
HD	Summer	Sch-cal	P-4	2.48	0.64	1.56
HD	Summer	Sch-cal	P-5	2.10	0.72	1.41
HD	Spring	Sch-am	P-6	1.80	1.80	1.80
HD	Spring	Sch-ac	P-7	4.46	1.80	3.13
HD	Spring	Sch-cal	P-8	2.90	1.50	2.20
HD	Spring	Typha	P-7	1.62	0.72	1.17
HD	Spring	Typha	P-8	2.38	0.59	1.48
HD	Winter	Sch-ac	P-9	6.40	2.45	4.42
HD	Winter	Sch-ac	P-10	6.85	3.50	5.17
HD	Winter	Sch-am	P-11	6.45	1.00	3.72
HD	Winter	Sch-am	P-12	5.45	2.15	3.80
HD	Winter	Sch-cal	P-13	1.95	0.50	1.22
HD	Winter	Sch-cal	P-14	1.40	2.40	1.90
PW	Winter	Sch-ac	P-15	11.65	9.30	10.47
PW	Winter	Sch-ac	P-15	14.80	8.70	11.75
PW	Winter	Sch-am	P-16	20.15	11.45	15.80
PW	Winter	Sch-am	P-16	18.11	14.53	16.32
PW	Winter	Sch-cal	P-17	8.60	6.45	7.52
PW	Summer	Sch-ac	P-18	12.00	2.45	7.22
PW	Summer	Sch-ac	P-18	9.65	3.27	6.46
PW	Summer	Sch-am	P-19	21.75	11.75	16.75
PW	Summer	Sch-am	P-19	17.56	15.28	16.42
PW	Summer	Sch-cal	P-20	5.90	2.20	4.05
PW	Summer	Sch-cal	P-21	7.54	5.21	6.37
PW	Summer	Sch-cal	P-21	8.00	4.15	6.07

Site	Season	Plant	Sample ID	Selenium (μg/g)		
				Shoot	Root	Total
PW	Summer	Sch-cal	P-22	6.38	0	6.38
PW	Winter	Sch-cal	P-22	5.20	4.21	4.70
PW	Winter	Sch-cal	P-23	14.70	3.65	9.17
PW	Winter	Sch-cal	P-23	17.51	5.36	11.43
FW	Summer	Typha	P-9	2.45	1.20	1.82
FW	Summer	Typha	P-10	1.90	0.15	1.02
FW	Summer	Typha	P-11	1.32	0.82	1.07
FW	Summer	Typha	P-12	1.76	0.72	1.24

Appendix E2 - Selenium concentrations (Se) in Water Column from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands. (Ref: SNWA database).

Site	**Location**	**Sampling Date**	**Selenium (µg/L)**
			Water Column
LVW	Inlet	Jan-07	2.6
LVW	Inlet	Feb-07	2.9
LVW	Inlet	Mar-07	2.8
LVW	Inlet	Jan-07	3.8
LVW	Inlet	Feb-07	4.1
LVW	Inlet	Mar-07	3.9
LVW	Inlet	May-07	2.7
LVW	Inlet	Jun-07	2.7
LVW	Inlet	Jul-07	2.9
LVW	Inlet	Aug-07	2.6
LVW	Inlet	May-07	3.7
LVW	Inlet	Jun-07	3.3
LVW	Inlet	Jul-07	3.6
LVW	Inlet	Aug-07	3.3
LVW	Inlet	Sep-07	3.0
LVW	Inlet	Oct-07	2.6
LVW	Inlet	Nov-07	2.9
LVW	Inlet	Dec-07	2.7
LVW	Inlet	Sep-07	3.6
LVW	Inlet	Oct-07	4.0
LVW	Inlet	Nov-07	3.9
LVW	Inlet	Dec-07	3.7
LVW	Inlet	Nov-07	3.1
LVW	Inlet	Dec-07	4.2
LVW	Outlet	Jan-07	3.4
LVW	Outlet	Feb-07	3.7
LVW	Outlet	Mar-07	3.6
LVW	Outlet	May-07	3.2
LVW	Outlet	Jun-07	2.8
LVW	Outlet	Jul-07	2.9
LVW	Outlet	Aug-07	3.1
LVW	Outlet	Oct-07	4.0
LVW	Outlet	Nov-07	3.4
LVW	Outlet	Dec-07	3.1

Site	Location	Sampling Date	Selenium (µg/L)
			Water Column
LVW	Outlet	Nov-07	3.2
LVW	Outlet	Dec-07	3.3
HD	Inlet	Jan-07	1.6
HD	Inlet	Feb-07	2.6
HD	Inlet	Jul-07	2.1
HD	Inlet	Aug-07	2.2
HD	Inlet	Dec-07	2.0
HD	Outlet	May-07	2.0
HD	Outlet	Jun-07	1.9
HD	Outlet	Jul-07	1.6
HD	Outlet	Aug-07	1.8
HD	Outlet	May-07	2.0
HD	Outlet	Jun-07	1.3
HD	Outlet	Jul-07	1.2
HD	Outlet	Aug-07	2.1
PW	Inlet	Jan-07	9.3
PW	Inlet	Feb-07	11
PW	Inlet	Mar-07	9.8
PW	Inlet	Jan-07	11
PW	Inlet	Feb-07	12
PW	Inlet	Mar-07	11
PW	Inlet	May-07	10
PW	Inlet	Jun-07	11
PW	Inlet	Jul-07	11
PW	Inlet	Aug-07	10
PW	Inlet	Oct-07	9.8
PW	Inlet	Nov-07	11
PW	Inlet	Dec-07	11
PW	Outlet	Jan-07	9.1
PW	Outlet	Feb-07	10
PW	Outlet	Mar-07	12
PW	Outlet	Jan-07	11
PW	Outlet	Feb-07	11
PW	Outlet	Mar-07	11
PW	Outlet	Jan-07	11
PW	Outlet	Feb-07	11
PW	Outlet	Mar-07	12
PW	Outlet	Jan-07	12

Site	Location	Sampling Date	Selenium (μg/L)
			Water Column
PW	Outlet	Feb-07	8.6
PW	Outlet	Mar-07	9.2
PW	Outlet	Jan-08	11
PW	Outlet	Feb-08	10
PW	Outlet	May-07	10
PW	Outlet	Jul-07	11
PW	Outlet	Aug-07	11
PW	Outlet	May-07	9.9
PW	Outlet	Jun-07	11
PW	Outlet	Jul-07	11
PW	Outlet	Aug-07	11
PW	Outlet	Oct-07	11
PW	Outlet	Nov-07	11
PW	Outlet	Dec-07	11
FW	Inlet	Jan-07	8.6
FW	Inlet	Feb-07	8.4

Appendix E3-Selenium concentrations (Se) in sediment from the Las Vegas Wash (LVW), Flamingo Wash (FW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD) and Pittman Wash Pilot Wetlands (PW) wetlands.

Site	Location	Season	Selenium (µg/g)
			Sediment
LVMW	Inlet	Spring 09	3.50
LVMW	Inlet	Spring 09	3.69
LVMW	Inlet	Summer 09	3.86
LVMW	Inlet	Summer 09	4.72
LVMW	Inlet	Summer 09	4.71
LVMW	Inlet	Summer 09	5.49
LVMW	Inlet	Winter 08	5.68
LVMW	Inlet	Winter 08	5.33
LVMW	Outlet	Summer 09	3.63
LVMW	Outlet	Summer 09	4.12
LVMW	Outlet	Summer 09	5.78
LVMW	Outlet	Summer 09	5.27
LVMW	Outlet	Winter 08	4.72
LVMW	Outlet	Winter 08	5.56
HD	Inlet	Spring 09	3.53
HD	Inlet	Spring 09	3.46
HD	Inlet	Summer 09	5.94
HD	Inlet	Summer 09	3.23
HD	Inlet	Summer 09	2.53
HD	Inlet	Summer 09	2.57
HD	Inlet	Winter 08	4.32
HD	Inlet	Winter 08	3.85
HD	Outlet	Summer 09	2.74
HD	Outlet	Summer 09	3.38

Site	Location	Season	Selenium (µg/g)
			Sediment
HD	Outlet	Summer 09	3.64
HD	Outlet	Winter 08	2.32
HD	Outlet	Winter 08	2.52
PW	Inlet	Summer 09	5.99
PW	Inlet	Summer 09	6.21
PW	Inlet	Winter 08	7.60
PW	Inlet	Winter 08	6.35
PW	Outlet	Spring 09	5.60
PW	Outlet	Spring 09	4.03
PW	Outlet	Summer 09	6.80
PW	Outlet	Summer 09	6.90
PW	Outlet	Summer 09	4.11
PW	Outlet	Summer 09	3.63
PW	Outlet	Summer 09	5.80
PW	Outlet	Summer 09	8.30
PW	Outlet	Winter 08	6.38
PW	Outlet	Winter 08	7.25
FW	Inlet	Summer 09	2.44
FW	Inlet	Summer 09	3.02
FW	Inlet	Summer 09	1.99
FW	Inlet	Summer 09	2.45
FW	Inlet	Winter 08	3.03
FW	Inlet	Winter 08	3.56
FW	Outlet	Spring 09	3.86
FW	Outlet	Spring 09	2.51
FW	Outlet	Spring 09	3.06
FW	Outlet	Summer 09	4.37

Site	Location	Season	Selenium (µg/g)
			Sediment
FW	Outlet	Summer 09	3.89
FW	Outlet	Summer 09	2.38
FW	Outlet	Summer 09	2.53
FW	Outlet	Winter 08	3.61

Appendix F

Plant tissue nutrient concentration from fall 2008 samplings from four wetland sites

Appendix F: Plant tissue total phosphorous (TP) and total nitrogen (TN) from the Las Vegas Wash (LVW), Demonstration Wetland at the City of Henderson Water Reclamation Facility (HD), Pittman Wash Pilot Wetlands (PW) and Flamingo Wash (FW)

				TP (%)		
Site	**Season**	**Plant**	**Plant ID**	**Shoot**	**Root**	**Total**
LVW	Fall	Typha	P-1	0.07	0.12	0.09
LVW	Fall	Typha	P-2	0.18	0.15	0.17
LVW	Fall	Typha	P-3	0.07	0.09	0.08
LVW	Fall	Typha	P-4	0.09	0.07	0.08
HD	Fall	Sch-cal	P-1	0.05	0.08	0.06
HD	Fall	Sch-cal	P-2	0.08	0.07	0.07
HD	Fall	Sch-cal	P-3	0.10	0.16	0.13
HD	Fall	Sch-cal	P-4	0.07	0.14	0.10
PW	Fall	Sch-cal	P-1	0.05	0.09	0.07
PW	Fall	Sch-cal	P-2	0.01	0.04	0.03
PW	Fall	Sch-cal	P-3	0.02	0.03	0.03
PW	Fall	Sch-cal	P-4	0.02	0.05	0.04
FW	Fall	Typha	P-1	0.02	0.08	0.05
FW	Fall	Typha	P-2	0.02	0.04	0.03
FW	Fall	Typha	P-3	0.02	0.05	0.03
FW	Fall	Typha	P-4	0.02	0.04	0.03
				TN (%)		
Site	**Season**	**Plant**	**Plant ID**	**Shoot**	**Root**	**Total**
LVW	Fall	Typha	P-1	2.28	1.12	1.70
LVW	Fall	Typha	P-2	3.18	1.05	2.12
LVW	Fall	Typha	P-3	0.75	0.84	0.80
LVW	Fall	Typha	P-4	0.96	0.73	0.85
HD	Fall	Sch-cal	P-1	1.46	1.58	1.52
HD	Fall	Sch-cal	P-2	1.24	1.09	1.17
HD	Fall	Sch-cal	P-3	2.88	1.04	1.96
HD	Fall	Sch-cal	P-4	1.69	1.31	1.50
PW	Fall	Sch-cal	P-1	2.58	0.68	1.63
PW	Fall	Sch-cal	P-2	2.08	0.91	1.50
PW	Fall	Sch-cal	P-3	1.28	0.78	1.03
PW	Fall	Sch-cal	P-4	2.13	0.95	1.54
FW	Fall	Typha	P-1	1.24	0.72	0.98
FW	Fall	Typha	P-2	1.18	0.87	1.03
FW	Fall	Typha	P-3	1.15	0.63	0.89
FW	Fall	Typha	P-4	1.35	0.83	1.09